Optimizing Ability of Message Receipt by People with Disabilities

Prototype Findings Report/Vibration Scale Final Report

First Responders Group

October 2015

Homeland Security

Science and Technology

CONTENTS

FIGURES

TABLES

ACKNOWLEDGEMENTS

The research and development activities detailed in this report were performed by the following team: Principal Investigator (PI), Helena Mitchell, Ph.D. (Georgia Tech, Center for Advanced Communications Policy); Peter Presti (Georgia Tech, Interactive Media Technology Center); Salimah LaForce (Georgia Tech, Center for Advanced Communications Policy); Maureen Linden, MS (Georgia Tech, Center for Accessible Technology and Environmental Access); DeeDee Bennett, Ph.D. (University of Nebraska); Christina Touzet, Graduate Research Assistant (Georgia Tech, Center for Advanced Communications Policy); Abdelkareem Bedri, Graduate Research Assistant (Georgia Tech – School of Interactive Computing); Tyler Hamilton, undergraduate engineering student (Georgia State); Ed Price (Georgia Tech, Institute for People and Technology); Kay Chiodo (Deaf Link)); Rich Rarey (RAREworks LLC) consultant; and Frank Lucia (Consultant). The research was funded by the U.S. Department of Homeland Security (DHS) Science and Technology (S&T) Directorate.

The research in this report is supported by DHS S&T under contract # HSHQDC-14-B0004. The opinions contained herein are those of the contractor and do not necessarily reflect those of DHS S&T.

EXECUTIVE SUMMARY

In 2014, the U.S. Department of Homeland Security (DHS), Science and Technology (S&T) Directorate funded the Georgia Institute of Technology (Georgia Tech), Center for Advanced Communications Policy to examine and report on how to optimize Wireless Emergency Alerts (WEA) message receipt by people with disabilities. Reaching people with disabilities, including the deaf and hard of hearing, with WEA messages is critical, in part because people with disabilities utilize and depend on wireless devices, including mobile phones at more than 96 percent. Their devices become even more important during emergencies.

The aim of this project was to assist in understanding and identifying ways to ensure that people with disabilities had timely and effective access to WEA messages. Many tasks were developed to accomplish this scope of development to (1) to determine the ideal vibration strength for a WEA alert and (2) assess the utility of adding a display light to enhance alerting people who are deaf or hard of hearing of an incoming WEA message. These efforts resulted in several key products including a Market Analysis Report, Focus Group Summation, a device for validation of off-the-shelf models to enable accurate quantifying of the vibration strength of WEA-capable mobile phones, and an architectural design for the prototype "handsets" of which the findings and conclusions were utilized in the design and production of the prototypes.

After internal testing and several refinements to determine the optimal device specifications, a prototype with the approximate shape and size of a smartphone was created, which featured the ability to trigger low, medium and high vibration strengths; two distinctive light cadences; and the WEA sound attention signal . The prototype was then end-user tested by people who were deaf and hard of hearing, blind or had low vision, deaf-blind, and those only conversant in American Sign Language . The research and technical teams worked on assignments simultaneously to inform each other's efforts, especially during the usability testing phase.

These various steps all contributed to recommendations on the utility of light input to increase WEA message recognition and to create a vibration strength rating (V-rating) scale, which can advance efforts to optimize the receipt of WEA messages by people with disabilities. The conclusions from the utility of light output and vibration testing levels showed the benefits of both. The addition of a light cadence and different vibration strengths were important to the end user and dependent upon the individual's type of disability.

Several positive unintended consequences of the research and development activity have occurred. For example, researchers are often taught about the "observer effect;" how the act of observation changes the observed. During the usability studies, some participants indicated that going forward, they would carry their mobile phones in a manner more conducive to noticing WEA messages. Simply by virtue of conducting the research, we affected positive change. Additionally, early focus group findings led us to include people who are blind or have low vision in our target population and also to evaluate the WEA sound attention signal, although this was not initially part of the proposed research. We included an evaluation of the sound attention signal in the prototype design to be inclusive of all current and prospective WEA attention signals.

We found that vibration strength *is* a factor in response time to WEA messages, but stronger is not always better. For the participants that were deaf, the low vibration setting had the fastest response time. This unanticipated result suggests a need for further research to definitively answer *why* the medium and low vibration settings were more optimal than the high. We also found that adding a WEA light cadence can increase response time to WEA messages for certain populations. For participants who were hard of hearing, WEA Light had the quickest response time. For participants that had low vision, the WEA All (i.e., light, sound and vibration) received the quickest response time over any of the vibration signals alone.

It can be concluded, therefore, simultaneously activating all notification signals (sound, vibration and light) will increase the likelihood of timely receipt of WEA messages for certain populations. Based on our findings we suggest that activating all attention signals will increase the likelihood of timely notification. The following are specific technical and policy recommendations on how to optimize WEA message accessibility with regard to the attention signals:

- Manufacturers should design all handsets with the capability to adjust:
    - The strength of the vibration signal;
    - Pitch and frequency of the sound attention signal; and
    - Include a light signal feature that is activated by WEA messages.
- The Federal Communications Commission (FCC) should release a rulemaking concerning the next generation WEA (NG-WEA) that includes prescribing a specific light cadence for WEA messages.
- The FCC should solicit feedback from stakeholders regarding the V-rating scale and its potential to better inform consumers and sales associates of the ranges that optimize receipt of WEA messages.

WEA messages can only be as accessible as the rules and regulations prescribe and to the extent that manufacturers incorporate accessibility features into WEA-capable devices. When the device specifications are enhanced for WEA access, barriers to WEA will diminish and WEA message diffusion to the population will increase. As a result, more people with disabilities will be empowered with the access to information that is needed to take appropriate protective actions during emergency events.

1. INTRODUCTION

A review of the literature on accessible emergency alerting revealed that little attention has been paid to evaluating vibration strength, other than in the research of the Wireless Rehabilitation Engineering Research Center (RERC). The assumption by manufacturers seems to be that the inclusion of a vibration option satisfies the accessibility need. In fact, it does not. In earlier research by the Wireless RERC, field trials revealed that 40 percent of the deaf and hard of hearing participants found that the vibration was not strong enough.[1] Some stated that the vibration was not strong enough to capture their attention unless they were holding the phone. Earlier analysis of WEA-capable phones found that vibration strength varied among mobile phone models.[2] This was an important finding to assist in generating the technical specifications of the development work: ensuring the same timely and effective access to alerts and warnings for people who are deaf or hard of hearing by evaluating the utility of current vibration signals and the potential of a light notification. Quantifying and measuring the effectiveness of vibration strength of current devices enabled the creation a vibration strength rating system (V-rating) applicable to Wireless Emergency Alert (WEA)-capable devices. During the course of our research, focus group findings led us to include people who are blind or have low vision in our target population. They noted that they too rely on the vibration notification signal in certain situations when their phone is silenced.

No standards or measurements are available to consumers to know how strong a vibration motor is in a mobile device. Therefore, we evaluated variable motor strengths to determine a range of motor strength/size to develop criteria for selecting WEA-capable phones which fall inside the recommended range. Focus group respondents indicated they would like a screen flash or light to be added as a notification mechanism. These signaling methods were of equal importance as the vibration signal. The Federal Communications Commission (FCC) rules governing WEA do not require the use of light as an indicator of an incoming alert, however. The research reported herein evaluated the utility of light output in increasing WEA message recognition, as well as the effectiveness of the WEA vibration and sound attention signals.

Prototypes were developed to test the effectiveness of the various levels of vibration strengths and two flashing light signals in WEA-capable devices. One signal flashed in the same timing as the WEA vibration cadence and the other simulated the fire strobe often used during emergency drills and evacuations. Though evaluating the WEA sound attention signal was not initially part of the proposed research, we included it in the prototype design to be inclusive of all current and prospective WEA attention signals.

---

[1] Mitchell, H., Johnson, J., LaForce, S., Lucia, F., Price, E., Morris, J. (2011). Ex Parte Comments filed in the *Open proceedings of the Emergency Alert System [04-296] and the Commercial Mobile Alert System* [07-287].

[2] Center for Advanced Communications Policy (2014). Optimizing Ability of Message Receipt by People with Disabilities: Market Analysis Report [C.3.4.4] Georgia Institute of Technology: Atlanta, Georgia. (in press).

One output of the evaluations was the creation of a vibration rating which would ultimately define the proposed V-rating scale applicable to people living with hearing and/or vision loss, cognitive or sensation loss, as well as participants from the general population who may have "situational impairment" caused by factors such as bright or dim ambient lighting, high ambient noise levels, busy or distracting ambient environment, or by the placement of mobile devices in backpacks, purses, etc., where alert vibrations can be muffled. Additionally, we anticipated that adding a standard visual indicator to WEA messages, to occur simultaneously with the vibration signal, would not only increase their distinction from standard text messages, it would increase the probability of timely message receipt.

2. PROTOTYPE DESIGN METHODOLOGIES

2.1 Market Analyses

To advise the design and development of the prototype light sequence and V-rating, market analyses were conducted to ensure the prototype was based upon the market realities in which WEA currently operates. The market analyses assessed:

1. The accessibility level of WEA-capable devices determined which phones to include in the sample for evaluation of vibration strength.
2. The vibration strength of WEA-capable devices on the market was tested to quantify the low, mid and high vibration strengths to be included in the prototypes.
3. Technical specifications of assistive technology (AT) devices that use light and vibration to alert users of sounds in their environment were reviewed to determine if any AT features could be incorporated into the light sequence and V-rating prototypes.

2.1.1 Accessibility Review of WEA Capable Devices

WEA accessibility depends, in part, on the accessibility of the device. This review evaluated the accessibility of the WEA-capable devices available from the top four U.S. providers and one pre-paid provider: AT&T, Sprint, T-Mobile, Verizon and Metro PCS.[3] Researchers, using the providers' web pages as reference, identified 215 WEA-capable phones for evaluation. The list of evaluated phones (Appendix A) represents a sample of phones noted for WEA capability in April 2012 through July 2014. The sources used for the device assessment were the Global Accessibility Reporting Initiative (GARI) website, PhoneScoop.com and the device user manuals. We assessed up to 27 points of data for each device in the sample. In addition to noting the model, operating system (OS), providers, dimensions and display size, 15 features that impact accessibility and/or designed to provide access to people with vision, hearing, cognitive and mobility disabilities were tabulated.

Findings of the accessibility review indicated that the most frequently incorporated accessibility features were voice control to access the phone's features, voice dialing and text-to-speech technology (Figure 1). These features can be assistive to people who are blind, have

---

[3] The accessibility review builds on a list started in 2012 after the national rollout of WEA. At that time, the sample frame was the same, but the pre-paid provider chosen was Boost Mobile. Boost Mobile was since purchased by Sprint. Some of the phones evaluated may be pre-merger.

low vision, cognitive disabilities and/or physical disabilities. The review also found that features that could be assistive to people with hearing loss, such as vibration adjustment and two-way video capability, were present in approximately 40 percent of WEA-capable devices. Thus, for the evaluation of vibration strength, it was important for testing validity to evaluate a variety of phones.

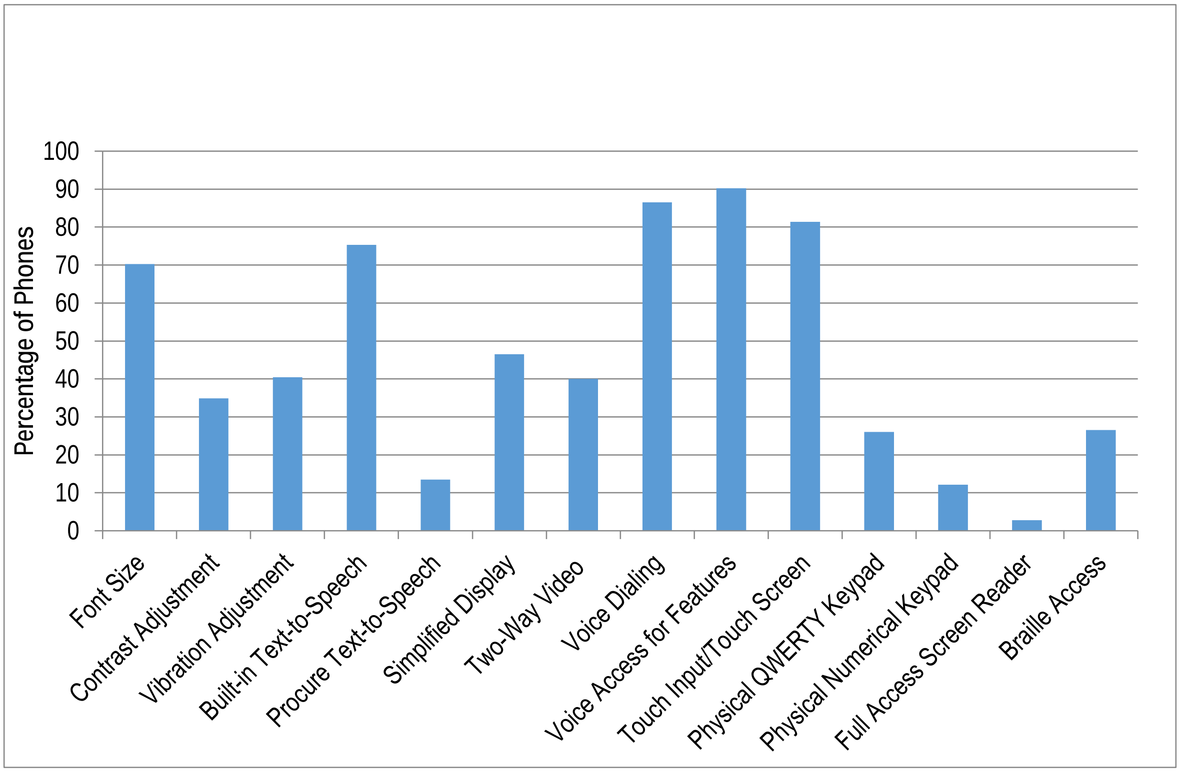

Figure 1: Accessibility Features of WEA Capable Phones

The results of the vibration evaluation revealed a broad range of vibration strengths, confirming the premise that WEA-capable devices lack consistency in this regard. This inconsistency could impact the perception of the WEA vibration cadence. The subsequent user evaluations of the vibration strengths provided new evidence regarding perception of WEA messages.

2.1.2 Evaluating Vibration Strength of WEA-Capable Devices

Many people do not upgrade their wireless devices every 18-24 months, which is the typical industry timeline for development and release of new phone models. A sample of twenty phones tested including a combination of brand new, just released and older phones. Motor strengths of WEA-capable devices were measured to determine the range of motor strengths in a sample of WEA enabled devices sold since 2012. The team also tested the latest generation of phones to account for users who prefer the latest handset technologies. Also considered were people who purchased models from a third-party Mobile Virtual Network Operator (MVNO) and often choose between either low-cost, value-engineered phones or the previous year's models.

To properly and repeatedly test the vibration strength of mobile phones, the technical team constructed a portable mechanism to quantify vibration strength. Vibration capture hardware, firmware and software were developed (Figure 2). Acceleration data was captured with an ST Microelectronics LIS331 accelerometer attached to a mobile phone suspended from a test rig. The phone was set to vibrate and the accelerometer measured the amount of shaking produced by the device. The accelerometer was configured to continuously capture acceleration data at a 1 kilohertz (kHz) sample rate using an internal clock. The microcontroller periodically polled the status information to determine when new data was available. The accelerometer values were read and sent with a microsecond-accurate timestamp to the host personal computer (PC) via a Universal Serial Bus (USB) connection.

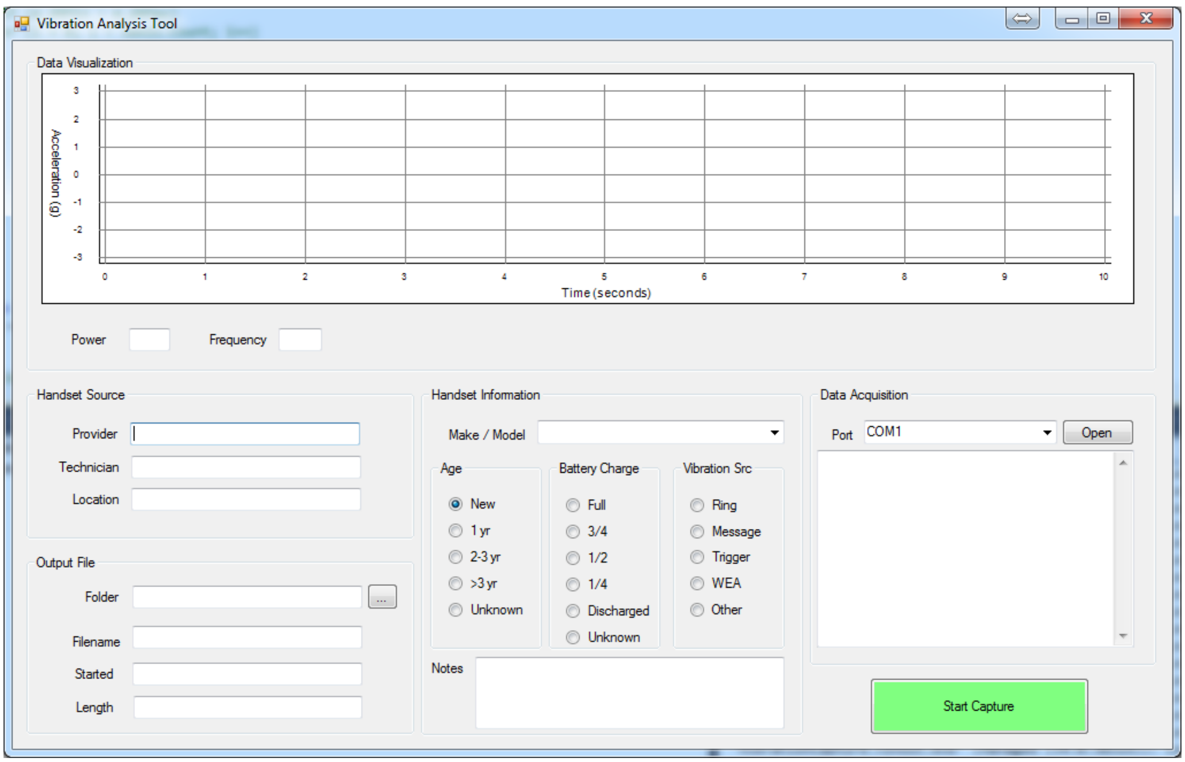

Figure 2: Vibration Analysis Software Interface

The data from the vibration sensor was in the form of a 3-D acceleration vector. When the device was not moving, the acceleration acting upon the sensor was a constant 1 g (1 unit of gravity) due to the force of gravity. When a vibration was imparted upon the device, the acceleration vector was agitated by the motion. To capture just the vibration signal, the three axes of acceleration data were averaged over time to find the mean 1 g acceleration vector due to gravity. The gravity acceleration vector was subtracted from the acceleration data to find only the acceleration due to vibration.

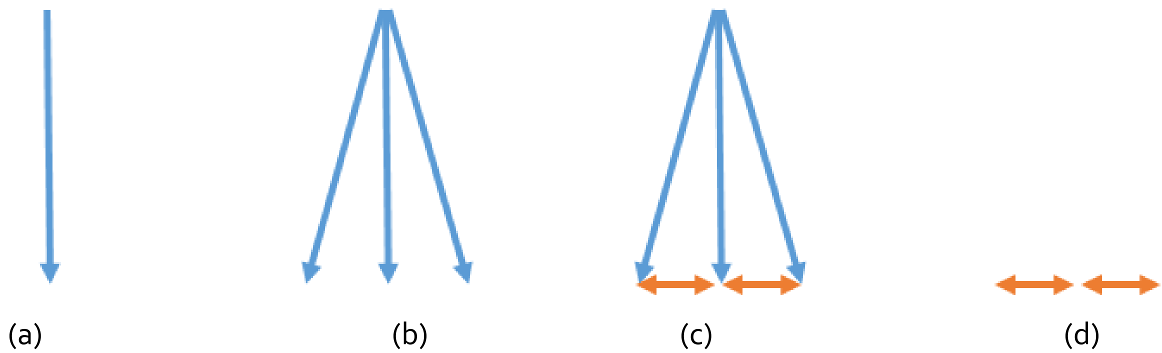

Figure 3: Extracting the acceleration due to vibration from the combined acceleration and gravity vector. Left to right: a) Constant acceleration vector due to gravity. b) Acceleration vector while device under vibration. c) Lateral movement due to vibration. d) Lateral vibration vector alone.

Since the vibration output of some of the devices was pulsed and not constant, the vibration segments needed to be separated from the non-vibrating segments. This was accomplished by only evaluating segments of data with a signal greater than a 0.1 g threshold. Segments less than 0.1 g were removed and assumed to be non-vibrating. A window of 10 milliseconds (ms) allowed the system to recognize segments of 50 Hz vibration frequency or greater.

The identified vibration segments were evaluated for root mean square (RMS) power of acceleration. [4] This metric compared the vibration strength between cellphones. The RMS power is the square root of the sum of the squared acceleration values (Figure 4). This provided a measure of the amount of energy imparted by the movement of the cellphone due to vibration.

$$y_{rms} = \sqrt{\frac{1}{T}\int_{0}^{T} y^2 dt}$$

Figure 4: Equation for Calculating RMS Power

Each cellphone was measured at least twice, (see Appendix A) and the results were averaged to produce vibration strength for each device. If a significant discrepancy was discovered between the two tests, the device was tested twice again until both samples agreed. Figure 5 shows a sample of the data collected from each device in the sample. The captured vibration data was stored in a text file with one data packet per line. Each line consisted of comma-delimited values. This format was selected because it is easy to parse in multiple programming languages and common spreadsheet programs. The first value indicates the type of data in the line. "B" lines are metadata, "A" lines are raw vibration data and "C" lines are calculated

[4] W. de Silva, C. (2006). Vibration: Fundamentals and Practice. *CRC Press*; 2 editions, September 14, 2006.

values. The file parser reads the first value and, based on this value, selects the appropriate logic to read the rest of the line.

The file has three sections. The first section includes metadata about the device. Note that each line in this section is marked by a “B” line type. The device provider, testing technician, location of test, make/model of device, age of device, battery charge state, source of vibration signal and any notes are stored here.

The second section contains the raw vibration data. Each line is marked by an “A” line type. The raw data consists of a timestamp in microseconds, an incremental index number, a sensor status field, the 3-D raw acceleration values scaled to 1 g, and the absolute magnitude of the acceleration vector (should average to 1 g). The timestamp indicates when the signal was sampled. In this system, the acceleration signal should be sampled about once a millisecond. The timestamp helps verify that the signal was sampled at the correct rate. The index is a monotonically increasing integer that uniquely identifies each sample. If a sample is lost due to congestion on the USB connection, there will be a discontinuity in this index value. The sensor status field is a snapshot of the accelerometer’s status byte at the time the data was read. Under normal operation it should be 15 or 0x00001111. These bits indicate that the data was read from the accelerometer in a timely fashion. The accelerometer data is reported as an X, Y, Z vector relative to 1 g. The magnitude of the vector is in the last column.

The third section contains results calculated from the sensor data stream. The last line is the RMS power value used to compare the vibration strength among devices.

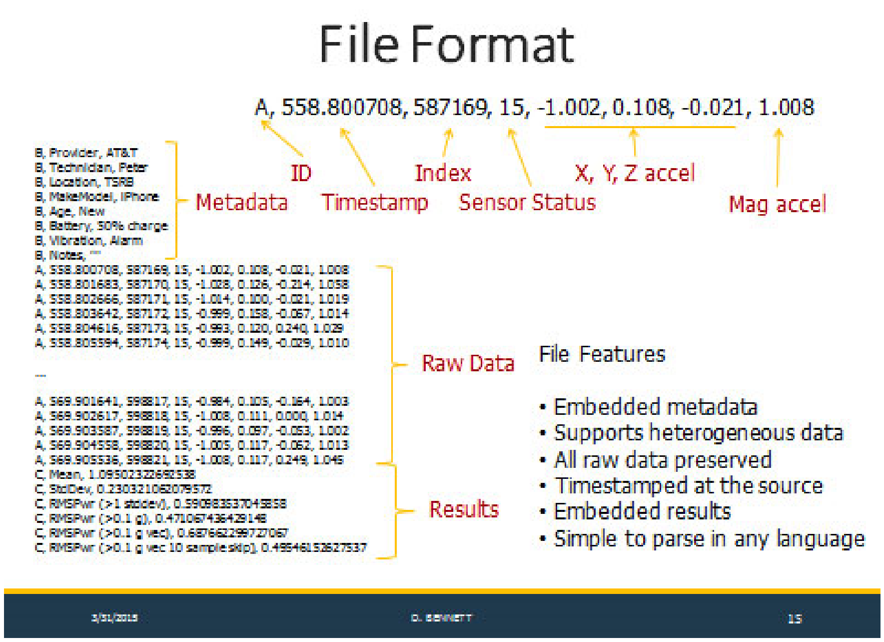

Figure 5: Sample of Data Capture from One Phone

Comparison of all results confirmed the premise that WEA-capable devices lack consistency with regard to vibration strength (Figure 6). This inconsistency could impact the perception of WEA vibration cadence, which is the feature publicized as making WEA messages accessible to people who are deaf and hard of hearing. Because a surprisingly wide variation of the vibration strengths (0.2 – 0.94 g) was obtained from the testing, the prototype V-rating was developed with a broad range of vibration strengths to determine a range of optimal strengths for increasing the likelihood of perception of an incoming WEA message. The results formed the basis for the vibratory strengths that were evaluated by end-users.

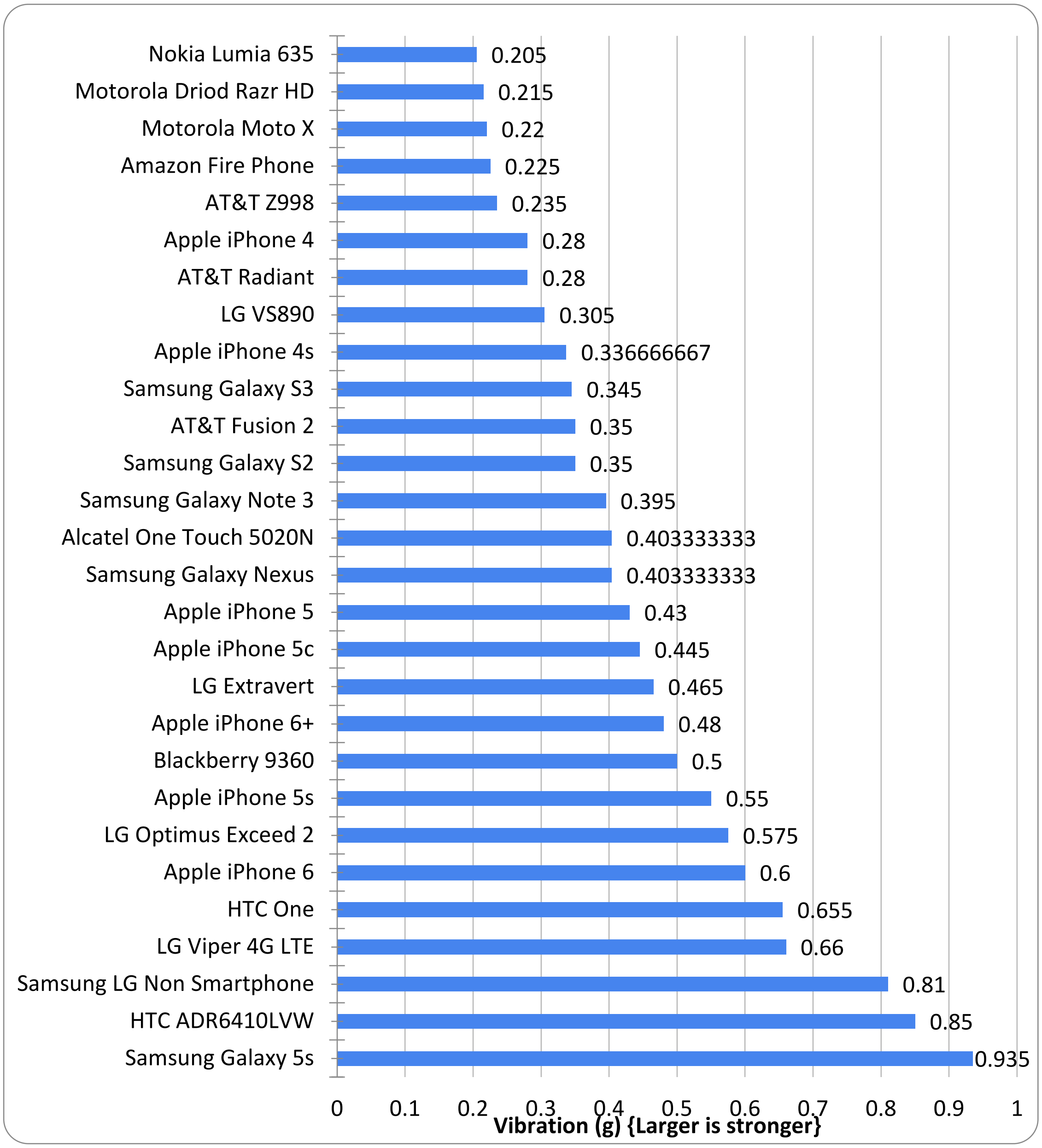

Figure 6: Vibration Testing Results

2.1.3 Assistive Technology Comparative Review

The AT review assessed specification data and standards to determine the most commonly used alert patterns for devices of similar application. For example, this review favored parameters of devices intended to be carried on one's person and those that incorporated a feature to alert the user of a WEA message. Recommendations were made for the most commonly cited parameters for vibration amplitude, frequency and cadence, as well as light intensity, frequency and cadence.

To compile a product listing for review, two web-based public databases on assistive technology were consulted. Both the National Public Internet Site on AT (Assistivetech.net) and Abledata (Abledata.com) were developed with federal funding to serve as a resource to individuals with disabilities by providing comparative information on AT products of all types. Sixteen distributors of products that alert individuals with sensory special needs to occurrences in their environment were found through these databases. A review of these distributors' product lines identified seven manufacturers of alerting products.

Project staff sampled web-based product literature to determine product specifications of interest to the prototype design, including amplitude, frequency[5] and duty cycle[6] of tactile (vibration) alerting devices; intensity, frequency and duty cycle of visible (lighted) alerting devices; and amplitude and frequency of audible (sound) alerting devices. This sampling found that only specifications for audible alerts were present in the device marketing literature. As a result, each of the manufacturers was contacted to request further specifications about each of their devices for alerting those with sensory impairments.

Recommendations are made for the most commonly cited parameters. These recommendations are detailed below.

(a) Tactile Alert Recommendations

- Vibration Amplitude: 1.6 millimeters (mm)
- Vibration Frequency: 60 Hz, 120 Hz
- Cadence Frequency: 0.25 Hz, 1 Hz
- Cadence Duty Cycle: 50 percent

(b) Visual Alert Recommendations

- Light Intensity: 12 lumen (lm), 117 lm
- Light Frequency: none (constantly lit within the controller cadence specifications)
- Cadence Frequency: 0.5 Hz, 1 Hz
- Cadence Duty Cycle: 33 percent, 50 percent

---

[5] **Amplitude** is the maximum distance (or displacement of) a vibrating body moves. **Frequency** is the number of times the vibrating body moves during a given time (typically in seconds).

[6] A **duty cycle** is the percentage of one period in which a signal is active. A period is the time it takes for a signal to complete one on-and-off sequence. For example, if a signal vibrates for 2 seconds then stops for 6 seconds, then vibrates for 2 seconds, the duty cycle would be 33.3 percent.

Note that these recommendations reflect the market analysis for AT products only. They do not reflect user preferences or what is technically feasible given the design constraints of a cellular phone. For the prototype, the vibration amplitude was reduced for comfort and to fall within the range achievable in wireless devices. The higher light intensity that is used in AT devices was achieved in the prototype by using LED light strips with the following millicandela (MCD) intensities: Red 405 MCD, Green 690 MCD and Blue 190 MCD.

2.2 Focus Groups / User Needs Analysis

To inform the design of the prototypes and usability testing, focus groups composed of individuals with hearing and vision disabilities were convened to explore their use and perception of vibration and light output signaling in mobile and other consumer electronic devices. Behavioral response to WEA messages were also discussed, because understanding the actions people take or do not take could better inform recommendations about whether there was an increase in the reception of the WEA message and what the response to the message was. The main objective of these focus groups was to explore the adequacy of the WEA vibration and alert signals. Several topics related to signaling were discussed, including: how environmental notification devices such as door knock alerts, smoke detector alarms and waking alarms signal the user; the effectiveness of signaling methods such as vibration, sound and light; how people carry mobile phones; and mobile phone accessibility features and applications.

Our purposeful sampling method[7] identified subgroups among our target population of people with hearing disabilities to include people who are deaf and people who are hard of hearing. The subgroups of people who are deaf were further stratified into people who are deaf and primarily conversant in American Sign Language (ASL) (with limited English proficiency), and people who are deaf and proficient in English (even if they prefer ASL). Sampling this population was important in understanding the sensory components of mobile devices and WEAs that would optimize signaling of an incoming message.

Attention Signals

To gauge the most effective way to alert users, participants were asked which attention signal worked best – vibration, sound or light. Preferences for a specific type of attention signal varied by group. The majority of participants that were deaf or hard-of hearing preferred a light and vibration attention signal, with the exception of the hard of hearing group that had some residual hearing preferring the vibration and sound signals. Individuals that were blind primarily used the sound attention signal and occasionally the vibration attention signal. Those with low vision indicated they preferred a light and/or vibration signal. All participants noted that while they prefer a specific type of signal, they are apt to miss calls based on how they carry their phone. The findings from the blind and low vision groups prompted Center for

---

[7] A **purposeful sampling**, also known as purposive sampling, is a population sampling method used in qualitative studies to compare perspectives of different groups and identify central themes within and across the groups; it is not meant to be a representative sample of the population.

Advanced Communications Policy researchers to include people with vision disabilities in the usability testing.

There was a difference of opinion about whether the pitch of the alert was noticeable. Participants suggested specific types of pitches and variation in pitches. One hard-of-hearing participant reported that the WEA audible signal was too high and felt a lower signal would be more audible. He was immediately contradicted by another participant who felt that the low signals were not audible and liked the higher pitch. Another hard of hearing participant reported having been alerted to a WEA because, *"The phone was constantly making a sound. I know it's not a regular phone message. It's very distinctive."* One individual recommended that the sound be something different that is never encountered in public, while another suggested the sound vary over its course, specifically mentioning an S.O.S. type of signal.

Participants were asked what they thought about the vibration signal on the WEA messages they had received. Despite the fact that WEAs do have a distinct vibrating cadence, most participants did not notice that the vibration was different from their incoming message vibration. Only five individuals reported that they had noticed that it was any different from the normal vibration. Three participants even mentioned that they wished they had a way to differentiate the vibration from other signals their phone exhibited. A few suggested that the user be able to select the vibration to be something that was distinctive to them.

A minority of deaf and hard of hearing participants (six) had specific memories of seeing the visual signals from WEAs. Others were not sure whether there was a visual signal or not. Some participants theorized that whether they noticed a signal would depend on how they positioned their phone. If the light source or screen was face up on the table, they would be more likely to see the visual signal. Some participants suggested that the visual signal should, at minimum, come from both sides of the phone. One participant specifically mentioned that the flashing light on her phone was too small to get her attention, and there needed to be a larger, brighter light source. Another participant suggested that the WEA light should be a different color than other visual phone signals. These suggestions were taken into account when developing the prototype signals to be tested. The final design incorporated bright lights that could be activated in different colors, as well as lit on the front (where a screen would be) and along the left side of the prototype.

Phone Placement Habits

In anticipation of the possibility of missed calls due to the location of the phone, participants were asked where they primarily carried their phones. The location varied based on gender. Women tend to carry their phone in their purse and most men mentioned carrying the phone in their pocket. Women were also more likely to carry the phone directly on their skin, such as in their brassiere, when their clothing did not have pockets. Several participants mentioned that even while at home or at work, they carried their phone wherever they went. Nearly all of the participants place their phone somewhere near their bed, typically on the night stand. These findings informed the design of the usability testing itself, namely asking participants to hold the prototype device in a manner which they would normally carry their mobile phone. This allowed for a more realistic accounting of response times to the different stimuli.

Table 1: Phone Placement Habits and Signal Preference

Groups	Mobile Phone Use		
	Attention Signal	Phone Location	
		Carry	Home/Work
Group A: Deaf with no residual hearing. Receptive and expressive in written English.	Light, Vibration	Pocket or bag	Nearby surface (e.g., end- table / desk)
Group B: Deaf with no residual hearing. Receptive and expressive in ASL	Light, Vibration	Pocket	Top of TV/ pocket
Group C: Deaf and hard of hearing that uses hearing aids or cochlear implants. No residual hearing without aids.	Light, Vibration	Pocket or belt clip	Nearby surface / desk
Group D: Hard of hearing, some residual hearing without the use of hearing aids or cochlear implants.	Sound, Vibration	Pocket or belt clip	Nearby surface
Group E: Blind	Sound	Pocket or bag	Night stand/ charger
Group F: Blind/Low Vision	Light/Vibration	Pocket or bag	Night stand/ charger/

Wireless Emergency Alerts

An accessible version including both captions and ASL interpretation of a WEA public service announcement (PSA) was obtained from Deaf Link.[8] Showing the Deaf Link video helped many participants to distinguish between the different types of alerts. Because of participants' confusion over which alerts received were actually WEA messages, however, it was difficult for

[8] See WEA PSA http://content.deaflink.com/pri/FEMA_1.html; captions and ASL interpretation produced by Deaf Link, Inc. under IPAWS Contract # HSFE5-13-P-0434.

them to discern different types of alerts when talking about how they are noticed, their accessibility, and the ease of their receipt and understandability. To keep all participants on the same topic, we used the emergency notification preview (available on the Samsung S5) to demonstrate the WEA sound alert and vibration cadence.

Many of the participants reported noticing the WEA message immediately, but many were unsure that it provided vibration. A couple of participants said they received the alert late because their phone was on silent. At least one participant did not think that her SafeLink phone ever received a WEA message—weather -related or America's Missing: Broadcast Emergency Response (AMBER).

Participants had several suggestions for improvement, among them were:

- Using different sounds for particular events;
- Flash in a different color light (Red);
- Override silent settings and have the phone speak the word "ATTENTION"; and
- Include a vocal alert.

3. PROTOTYPE DEVELOPMENT

Based on the market survey an alert test device was built. This device included a number of alert modalities including light in various colors, sound and vibrations. The WEA sound attention signal and vibrating cadence were developed using the specifications outlined in Part 10 §10.520, Common audio attention signal and §10.530 Common vibration cadence of the FCC rules concerning WEA. The prototype device generated test vibration strength signals at three levels. The low signal level was a 0.9 g vibration as captured by the device test system. This correlates to the highest level of the commodity devices tested. The medium signal level was a 1.43 g vibration and the high level was a 2.24 g vibration.

These signal levels were selected based on the commercial devices tested. The low level represents the maximum level currently available. The medium level is 50 percent stronger, and the high level is more than twice as strong. The goal is to evaluate if higher strength vibrations provide a benefit to people with disabilities. The prototype was linked to a PC via a Bluetooth connection and triggered by a technician performing the test (Figure 7).

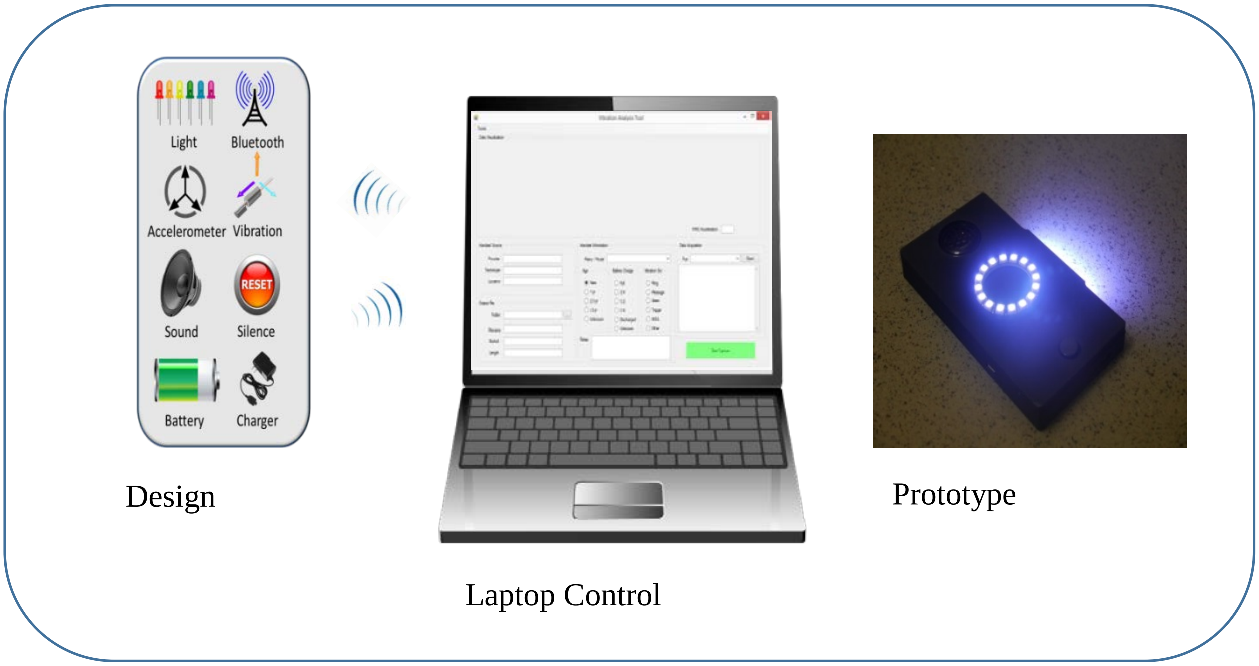

Figure 7: Prototype Design

The vibration test device was built from the following components:

- Teensy 3.1 embedded controller
- Battery charger - microUSB
- 850mah lithium polymer battery
- 600ma 5v power regulator
- A linear strip of LED lights (8 x WS2812 5050 RGB LED) on one side that can be flashed in a cadence pattern of colors denoting severity of event (red, green and blue). The colors are subject to change depending upon user feedback.
- A round circle of LED lights (16 x WS2812 5050 RGB LED) on the front of the device that can be animated and lit in colors denoting severity of event.
- A vibration motor (Precision Microdrives) that can be set to vibrate at a variety of strengths and can be set to any cadence, including the WEA cadence as prescribed in the FCC rules. We planned to change out the driver for the motor (DRV8830) to provide for a larger range of vibrations, as we discovered during initial testing that the vibration strength was not as strong as we would like. This is part of the refinement task for March.
- Roving Networks RN-41 Bluetooth module
- A piezo speaker driven by a class-D audio amplifier (Texas Instruments TPA2005D1) that plays back the Emergency Alert System (EAS) attention tone as prescribed by the FCC rules, and/or other sounds.

Figure 8: Vibration and Light Prototypes

For the purposes of testing user reception to varying vibrations and lights, a handheld prototype was constructed that mimics a cell phone. The device was about the same size as an iPhone 6 (but thicker due to the use of a 3-D printer to manufacture the custom case) (Figure 8). The device could be triggered via Bluetooth to work in a variety of ways. Figure 9 shows the usability testing software that was built to support the testing efforts. The software communicated with the prototype allowing the technician to trigger alerts upon command.

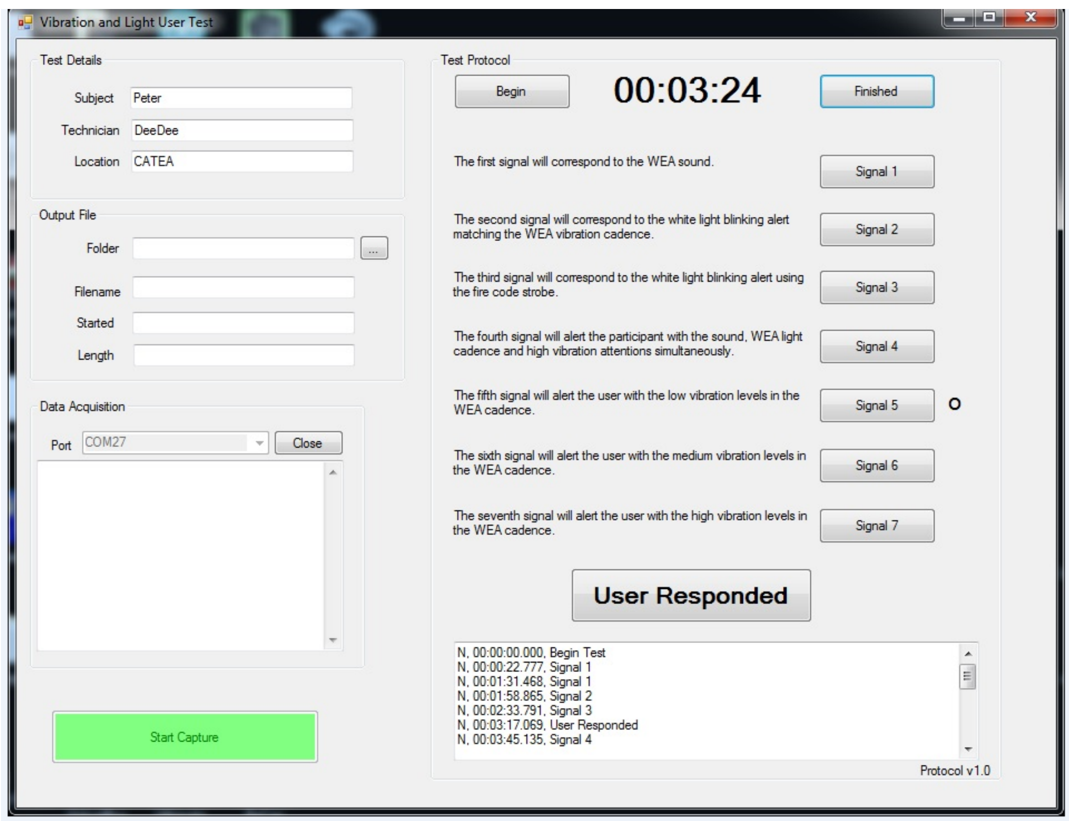

Figure 9: Usability Testing Software

4. USABILITY STUDY

4.1 Demographic Profile

The usability study sought to evaluate the prototype vibration, sound attention and light alert signals. The purpose was to identify optimal levels of vibration for WEA messages and to propose a vibration rating for mobile phones. Forty-six individuals participated in the usability study and within this group, the following characteristics were reported most frequently by respondents: Black/African American (52 percent) female (61percent) with low vision (33 percent) who are technically savvy (76 percent) and between the ages of 44 to 62 years (44 percent). A breakout of the demographics is below.

Disability Type

The respondents could select one of five disability types: blind, deaf, hard of hearing, hard of hearing/legally blind and low vision (Figure 10). There was no deaf/blind category; however, 2 percent of respondents indicated they had both hearing and vision limitations. The disability most reported was low vision (33 percent, 15 respondents), which was significantly higher than the next highest reported disability type, hard of hearing (28 percent, 13 respondents). Slightly fewer reported being deaf (26 percent, 12 respondents) and far fewer respondents selected blind (11 percent, five respondents) and one respondent reported hard of hearing/legally blind (2 percent).

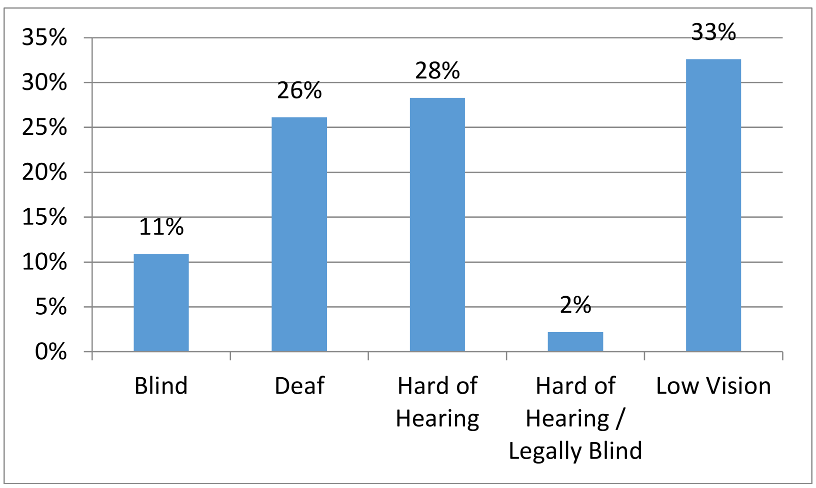

Figure 10: Disability Types

Technology Level

Respondents had three choices for self-reporting their familiarity with technology. A majority of respondents (76 percent) reported they were "technically savvy" (35 respondents). Far fewer respondents reported having "some technical know-how" (22 percent, 10 respondents), and one respondent reported being an "infrequent user of technology" (2.2 percent).

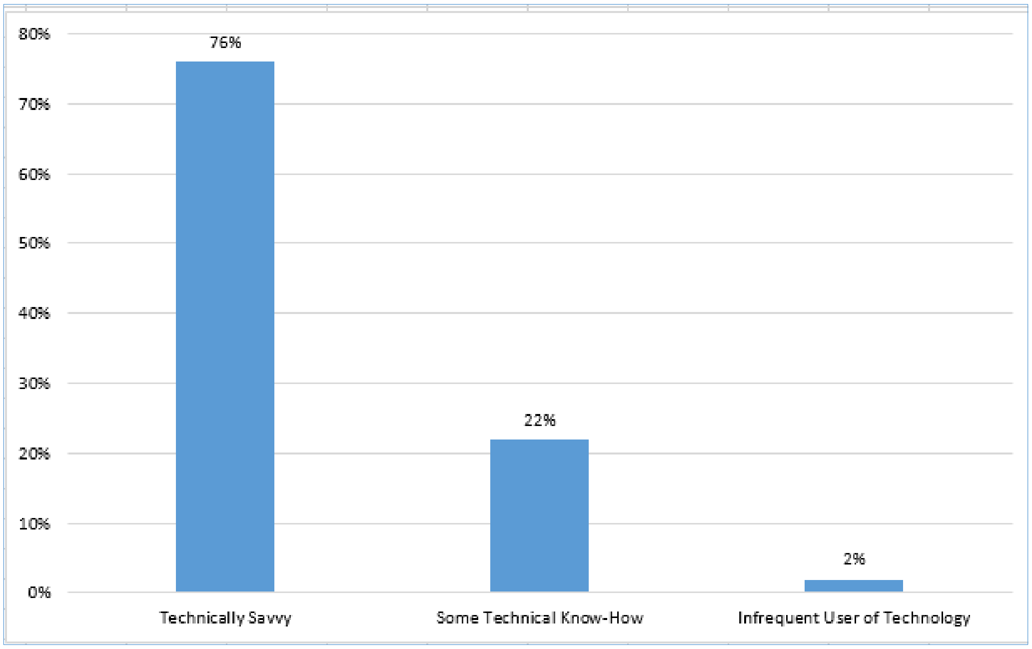

Figure 11: Technology Level

Gender

A majority of respondents identified themselves as female (61 percent, 28 respondents), and 17 respondents identified themselves as male (37 percent). These were the only two gender choices for this question; however, one individual chose not to answer the question.

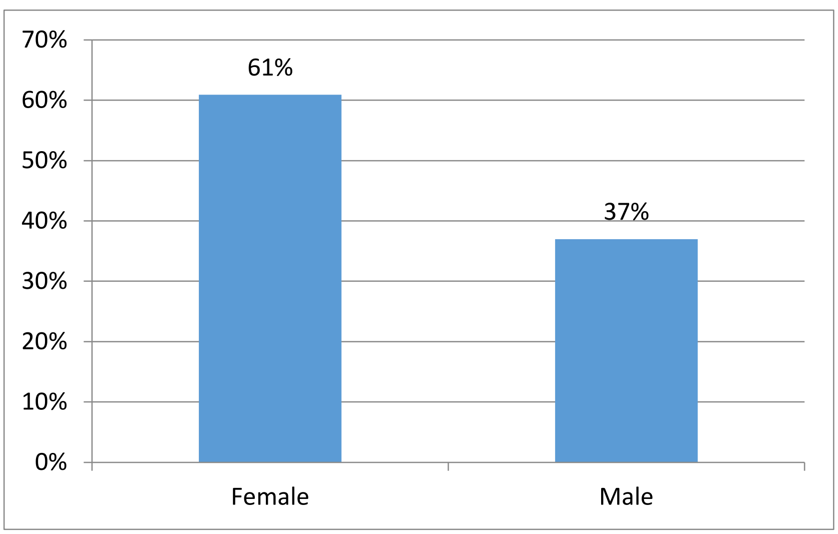

Figure 12: Gender Distribution

Ethnic Background

Respondents were asked to self-identify their ethnic background. A majority of respondents (52 percent) reported being Black/African-American. Fewer respondents (39 percent) reported being White/Caucasian, and three respondents (7 percent) reported their ethnic background as Other.

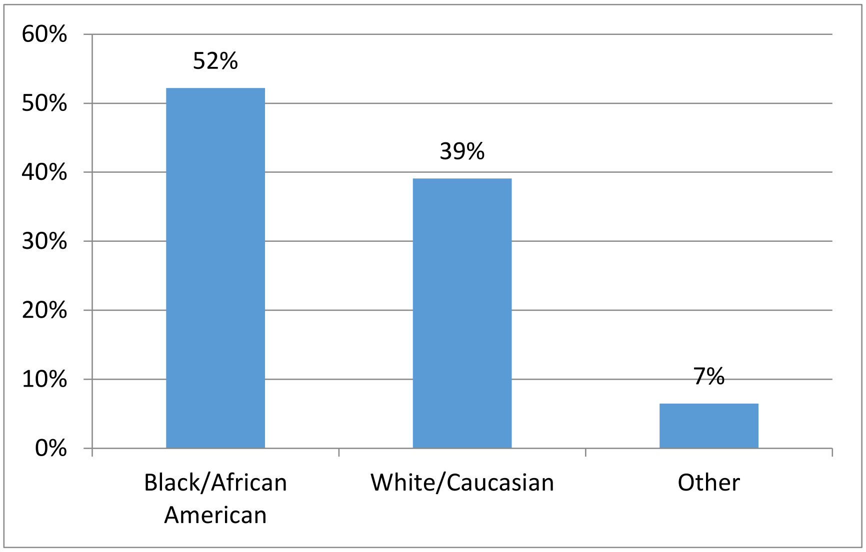

Figure 13: Participant Ethnicity

Age Distribution

Respondents were asked to select between four age ranges, the youngest range specified was 18-24. There were no respondents under the age of 18 in the study. There was no majority of any age range. The age range with the largest number of respondents was 44-62 with 20 respondents (44 percent). Far fewer respondents were in the next largest age range 25-43 years (28 percent, 13 respondents), closely followed by the 65+ age range (26 percent, 12 respondents). One respondent was in the 18-24 age range (2 percent).

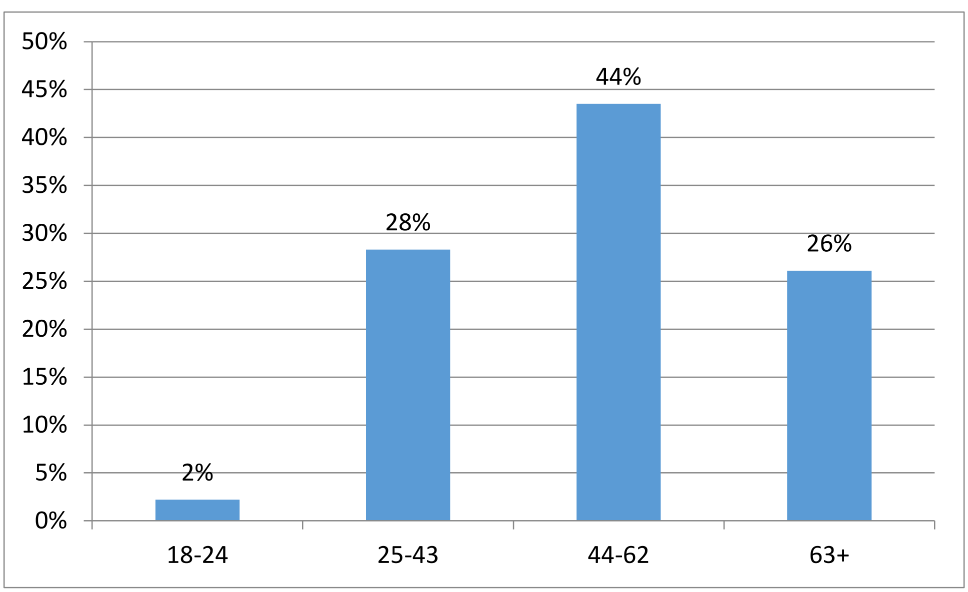

Figure 14: Age Distribution

4.2 Usability Study Parameters

The usability study was broken into two parts. After obtaining consent, participants were administered a demographics questionnaire/pre-test interview (Figure 16) which asked them to self-identify their disability type(s), race, age and gender. They were also asked questions about their personal mobile phone. For example, how they primarily carried it, how they would rate the strength of its vibration and whether they used assistive technology in conjunction with the device. Finally, we closed the pre-test interview by allowing the participants to hold the prototype device in their hand and give absolute rankings of different notification signals. The technician triggered the device in the order of low vibration, medium vibration, high vibration, white light, red light, green light and blue light. The technician recorded the participant's absolute ratings on a five-point Likert scale ranging from poor to excellent. These absolute ratings served as baseline for the participants' explicit opinions and preferences for the notification signals tested.

The second phase of usability study was designed to capture the participants' reaction time to the different notification signals tested. To provide a consistent testing environment for all study participants, they were placed in a simulated airport setting with distractions that included airport noises (from the Atlanta-Hartsfield Airport), news channels, other travelers, snacks and drinks, newspapers and magazines. Each participant was asked to carry the prototype handset in a manner similar to the way they primarily carry their mobile phone (i.e., in their hand, purse, pocket). Two participants were surveyed simultaneously in the same room; however, each of the handset devices was signaled at different times. This ensured that the participants were not alerted to the incoming signal because of another's reaction to the stimulus.

Seven signals were sent to each prototype device. The signals were sent in a different order so that subjects would not be aware of what signal to expect next. The signals were 10.5 seconds in length. Each signal was sent twice. This signal duration matched the length prescribed by the Alliance for Telecommunications Industry Solutions (ATIS) and the Telecommunications Industry Association (TIA) WEA Mobile Device Behavior Specification (Figure 15).

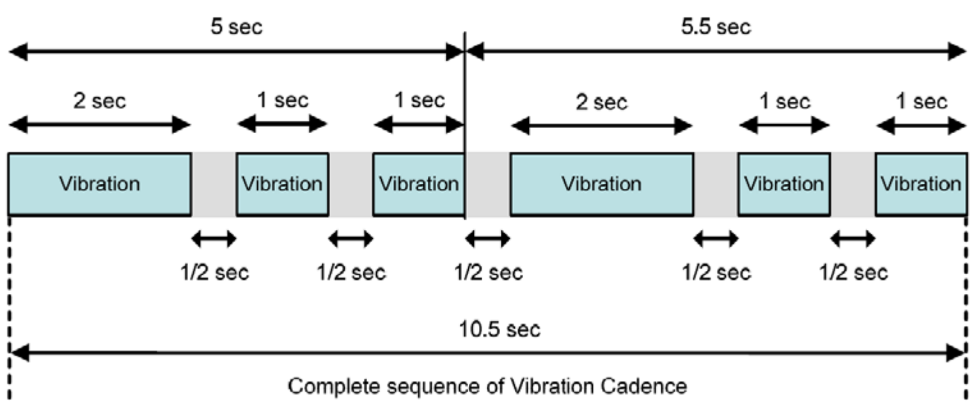

Figure 15: WEA Vibration Cadence Sequence

The first signal corresponded to the WEA sound attention signal (WEA Sound); the second signal corresponded to the white light blinking alert matching the WEA vibration cadence (WEA Light); the third signal corresponded to the white light blinking alert using the National Fire Protection Association's Code (Fire Code)[9] ; and the fourth signal alerted the participant with the WEA sound, WEA light cadence and high vibration attentions simultaneously (WEA All). The fifth, sixth and seventh signals alerted the user in the WEA cadence with the low, medium and high vibration levels (as determined from the WEA handset vibration testing). The vibration signals were consistently sent in the following sequence: medium, low, high; or high, medium, low depending on if they were assigned to receive the signals in the top-down order or reverse (refer to Figure 17: Usability Testing Software for the full listing of the seven signal sequences). For each signal, the participant response time was measured between when the signals were sent to the handset device and perception as observed by the computer software capturing the time; these were validated by observations. As each signal was administered, a researcher documented the participants' activity at the time the signal was administered, where the device was located and how the individual reacted.

The scenario room included:

- Atlanta-Hartsfield Airport sounds: https://www.youtube.com/watch?v=RzyiuGV6BX8;
- Large screen for CNN closed captioned video with low sound;
- Magazines and newspapers;
- Table with snacks and beverages; and
- Seating for at least six people (two researcher participants, two observers/note-takers and two technicians).

SEQUENCE OF EVENTS

The study closely adhered to the protocol, as required by Georgia Tech's Institutional Review Board (IRB). In addition, the following occurred:

1. Each participant was paired with an observer/note-taker.
2. The note-taker completed the demographics questionnaire (also referred to as the Usability Testing Form) with their participant.
3. For the last two questions, the note-taker allowed the participant to hold the prototype device.
4. The technician triggered the device in the following order: low vibration, medium vibration, high vibration, white light, red light, green light and blue light. The technician then recorded the participant's absolute rankings on a five point Likert scale ranging from poor to excellent.
5. The participants were placed into the scenario room (i.e. the usability lab at the Center for Assistive Technology and Environmental Access (CATEA)).

[9] The maximum pulse duration shall be 2/10 of a second.

6. Two note-takers and two technicians also sat in the room to observe their identified participant and signal the handset devices separately. Their role was also to play individuals waiting at the gate. This explained their presence in the room.
7. After all seven signals were sent twice to each participant, they were informed that the study was complete.
8. The participants were asked for their opinions on the different signals and the study.

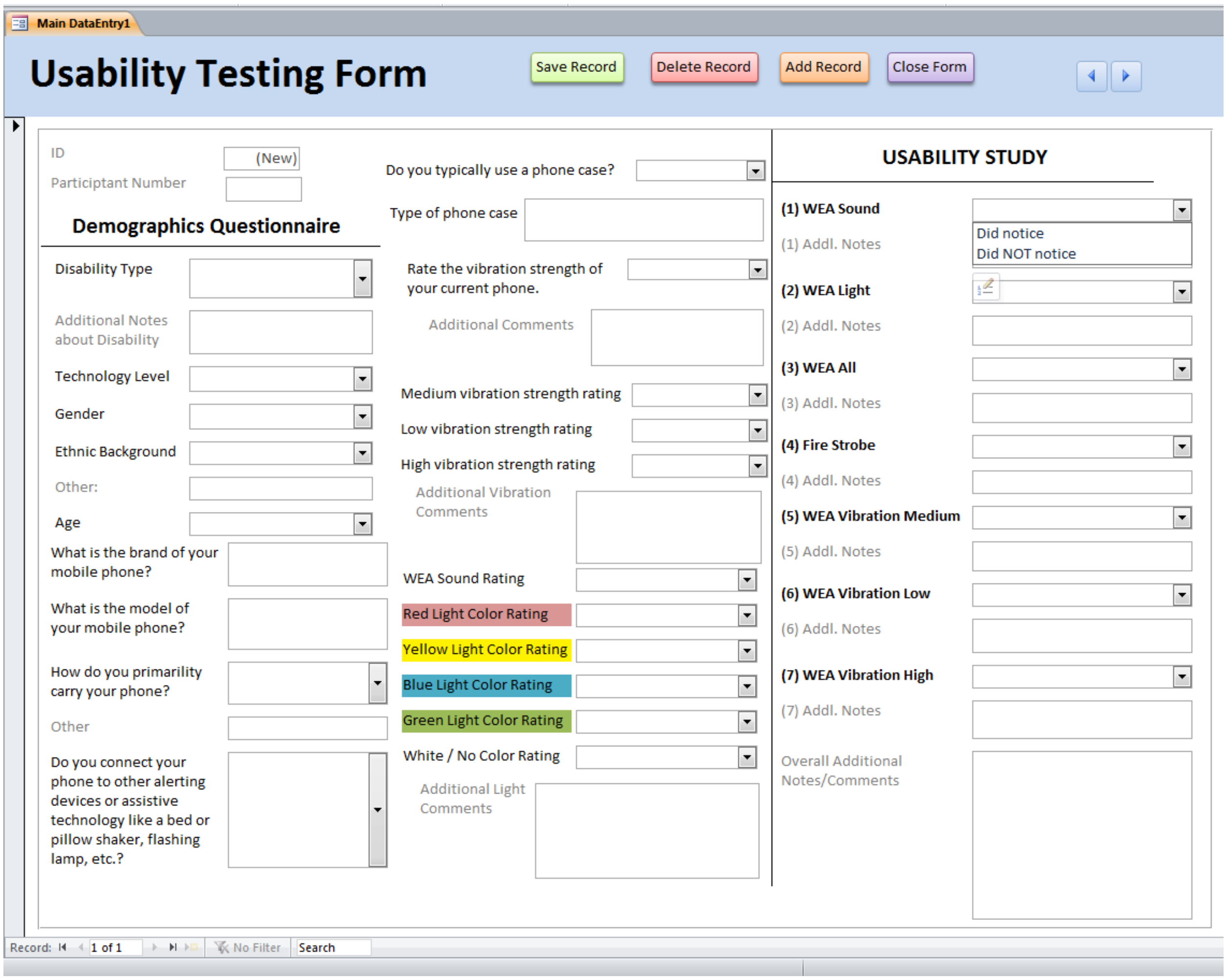

Figure 16: Usability Testing Form

5. RESULTS

5.1 Absolute Ratings

As discussed in Section 4 of this report, phase one of the study allowed participants to hold the prototype device in their hand during the pre-interview and asked them to provide absolute (i.e., pure) ratings for each signal. The technician triggered the device in the order of WEA Sound, low vibration, medium vibration, high vibration, white light, red light, green light and blue light. The participant's absolute ratings were recorded on a five-point Likert scale ranging from poor to excellent. The following graphs display the results of the participant responses using a simplified variable. Poor and fair ratings were combined, as were very good and excellent to more clearly define a low end and high end, resulting in a simplified three point rating of low, medium and high for the vibration rating analysis. For reporting consistency, the simplified variable approach was also applied to the WEA Sound data and the WEA Light option data.

Figure 18 shows that 59 percent of study participants found the WEA Sound attention signal to be very good or excellent, 9 percent indicated it was good and the remaining 33 percent rated it as poor or fair. Fifty-two percent of the participants that rated it poor or fair had a hearing disability.

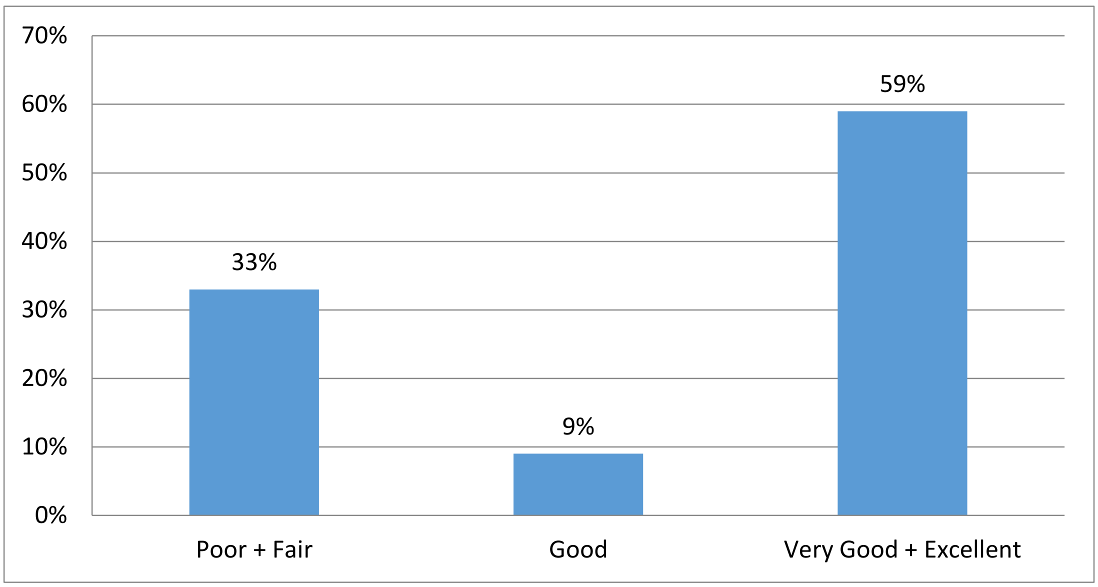

Figure 17: WEA Sound Rating (Absolute)

Figure 19 illustrates participant ratings of the low, medium and high WEA vibration strengths. Regarding the high vibration strength, 78 percent of respondents indicated it was very good or excellent, 11 percent stated it was good and 9 percent found it to be poor. Regarding the medium vibration strength, 61 percent of participants indicated it was very good or excellent, 15 percent found it to be good and 24 percent rated it as poor or fair. Finally, with the low vibration strength, 26 percent found it to be very good or excellent, 28 percent indicated it was good and 46 percent found it to be poor or fair. From these data, it is clear that the strength of the vibration has a direct positive relationship with the percentage of participants that found it to be effective (i.e., the higher the vibration strength, the higher the percentage of participants that rated it as very good or excellent). This logic holds for the reverse, as the vibration strength lessened the percentage of participants that rated it as poor or fair increased (i.e., indicating a negative relationship between the variables).

In addition to their Likert scale rankings, participants were asked if they had any comments about the different vibration strengths. The observers/note-takers recorded the following research subjects' comments (verbatim):

- [I] could feel the WEA sound. I use hearing aids but did not know there was an alert. I was aware the device was doing something.
- [It] depends on [the] vibration alert. I fall asleep with phone in hand or on chest.
- The medium strength is better than the ones I get on my phone; reminds me of my mom's pillow shaker.
- The medium vibration [tested] is better than my phone.
- The medium vibration is hard to feel. If placed on lap [the vibration is] not consistent.
- [My] service dog noticed high vibration immediately and came to attention.
- Slower vibrations are easier to feel.
- I don't think that the low and medium [vibrations] would get my attention if it were an emergency.
- There should be better differentiation between the vibration signals. There is nothing really special about them to dig in my pocket and see what the message was about.
- Vibrate [should be] a little deeper so it can be felt more intensely, especially for someone who carries it in a bag like I do, especially when moving around in traffic, you want to be able to feel it.
- [The] vibration feels different [when] holding versus in [my] pocket.

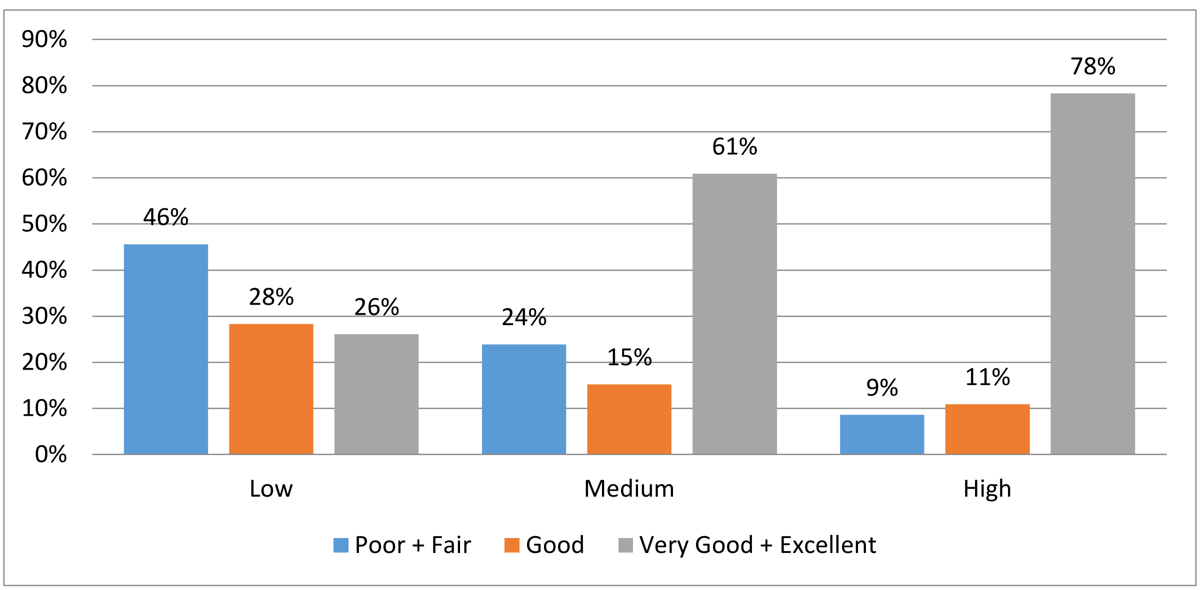

Figure 18: Vibration Strength Ratings (Absolute)

Regarding the different colors that could be used in a WEA Light attention signal, generally, the data indicate a favorable response to the incorporation of colored lights as a WEA attention signal (Figure 20). A majority of participants rated the green light (72 percent), red light (70 percent), blue light (67 percent) and yellow light (63 percent) as very good or excellent. The white light, or colorless option, was rated the lowest. This rating may be due to the fact that it is very similar to the flashlight incorporated into many smartphones on the market. The observers/note-takers recorded the following research subjects' comments verbatim) regarding the light options:

- As long as [the device] is on [my] left side [I] can see the light. Regarding the blue light, [I] thought the police were coming. The blue and red lights stand out in peripheral vision.
- As long as [the device] is within line of sight [I would notice it]. The white [light] could get lost in the day to day activities.
- The blue light was the most eye grabbing.
- [I] might not see [the] red light if it were a small light, like on most phones.
- I do not like the red but it would get my attention. I like the blue light the best.
- If a color is supposed to signify something I don't like the white signal...what does it mean?
- The red light may be confusing with recording features. White is too generic.
- The red light was really great because it has connotation with it. The yellow would be a good follow-up if you couldn't use red, because yellow...caution. But the other ones I wouldn't really pay attention to because they are not move to action colors.
- I prefer yellow over red, but the green light is better than the yellow. There should be different lights for different levels of alerts.
- The red is blurry, but the green cuts through; blue illuminates in poor lighting conditions.
- The red was not as distinctive. The white light and blue light were better.
- White is softer in color – I like it better.

Figure 19: Ratings of Potential WEA Light Color Options

5.2 Response Time Ratings

In phase 2 of the usability study, participants were asked to place the prototype where they would normally carry their cell phone. When response times for all participants were averaged, the quickest reaction time was to the medium WEA vibration cadence (4.7 seconds). The WEA Sound, WEA All and the high vibration cadence all received a five-second response time (Figure 21). The Fire Strobe received the slowest reaction.

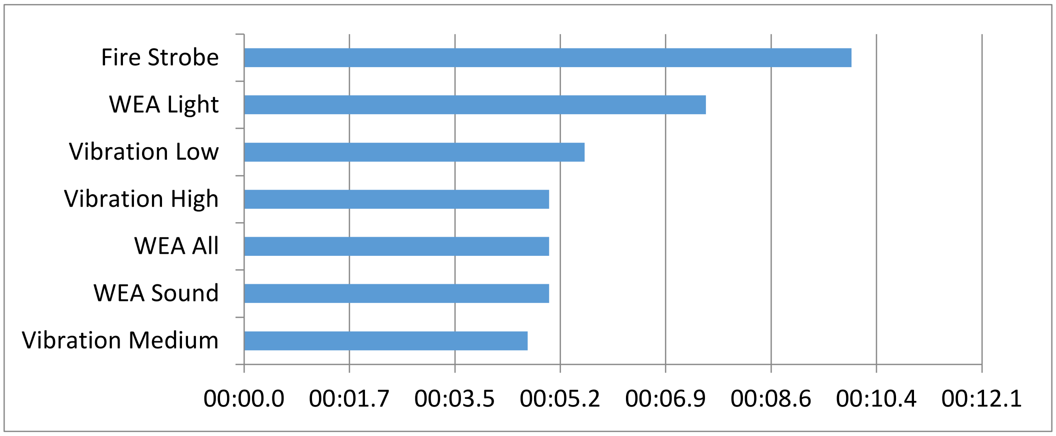

Figure 20: Aggregate Response Times (All Participants)

For participants that were deaf, the top three quickest response times were the low vibration at 4.5 seconds, the medium vibration at 4.9 seconds and the WEA Light cadence at 5.1 seconds (Figure 2\2). The signals that received the slowest response times were the Fire Strobe at 10.6 seconds, the WEA Sound[10] at 6.6 seconds and WEA All at 5.9 seconds. It was surprising to find that the participants that were deaf responded more quickly to the lower vibration strengths than to the high. Potentially, the unfamiliarity of the highest vibration signal startled the participant, creating latency between noticing the signal and reacting.

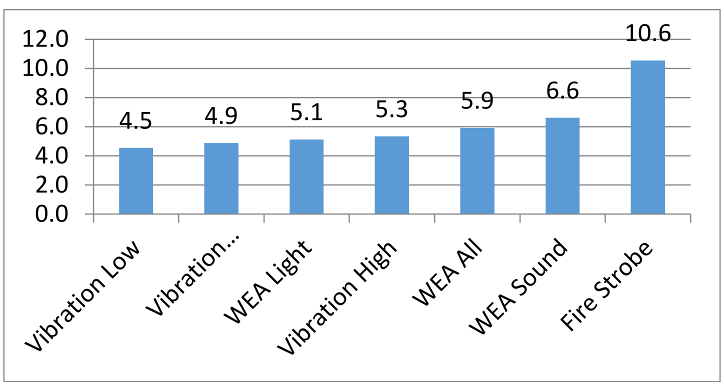

Figure 21: Response Times of Participants That Were Deaf

Participants that were hard of hearing had the quickest response time to the WEA Light cadence; then the high, medium and low vibrations; then the WEA Sound, WEA All and lastly

[10] Some the participants that identified as being deaf used hearing aids which accounts for their ability respond to the WEA sound attention signal.

the Fire Strobe signal (Figure 23). At 16.9 seconds, they had the slowest response time to the Fire Strobe. The WEA All signal response time was 5.1 seconds and the WEA Sound and WEA low vibration responses were equal at 4.5 seconds. These data suggest that for people with hearing loss, the inclusion of the WEA Light signal would increase their ability to notice incoming WEA messages.

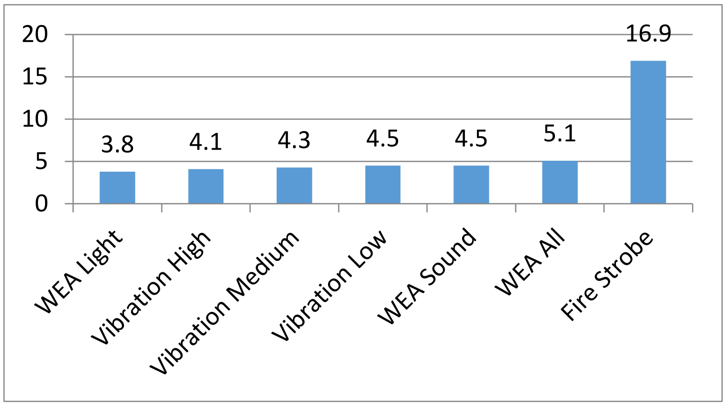

Figure 22: Response Times of Participants That Were Hard of Hearing

We anticipated that for the participants with vision disabilities that the WEA Sound signal would have the quickest response time. Participants that were blind responded most quickly to the vibration signals, however. Figure 24 shows that they responded equally as fast (3.5 seconds) to the low and medium vibration strengths, then the high vibration strength (3.6 seconds), WEA All (4.2 seconds) and lastly the WEA Sound (4.8 seconds).

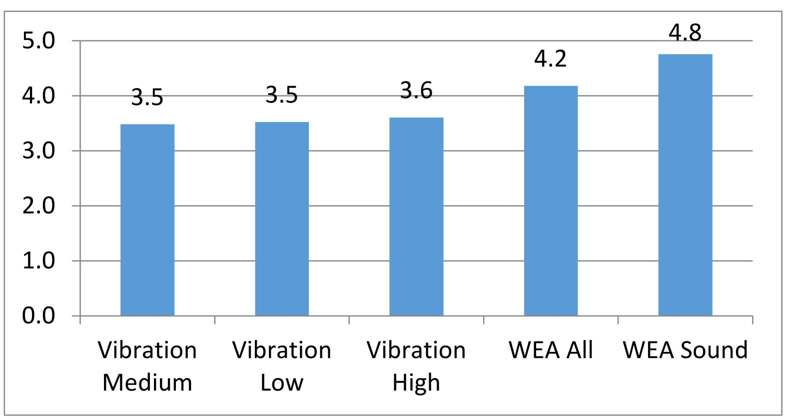

Figure 23: Response Times of Participants That Were Blind

Participants that had low vision responded most quickly to the WEA Sound and WEA All signals (both at 4.5 seconds); then the high vibration at 5.1 seconds, medium vibration at 5.3 seconds and low vibration at 5.4 seconds. For this group, the longest response times were to the WEA Light at 7.3 seconds and the Fire Strobe at 8.5 seconds. Still, all of the response times fall below the 10.5 second length of the current WEA attention signals.

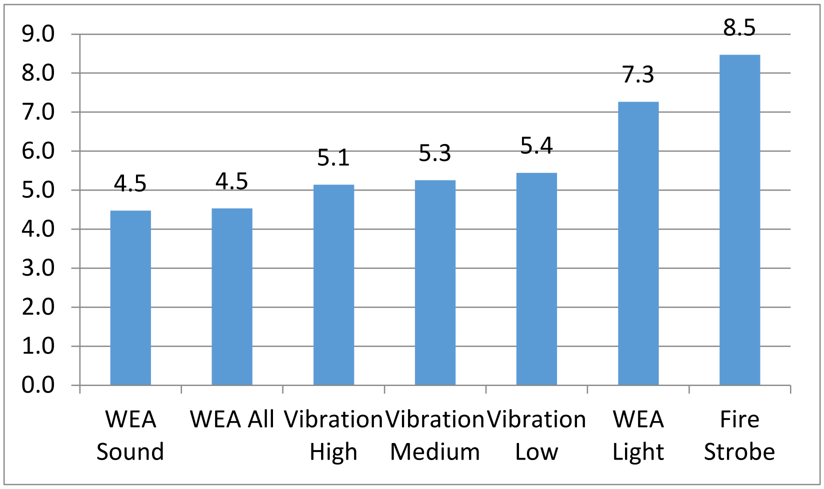

Figure 24: Response Times of Participants That Were Low Vision

5.3 No-Response Rate

Although the data reported above discusses response times, it is important to note that some of the attention signals also received no response from some of the participants. Figure 25 shows the no-response rate by disability type. Of note, 15 percent of participants that were hard of hearing did not respond to the WEA Sound attention signal. This is consistent with the hard of hearing focus group participants' variance in ability to hear high and/or low frequencies. While the WEA Sound attention signal currently employs both high and low frequencies, they are not to a degree that makes it fully accessible (i.e., audible) by all people who are hard of hearing. In the real world, this could translate into a missed WEA message. The vibration signals had similar no-response rates for participants that were hard of hearing: 23 percent did not respond to the low vibration, 8 percent missed the medium vibration and 15 percent had no response to the high vibration.

Of all the signals, the Fire Strobe and the high vibration were noticed the most (i.e., the no-response rate was lowest across disability types). While both of these signals received slower response times (see Section 5.2), they had higher response rates (Figure 26). Regarding the WEA Light and WEA All signals, a majority of participants that were blind and those that were hard of hearing had no-response; a significant amount (the least being 25 percent) of participants that were deaf or had low vision also missed these signals types. We attribute this, in part, to where the participants placed the prototype device. As noted, participants were asked to place the prototype where they would normally carry their phone; a majority of participants put the prototype in a pocket or purse. These data suggest a need for further research that employs an experimental methodology and includes a control group to determine a range of optimal attention signals for people with different sensory abilities when devices are buffered by clothes, phone cases and bags.

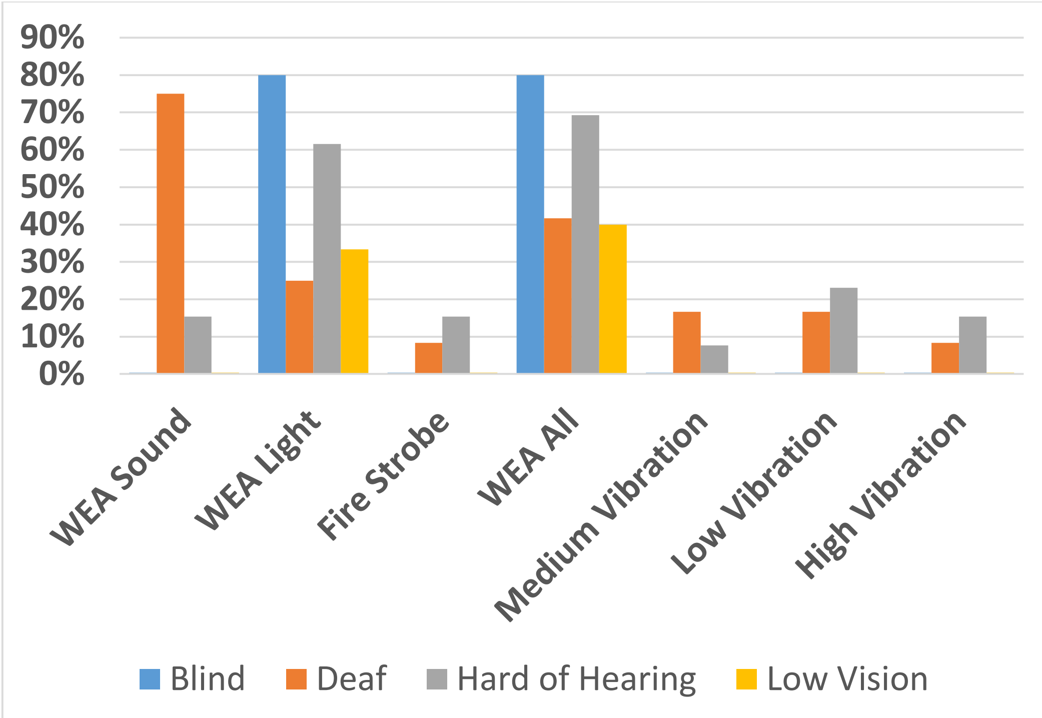

Figure 25: Signal No-Response Rate by Disability Type

5.4 V-rating System

The FCC requires cellular phone manufacturers to provide an M rating and a T rating for consumers using hearing aids or cochlear implants. The M rating is for the phone in Microphone mode and the T rating is for telecoil use of the phone. The higher the rating (on a 1-5 scale), the more compatible the phone is and the better the sound quality will be. This simple measure is mandated on phone packaging and on in-store displays, and provides all users with more information in a simple to understand manner.

We proposed a V-rating scale. This scale, analogous to the M and T ratings, would provide a measurement of the strength of the vibrations in the cell phone. Some users rely on a stronger vibration than other users; the V-rating scale would let them conduct research online or in a store to determine which phone might be right for them. In addition, the V-rating scale would provide another way for manufacturers to compete with each other, with the benefit that vibrations may get stronger, especially on larger phones.

The V-rating scale is based on the vibration strength of the device measured in "g" using the test rig described in section 2.1.2.

Table 2: V-rating Scale

V-rating	Acceleration Range	Notes
1	Up to 0.5 g	Low range of tested mobile devices
2	0.5 to <0.8 g	Middle range of tested mobile devices

V-rating	Acceleration Range	Notes
3	0.8 to <1.1 g	Upper range of tested mobile devices
4	1..1 to <1.4 g	
5	1.4+ g	Recommended for certain groups of users with disabilities

The V-rating scale is from 1 to 5. All of the WEA-capable market devices in the sample fell into the V-rating range of 1 to 3. User testing indicated that certain groups would be best served by a device with a V-rating of 5 (1.4 g) which is 50 percent stronger than the maximum level currently available in the WEA-capable devices evaluated. The participants in our study that were deaf and those that were blind responded more quickly to the low and medium vibration strengths. The low vibration strength (0.9 g) is equivalent to the strongest vibration available in the WEA-capable devices evaluated.

The testing and assessment of all the technical vibration components by end users in the usability testing led the team to propose the concluding V-rating scale which would be valuable to both FCC future rulemakings and public notices, and to industry, as many of the manufacturers might have devices which are already in the accessible range. It may also be useful to future manufacturers and carriers working with agencies such as the Federal Emergency Management Agency (FEMA) and other DHS components that are interested in the WEA space for next generation WEA (NG-WEA). The cost to manufacturers to implement this V-rating should be low. Several measurements are already required by the FCC to sell a product and testing the vibration strength of their device could be done and documented at the same time. At least one mobile phone testing company already measures vibrations in phones in a similar manner to the way we measured them. We discovered their test method after we had developed our own testing rig and process.

6. CONCLUSIONS AND RECOMMENDATIONS

Sometimes the introduction of new product designs can diminish or eliminate longstanding accessibility features. This is especially true in the fast-moving area of consumer technology.

People with disabilities' reviews and experiences with different technologies have shown early identification of potential usability challenges. The same is true for discovering usability opportunities. Closed captioning for television was intended to make television accessible to people with hearing disabilities, but has come to be used by the general population in situations when their hearing is situationally impaired, such as in a crowded bar or airport. As wireless technology continues to evolve in both predictable and unforeseen ways, broader consumer participation – especially of users with diverse intellectual, physical and sensory abilities – will be even more critical for the success of design and development initiatives.

To that point, unanticipated benefits of this project were revealed and will prove important in WEA messaging receipt, especially to people with disabilities. While our initial proposed research concerning the vibration and light intended only to target people with hearing disabilities, through focus group research that incorporated diverse groups of people with other sensory disabilities, we discovered that people with vision disabilities sometimes relied on sound and visual attention signals, too. This led us to include them into the usability studies.

Although evaluating the WEA Sound attention signal was not initially part of the proposed research, we included it in the prototype design to be inclusive of all current and prospective WEA attention signals. People with vision loss were included in our usability study of the prototype signals. This double variable expansion proved an important component because the results for participants that had low vision showed that they responded more quickly to the vibration signals than to the sound. Had we not tested the sound attention signal, that finding would have been left undiscovered. Extending our target population to include people with both vision and hearing disabilities, and evaluating their similar responses to the vibration strengths, is a testament to the potential universality of our findings related to optimal vibration strengths. While the research was focused on improving message receipt by people with sensory disabilities, implementing our recommendations would likely improve message receipt for all.

We found that vibration strength *is* a factor in response time to WEA messages, but stronger is not always better. For the participants that were deaf, the low vibration setting had the fastest response time. This contradicts the earlier absolute ratings where the majority of participants who were deaf (78 percent) indicated they preferred the strongest/high vibration setting. We can only surmise that the medium and low vibration settings, which received quicker response times in some cases, could have resulted from the type of vibration device we used. It varied frequency (i.e., cycles per second) with strength and the higher frequency may not have transmitted through the purse or pocket where the prototype was placed for the test. Another possibility is that the high vibrating setting (being outside of the range of vibration strengths currently available on the market – over twice as strong) was too unfamiliar and thus startling. This may have created a lag time between being startled and then remembering to react by pressing the button. Further research is needed to definitively answer *why* the medium and low vibration settings were more optimal than the high.

We also found that adding a WEA light cadence can increase response time to WEA messages for certain populations. For participants who were hard of hearing, WEA Light had the quickest response time. For participants that had low vision, the WEA All (i.e., light, sound and vibration) received the quickest response time over any of the vibration signals alone. Therefore, we can conclude that simultaneously activating all notification signals – sound, vibration and light – will increase the likelihood of timely receipt of WEA messages for certain populations. In addition to the positive response time findings regarding the utility of the WEA light for the participants with low vision and those that were hard of hearing, the majority of *all* participants (74 percent) carry their phone in a location that could negatively impact their perception of incoming WEA messages (i.e., purse, bag, briefcase, pants or jacket pocket). Additional research needs to be conducted to determine perception thresholds for the different signals in different circumstances. For example, quantifying the absolute and recognition perception thresholds for the WEA Sound attention signal for people who are hard of hearing with a device in their pocket, would help inform manufacturers on the minimum type of sound (i.e., mixed frequencies) it takes for individuals to notice and identify the sound. Until then, we suggest that activating all attention signals will increase the likelihood of timely notification. Following are specific technical and policy recommendations on how to optimize WEA message accessibility with regard to the attention signals:

- Manufacturers should design all handsets with the capability to:
    - Adjust the strength of the vibration signal;
    - Adjust the pitch and frequency of the sound attention signal; and
    - Include a light signal feature that is activated by WEA messages.
- The FCC should release a rulemaking concerning the NG-WEA that includes prescribing a specific light cadence for WEA messages.
- The FCC should, perhaps though a public notice, solicit feedback regarding the V-rating scale and its potential to better inform the buyers and sellers of the ranges that optimize receipt of WEA messages specifically, and other phone activity (e.g., calls, texts, emails), generally. This step is important because as noted earlier, some of the WEA-capable devices on the market already fall within the acceptable range, and next generation devices could easily increase their strength.

The development of the V-rating provides a new way for handset manufacturers to differentiate their products from those of their competitors. We will work closely with the Wireless RERC's corporate partners, including Blackberry, Microsoft, Samsung and LG, to share our findings and make recommendations to them that will make their devices better for all users, and especially for those with disabilities. We will also work with trade associations such as the Cellular Telephone Industry Association (CTIA) and Consumer Electronics Association to promulgate these findings to their members. Our partnerships with industry may provide us the opportunity to implement some of our findings in prototype phones currently under development. If the corporate partners accept, they could run tests similar to ours to gather compatible information without disclosing any technical secrets.

In closing, the accessibility of WEA messages can only be as accessible as the rules and regulations prescribe and to the extent that manufacturers incorporate accessibility features into WEA-capable devices. When these citizens' needs are addressed, they will be empowered with the information to take appropriate protective actions. Improving current WEA and NG-WEA parameters to be more inclusive can ensure timely and appropriate responses during natural and manmade disasters.

APPENDIX A

Data Set: Accessibility Review of WEA-Capable Devices

Phone	HAC Rating?	Adjust Font?	Contrast Adjustment?	Vibration Adjustment?	Built-in TTS?	Buy TTS?	Simple Display?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader?	Braille Access?
Alcatel 510A	M3/T3	no	no	no	no	n/a	no	no	no	no	no	no	yes		n/a
Alcatel 871A	M3/T3	no	no	no	no	n/a	no	no	no	no	no	yes	no		n/a
Alcatel OneTouch 768	M4/T4	n/a	n/a	n/a	n/a	n/a	n/a	no	n/a	n/a	no	no	yes		n/a
Alcatel OneTouch Evolve	M3/T3	yes	n/a	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		yes
Alcatel OneTouch Fierce	M3/T3	yes	n/a	n/a	yes	n/a	yes	yes	n/a	yes	yes	no	no		yes
Apple iPhone 4	M3/T3	yes	yes	yes	yes	n/a	yes	yes	yes	yes	yes	no	no	yes	yes
Apple iPhone 4S	n/a	yes	yes	yes	yes	n/a	yes	yes	yes	yes	yes	no	no	yes	yes
Apple iPhone 5	M3/T4	yes	no	yes	yes	n/a	yes	yes	yes	yes	yes	no	no	yes	yes
Apple iPhone 5c	M3/T4	yes	no	yes	yes	n/a	yes	yes	yes	yes	yes	no	no	yes	yes

Phone	HAC Rating?	Adjust Font?	Contrast Adjustment?	Vibration Adjustment?	Built-in TTS?	Buy TTS?	Simple Display?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader?	Braille Access?
Apple iPhone 5s	M3/T4	yes	no	yes	yes	n/a	yes	yes	yes	yes	yes	no	no	yes	yes
ASUS PadFone X	M3/T4	n/a	n/a	n/a	yes	n/a	n/a	n/a	n/a	yes	yes	no	no		yes
BlackBerry Bold 9900	M3/T3	yes	yes	yes	no	n/a	yes	no	yes	yes	yes	yes	no		n/a
BlackBerry Bold 9930	M3/T3	yes	yes	yes	no	n/a	yes	no	yes	yes	yes	yes	no		n/a
BlackBerry Curve 3G 8530	M4/T4	yes	yes	yes	no	n/a	yes	no	yes	yes	no	yes	no		n/a
BlackBerry Curve 9310	M3	yes	yes	yes	no	n/a	yes	no	yes	yes	no	yes	no		n/a
BlackBerry Curve 9330	M4/T4	yes	yes	yes	no	n/a	yes	no	yes	yes	no	yes	no		n/a
BlackBerry Curve 9350	M4/T4	yes	yes	yes	no	n/a	yes	no	yes	yes	no	yes	no		n/a
BlackBerry Curve 9360	M3/T3	yes	yes	yes	no	n/a	yes	no	yes	yes	no	yes	no		n/a
BlackBerry Curve 9370	M3	yes	yes	yes	no	n/a	yes	no	yes	yes	no	yes	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
BlackBerry Q10	M3/T 4	yes	no	yes	yes	n/a	yes	yes	yes	yes	yes	yes	no		n/a
BlackBerry Torch 9810	M3/T 3	yes	yes	yes	no	n/a	yes	no	yes	yes	yes	yes	no		n/a
BlackBerry Torch 9850	M3/T 3	yes	yes	yes	no	n/a	yes	no	yes	yes	yes	no	no		n/a
BlackBerry Torch 9860	M3/T 3	yes	yes	yes	no	n/a	yes	no	yes	yes	yes	no	no		n/a
BlackBerry Tour 9630	M3	yes	yes	n/a	n/a	n/a	yes	n/a	yes	yes	no	yes	no		n/a
BlackBerry Z10	--	yes	no	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
BlackBerry Z30	M3/T 4	yes	no	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Casio GZ One Commando	M4/T 4	n/a	n/a	n/a	yes	yes	no	no	yes	n/a	yes	no	no		n/a
Casio GZ One Ravine	M4/T 4	yes	n/a	n/a	yes	n/a	yes	n/a	yes	yes	no	no	yes		n/a

Phone	HAC Rating?	Adjust Font?	Contrast Adjustment?	Vibration Adjustment?	Built-in TTS?	Buy TTS?	Simple Display?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader?	Braille Access?
Casio GZ One Ravine 2	M4/T4	yes	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	no	no	yes		n/a
Casio G'zOne Commando 4G LTE	M3/T4	yes	yes	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
HTC 8XT	M4/T4	yes	yes	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
HTC Droid DNA	M3/T3	n/a	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	no	no		yes
HTC Droid Incredible	M4/T4	n/a	n/a	n/a	yes	yes	n/a	n/a	yes	yes	yes	no	no		n/a
HTC Droid Incredible 2	M4/T4	n/a	n/a	n/a	n/a	yes	n/a	n/a	yes	n/a	yes	no	no		n/a
HTC Droid Incredible 4G LTE	M4/T4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
HTC EVO 3D	M4/T3	n/a	n/a	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
HTC EVO 4G LTE	M4/T3	yes	n/a	n/a	n/a	n/a	n/a	yes	n/a	yes	yes	no	no		n/a
HTC EVO Design 4G	M4/T4	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	yes	no	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
HTC Hero with Google	M4/T4	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	n/a	yes	no	no		n/a
HTC One	M3/T4	n/a	n/a	n/a	yes	yes	n/a	n/a	yes	yes	yes	no	no		yes
HTC One M8	M4/T3	yes	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	no	no		yes
HTC One Max	M4/T3	yes	n/a	n/a	yes	n/a	n/a	n/a	n/a	n/a	yes	no	no		yes
HTC One mini	M3/T4	n/a	n/a	n/a	n/a	n/a	yes	n/a	yes	yes	yes	no	no		yes
HTC One S	M4/T3	n/a	n/a	n/a	n/a	n/a	yes	n/a	yes	yes	yes	no	no		n/a
HTC Rezound	M4/T4	n/a	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	no	no		n/a
HTC Rhyme	M4/T4	n/a	n/a	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no		n/a
HTC Thunderbolt	M4/T3	n/a	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	no	no		n/a
HTC Trophy	M4/T4	n/a	n/a	n/a	n/a	n/a	n/a	Yes	yes	yes	yes	no	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
HTC Windows Phone 8x (CDMA)	M4/T 4	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
HTC Windows Phone 8X (GSM)	M4/T 4	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
Huawei AT&T Fusion 2 (U8665)	M3	n/a	n/a	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no		n/a
Huawei Express	M4/T 4	n/a	n/a	n/a	yes	n/a	n/a	n/a	n/a	yes	yes	yes	no		n/a
Huawei Prism II T-Mobile	M3/T 3	yes	n/a	n/a	yes	n/a	n/a	n/a	yes	n/a	yes	no	no		yes
Huawei Prism T-Mobile	M3/T 3	n/a	n/a	n/a	yes	n/a	n/a	n/a	n/a	n/a	yes	no	no		n/a
Huawei Summit	M3/T 3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	no	no		n/a
Huawei T-Mobile MyTouch	M3/T 4	n/a	n/a	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no		n/a
Huawei T-Mobile MyTouch Q	M3/T 3	n/a	n/a	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Kyocera Brio	M4/T 4	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	yes	no		n/a
Kyocera Duracore	M4/T 4	yes	n/a	yes	yes	n/a	n/a	n/a	yes	n/a	no	no	yes		n/a
Kyocera Duramax	M4/T 4	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no	yes		n/a
Kyocera DuraPlus (E4233)	M4/T 4	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no	yes		n/a
Kyocera DuraXT	M4/T 4	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no	yes		n/a
Kyocera Hydro EDGE	M4/T 4	yes	n/a	yes	yes	n/a	n/a	yes	yes	yes	yes	no	no		yes
Kyocera Hydro Elite	M3/T 3	yes	n/a	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Kyocera Hydro Vibe	M4/T 3	yes	n/a	yes	yes	n/a	n/a	yes	yes	yes	yes	no	no		yes
Kyocera Hydro XTRM	M4/T 3	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	yes	no	no		yes

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Kyocera Kona	M4/T 4	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no	yes		n/a
Kyocera Milano	M4/T 4	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
Kyocera Rise	M4/T 4	yes	yes	n/a	yes	n/a	n/a	yes	yes	yes	yes	yes	no		n/a
Kyocera Sanyo Vero	M4/T 4	yes	yes	yes	yes	n/a	n/a	no	yes	yes	no	no	yes		n/a
Kyocera Torque	M4/T 3	yes	n/a	yes	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
Kyocera Verve	M4/T 3	yes	yes	yes	yes	n/a	yes	n/a	yes	yes	no	yes	yes		n/a
LG Cosmos 2 (VN-251)	M4/T 4	yes	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	no	yes	yes		n/a
LG Cosmos 3 (VN-251S)	M4/T 4	yes	yes	yes	yes	n/a	yes	no	yes	yes	no	yes	yes		n/a
LG Double Play	M3/T 3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	n/a	yes	yes	no		n/a
LG Elite (LS696)	M4/T 3	no	no	yes	yes	n/a	no	no	yes	yes	yes	no	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
LG Enact (VS890)	M4/T4	yes	yes	yes	yes	n/a	yes	no	yes	yes	yes	yes	no		yes
LG Enlighten (VS700)	M4/T4	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
LG Extravert (VN-271)	M4/T4	yes	n/a	yes	n/a	n/a	yes	n/a	yes	yes	yes	yes	no		n/a
LG G Flex (D950)	M3/T3	yes	yes	yes	yes	n/a	yes	n/a	yes	yes	yes	no	no	yes	yes
LG G2 (LS980)	M4/T4	yes	yes	yes	yes	n/a	yes	n/a	yes	yes	yes	no	no		yes
LG G3	M4/T3	yes	n/a	yes	yes	n/a	n/a	n/a	n/a	yes	yes	no	no		yes
LG Google Nexus 4	M3	yes	no	yes	yes	n/a	yes	yes	no	no	yes	no	no		yes
LG Google Nexus 5 (D821)	--	yes	yes	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
LG Inutition (VS950)	M3/T 3	yes	yes	yes	yes	n/a	yes	n/a	yes	yes	yes	no	no		yes
LG Lucid (VS840)	M4/T 4	n/a	n/a	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
LG Lucid 2 (MS870)	M4/T 3	yes	yes	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
LG Mach (LS860)	M4/T 4	yes	yes	yes	yes	n/a	n/a	yes	yes	yes	yes	yes	no		n/a
LG Marquee (LG855)	M4/T 4	n/a	yes	n/a	yes	n/a	yes	n/a	yes	yes	yes	no	no		n/a
LG Optimus Elite (LG696)	M4/T 3	no	no	yes	yes	n/a	no	no	yes	yes	yes	no	no		n/a
LG Optimus Exceed (VS840PP)	M4/T 4	yes	no	yes	yes	n/a	yes	no	n/a	n/a	yes	no	no		n/a
LG Optimus F3	M4/T 3	yes	yes	yes	yes	n/a	yes	no	yes	yes	yes	no	no		yes
LG Optimus F6	M3/T 4	yes	yes	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
LG Optimus G (LS970)	M3/T 3	yes	no	yes	yes	n/a	yes	no	yes	yes	yes	no	no		n/a
LG Optimus G Pro (E980)	M3/T 3	yes	no	yes	yes	n/a	yes	no	yes	yes	yes	no	no		yes
LG Optimus L70	M3/T 3	yes	n/a	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
LG Optimus L9	M3/T 4	yes	no	no	yes	n/a	yes	yes	yes	no	yes	no	no		n/a
LG Optimus L90	M3/T 4	yes	yes	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		yes
LG Optimus S	M4/T 4	n/a	yes	n/a	yes	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
LG Remarq	M4/T 4	yes	n/a	yes	n/a	n/a	n/a	n/a	yes	yes	no	yes	no		n/a
LG Revere	M4/T 4	yes	yes	no	n/a	n/a	n/a	no	yes	yes	no	no	yes		n/a
LG Revere 2 (VN150s)	M4/T 4	yes	yes	no	yes	n/a	yes	no	yes	yes	no	no	yes		n/a
LG Revolution (VS910)	M4/T 4	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	no	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
LG Rumor Reflex (LN272)	M4/T4	yes	no	yes	yes	n/a	no	no	yes	yes	yes	yes	no		n/a
LG Rumor Reflex S (LN272s)	M4/T4	yes	yes	n/a	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
LG Rumor Touch (LS510)	M4/T4	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
LG Spectrum (VS920)	M3	yes	yes	yes	yes	n/a	yes	n/a	yes	yes	yes	no	no		n/a
LG Spectrum 2 (VS930)	M3/T3	yes	n/a	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
LG T-Mobile MyTouch	M3/T3	n/a	n/a	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	no		n/a
LG T-Mobile MyTouch Q	M3/T3	n/a	n/a	n/a	yes	yes	n/a	n/a	n/a	yes	yes	yes	no		n/a
LG Viper 4G LTE (LS840)	M4/T4	yes	yes	yes	yes	n/a	yes	n/a	yes	yes	yes	no	no		n/a
Motorola ADMIRAL	M4/T3	n/a	n/a	yes	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Motorola Atrix 2	M3/T3	yes	n/a	n/a	yes	yes	n/a	yes	yes	yes	yes	no	no		yes
Motorola Barrage V860	M4/T3	yes	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	no	no	yes		n/a
Motorola Citrus	M3/T3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
Motorola Droid 2	M3/T3	n/a	n/a	n/a	n/a	yes	n/a	n/a	yes	yes	yes	yes	no		n/a
Motorola Droid 2 Global	M3/T3	n/a	n/a	n/a	yes	yes	n/a	n/a	yes	yes	yes	yes	no		n/a
Motorola Droid 4 4G	M4/T4	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	yes	no		n/a
Motorola Droid Bionic	M4/T4	yes	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
Motorola Droid Maxx	M3/T3	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no		n/a
Motorola Droid Mini	M3/T3	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no		yes

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Motorola Droid Pro	M3/T3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
Motorola Droid Razr	M4/T4	yes	no	no	yes	yes	yes	yes	yes	yes	yes	no	no		n/a
Motorola Droid Razr HD	M3/T4	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	no		n/a
Motorola Droid Razr M	M4/T4	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	no		n/a
Motorola Droid Razr Maxx	M3/T3	n/a	n/a	n/a	yes	yes	n/a	n/a	yes	yes	yes	no	no		n/a
Motorola Droid Razr Maxx HD	M3/T4	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	no		n/a
Motorola Droid Ultra	M3/T4	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no		yes
Motorola Droid X	M4/T3	n/a	n/a	n/a	yes	yes	n/a	n/a	yes	yes	yes	no	no		n/a
Motorola Droid X2	M4/T3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	no	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Motorola ES400S	--	n/a	n/a	n/a	n/a	n/a	yes	n/a	yes	yes	yes	yes	no		n/a
Motorola Moto G	M3/T 4	yes	no	no	yes	yes	yes	yes	yes	yes	yes	no	no		yes
Motorola Moto X	M3/T 3	yes	no	n/a	yes	yes	n/a	yes	yes	yes	yes	no	no		yes
Motorola Photon Q 4G LTE	M4/T 4	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no		n/a
Nokia Lumia 1020	M3/T 4	yes	no	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Nokia Lumia 1520	M4/T 3	yes	no	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Nokia Lumia 520	M3/T 3	yes	no	no	yes	n/a	yes	no	yes	yes	yes	no	no		n/a
Nokia Lumia 521	M3/T 3	yes	no	no	yes	n/a	yes	no	yes	yes	yes	no	no		n/a
Nokia Lumia 710	M3/T 3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	no	no		n/a

Phone	HAC Rating?	Adjust Font?	Contrast Adjustment?	Vibration Adjustment?	Built-in TTS?	Buy TTS?	Simple Display?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader?	Braille Access?
Nokia Lumia 810	M3/T4	yes	no	n/a	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Nokia Lumia 820	M3/T4	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Nokia Lumia 822	M3/T4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
Nokia Lumia 920	M3/T3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Nokia Lumia 925	M3/T3	yes	no	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Nokia Lumia 928	M3/T4	yes	no	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Nokia Lumia Icon	M4/T4	yes	yes	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
Pantech Breakout	M4/T4	yes	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
Pantech Hotshot	M4/T4	yes	yes	yes	no	n/a	n/a	no	yes	yes	yes	no	no		n/a
Pantech Jest 2	M3/T3	yes	n/a	n/a	yes	n/a	yes	n/a	yes	yes	no	yes	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Pantech Marauder	M4/T3	yes	n/a	n/a	yes	n/a	yes	n/a	n/a	yes	yes	yes	no		n/a
Pantech Perception	M4/T3	yes	n/a	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Array (M390)	M3/T4	yes	no	no	yes	n/a	no	no	yes	yes	no	yes	yes		n/a
Samsung ATIV Odyssey	M3	yes	yes	no	yes	n/a	yes	no	yes	yes	yes	no	no		n/a
Samsung ATIV S Neo	M3/T4	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Samsung Brightside (U380)	M4/T4	yes	no	no	yes	n/a	no	no	yes	yes	yes	yes	no		n/a
Samsung Captivate (I897)	M3	yes	yes	n/a	no	n/a	n/a	yes	yes	n/a	yes	no	no		n/a
Samsung Captivate Glide (SGH-I927)	M3/T3	no	no	no	yes	n/a	yes	yes	no	yes	yes	yes	no		n/a
Samsung Convoy 2 (U660)	M4/T4	yes	no	no	yes	n/a	no	no	yes	yes	no	no	yes		n/a
Samsung Convoy 3	M4/T4	yes	no	yes	yes	n/a	no	no	yes	yes	no	no	yes		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Samsung Droid Charge	M4/T 4	n/a	n/a	yes	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
Samsung Epic 4G Touch (SPH-D710)	M4/T 3	no	no	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Samsung Fascinate	M4	n/a	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	no	no		n/a
Samsung Freeform	M4/T 4	yes	yes	n/a	n/a	n/a	n/a	n/a	yes	yes	no	yes	no		n/a
Samsung Galaxy Appeal (I827)	M3	yes	no	yes	no	n/a	yes	yes	yes	no	yes	yes	no		n/a
Samsung Galaxy Exhibit (T599)	M3/T 4	yes	no	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy Exhibit II (T679)	M3/T 3	yes	yes	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Samsung Galaxy Glide	M3/T 3	n/a	n/a	n/a	yes	n/a	n/a	yes	n/a	yes	yes	yes	no		n/a
Samsung Galaxy Legend	M4	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Samsung Galaxy Light	M3/T 3	yes	no	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy Mega	M3/T 3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy Nexus	M4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	no	no		yes
Samsung Galaxy Note	M3	yes	n/a	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
Samsung Galaxy Note 3	M4/T 3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy Note II	M3	yes	yes	yes	yes	n/a	n/a	yes	n/a	yes	yes	no	no		yes
Samsung Galaxy Rush (M830)	M4/T 4	yes	no	yes	yes	n/a	yes	no	yes	yes	yes	no	no		n/a
Samsung Galaxy S Blaze (T769)	M3/T 4	no	yes	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Samsung Galaxy S Relay 4G	M3/T 3	yes	yes	yes	yes	n/a	n/a	yes	yes	yes	yes	yes	no		n/a

Phone	HAC Rating ?	Adjust Font?	Contrast Adjustment ?	Vibration Adjustment ?	Built-in TTS?	Buy TTS ?	Simple Display ?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader ?	Braille Access ?
Samsung Galaxy S4	M3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy S4 Active	M3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy S4 Mini (L520)	M3/T3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy S4 Zoom	M3/T3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy S5	M3/T3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy S5 Sport	M3/T3	yes	yes	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy SII (I777)	M4/T3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		n/a
Samsung Galaxy SIII (T999L)	M3	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy SIII mini	M4/T4	yes	yes	no	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
Samsung Galaxy Stellar	M4	yes	n/a	yes	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a

Phone	HAC Rating?	Adjust Font?	Contrast Adjustment?	Vibration Adjustment?	Built-in TTS?	Buy TTS?	Simple Display?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader?	Braille Access?
Samsung Galaxy Victory	M4	yes	yes	yes	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
Samsung Galaxy Victory 4G LTE	M4	yes	yes	yes	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
Samsung Gravity Q	M3/T3/T4	no	no	no	no	n/a	yes	no	yes	yes	yes	yes	no		n/a
Samsung Gusto 2 (U365)	M4/T4	yes	no	no	yes	n/a	no	no	yes	yes	no	no	yes		n/a
Samsung Illusion (I110)	M4	no	no	no	yes	n/a	no	no	yes	yes	yes	no	no		n/a
Samsung Intensity III (U485)	M4	yes	no	no	yes	n/a	no	no	yes	yes	no	yes	yes		n/a
Samsung M370	M4/T4	no	yes	yes	yes	n/a	no	no	yes	yes	no	no	yes		n/a
Samsung M400	M4/T4	yes	yes	n/a	yes	n/a	yes	n/a	yes	yes	no	no	yes		n/a
Samsung Replenish (M580)	M4/T3	yes	yes	yes	yes	n/a	yes	no	yes	yes	yes	yes	no		n/a
Samsung Seek (M350)	M4	yes	n/a	yes	n/a	n/a	yes	n/a	yes	yes	yes	yes	no		n/a

Phone	HAC Rating?	Adjust Font?	Contrast Adjustment?	Vibration Adjustment?	Built-in TTS?	Buy TTS?	Simple Display?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader?	Braille Access?
Samsung Stratosphere	M4	n/a	n/a	yes	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
Samsung Stratosphere 2	M3	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
Samsung t159	M3/T4	yes	yes	no	no	n/a	no	no	yes	no	no	no	yes		n/a
Samsung Transform	M4/T3	n/a	yes	n/a	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
Samsung Transform Ulta	M4	n/a	yes	n/a	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
Samsung Trender (M380)	M4/T4	yes	n/a	n/a	yes	n/a	n/a	n/a	yes	yes	yes	yes	no		n/a
Sanyo Innuendo	M4/T4	yes	n/a	yes	yes	n/a	n/a	n/a	yes	yes	no	yes	yes		n/a
Sonim XP Strike	M4/T3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	no	yes		n/a
Sony Xperia Z	M3	yes	no	yes	no	n/a	yes	yes	yes	yes	yes	no	no		yes
ZTE Aspect	M3/T3	yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	yes	no		n/a
ZTE AT&T Avail 2 (Z992)	M3/T3	yes	n/a	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		yes
ZTE AT&T Avail	M3/T4	yes	n/a	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes

Phone	HAC Rating?	Adjust Font?	Contrast Adjustment?	Vibration Adjustment?	Built-in TTS?	Buy TTS?	Simple Display?	Two Way Video	Voice Dial	Other Voice Control Features	Touch Input	Physical QWERTY	Physical # Keypad	Full Access Screen Reader?	Braille Access?
Evolution (Z998)															
ZTE AT&T Radiant (Z740)	M3/T4	yes	n/a	yes	yes	n/a	yes	yes	yes	yes	yes	no	no		yes
ZTE Concord II	M3/T4	yes	yes	yes	no	n/a	yes	no	yes	yes	yes	no	no		yes
ZTE Fury	M4/T4	n/a	n/a	n/a	yes	yes	n/a	n/a	yes	yes	yes	no	no		n/a
ZTE Sprint Flash	M4/T4	yes	n/a	n/a	yes	n/a	n/a	yes	yes	yes	yes	no	no		n/a
ZTE Sprint Vital	M4/T4	yes	n/a	yes	yes	n/a	n/a	yes	yes	yes	yes	no	no		yes
ZTE Sprint WeGo	M4/T3	yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	no	no		n/a

APPENDIX B

Data Set: Cell Phone Vibration Strengths & Rating

Phone #	Make/Model	Age	Battery	Trigger Source	V-rating	RMS Power of vibration (g)[11]
1	Blackberry 9360	New	Full Charge	Alarm	2	0.50
2	Samsung Galaxy S3	Two or three years	50%	Ring	1	0.31
2	Samsung Galaxy S3	Two or three years	Full Charge	Alarm	1	0.36
2	Samsung Galaxy S3	Two or three years	Full Charge	Alarm	1	0.38
2	Samsung Galaxy S3	Two or three years	Full Charge	Alarm	1	0.33
3	HTC ADR6410LVW	New	Full Charge	Alarm	3	0.85
4	Alcatel One Touch 5020N	New	Full Charge	Alarm	1	0.41
4	Alcatel One Touch 5020N	New	Full Charge	Alarm	1	0.41
4	Alcatel One Touch 5020N	New	Full Charge	Alarm	1	0.39
5	HTC One	Unknown	Full Charge	Alarm	2	0.65
5	HTC One	Unknown	Full Charge	Alarm	2	0.66
6	iPhone 4	Greater than 3 years	Full Charge	Ring	1	0.27
6	iPhone 4	Greater than 3 years	Full Charge	Ring	1	0.28
6	iPhone 4	Greater than 3 years	Full Charge	Ring	1	0.28
6	iPhone 4	Greater than 3 years	Full Charge	Alarm	1	0.29
7	iPhone 4s	Greater than 3 years	25%	Ring	1	0.40
7	iPhone 4s	Greater than 3 years	25%	Ring	1	0.29
7	iPhone 4s	Greater than 3 years	25%	Ring	1	0.32
8	iPhone 5s	One year old	Full Charge	Ring	2	0.55
9	iPhone 5	Unknown	Full Charge	Alarm	1	0.44
9	iPhone 5	Unknown	Full Charge	Alarm	1	0.42
10	Samsung Galaxy 5s	New	50%	Ring	3	0.93
10	Samsung Galaxy 5s	New	50%	Ring	3	0.94
11	Samsung Galaxy Nexus	Unknown	Full Charge	Alarm	1	0.42
12	Samsung LG Non Smartphone	Greater than 3 years	Full Charge	Ring	3	0.81
12	Samsung LG Non Smartphone	Greater than 3 years	Full Charge	Ring	3	0.81
13	LG VS890	Unknown	Full Charge	Alarm	1	0.31
13	LG VS890	Unknown	Full Charge	Alarm	1	0.30

[11] Higher is stronger.

Data Set: Cell Phone Vibration Strengths & Rating

Phone #	Make/Model	Age	Battery	Trigger Source	V-rating	RMS Power of vibration (g)[11]
14	Samsung Galaxy Nexus	Unknown	Full Charge	Alarm	1	0.40
14	Samsung Galaxy Nexus	Unknown	Full Charge	Alarm	1	0.39
15	Motorola Droid Razr HD	Unknown	Full Charge	Alarm	1	0.22
15	Motorola Droid Razr HD	Unknown	Full Charge	Alarm	1	0.21
16	Samsung Galaxy Note 3	Unknown	Full Charge	Alarm	1	0.39
16	Samsung Galaxy Note 3	Unknown	Full Charge	Alarm	1	0.40
17	Nokia Lumia 520	New	Full Charge	Alarm		N/A
17	Nokia Lumia 520	New	Full Charge	Alarm		N/A
18	AT&T Fusion 2	New	Full Charge	Alarm	1	0.32
18	AT&T Fusion 2	New	Full Charge	Alarm	1	0.38
19	AT&T Z998	New	Full Charge	Alarm	1	0.24
19	AT&T Z998	New	Full Charge	Alarm	1	0.23
20	AT&T Radiant	New	Full Charge	Alarm	1	0.28
20	AT&T Radiant	New	Full Charge	Alarm	1	0.28
21	LG Optimus Exceed 2	New	Full Charge	Alarm	2	0.56
21	LG Optimus Exceed 2	New	Full Charge	Alarm	2	0.59
22	LG Extravert	New	Full Charge	Calendar alert	1	0.46
22	LG Extravert	New	Full Charge	Calendar alert	1	0.47
Phone #	Make/Model	Age	Battery	Trigger Source	V-rating	RMS Power of vibration (g)[12]
23	Apple iPhone 6+	New	Full Charge	Ring	1	0.48
23	Apple iPhone 6+	New	Full Charge	Ring	1	0.48
24	Motorola Moto X	New	Full Charge	Alarm	1	0.22
24	Motorola Moto X	New	Full Charge	Alarm	1	0.22

[12] Higher is stronger.

Data Set: Cell Phone Vibration Strengths & Rating

Phone #	Make/Model	Age	Battery	Trigger Source	V-rating	RMS Power of vibration (g)[11]
25	Amazon Fire Phone	New	Full Charge	Alarm	1	0.22
25	Amazon Fire Phone	New	Full Charge	Alarm	1	0.23
26	Apple iPhone 5c	New	Full Charge	Alarm	1	0.44
26	Apple iPhone 5c	New	Full Charge	Alarm	1	0.45
27	Apple iPhone 6	New	Full Charge	Ring	2	0.60
28	LG Viper 4G LTE	New	Full Charge	Alarm	2	0.66
28	LG Viper 4G LTE	New	Full Charge	Alarm	2	0.66
29	Nokia Lumia 635	New	Full Charge	Alarm	1	0.21
29	Nokia Lumia 635	New	Full Charge	Alarm	1	0.20
30	Samsung Galaxy S2	New	Full Charge	Alarm	1	0.33
30	Samsung Galaxy S2	New	Full Charge	Alarm	1	0.37