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A Study of Users with Visual Disabilities and a Fingerprint Process

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1 Executive Summary

The Department of Homeland Security's (DHS) United States Visitor and Immigrant Status Indicator Technology (US-VISIT) program is a biometrically-enhanced identification system primarily situated at border points of entry such as airports and seaports. Section 508 applies to accessibility of US-VISIT when it procures, develops, maintains, or uses Electronic and Information Technology (EIT) products. The NIST Biometrics Usability group performed a usability test to study the interaction of people with disabilities with fingerprint devices.

This report presents the results of a usability study that examined how persons with visual impairments interact with a fingerprint scanner. The study was designed to investigate how those with a visual impairment:

1. locate the scanning device
2. properly place their hand on the device
3. determine the duration of a fingerprint scan.

This study was executed as follows: first, we interviewed ten federal employees from a pool of 17 candidates about their experiences with fingerprinting in order to understand the user population and their needs. Based on this feedback, ten participants participated in the study. Each participant performed three different trials. For each trial, the participant located the scanner by a tone. They used a textured surface to identify the proper hand position. Tones and haptic feedback were employed to demarcate the scanning process. Finally, they listened to six tones that are commonly used by the visually impaired community as indicators to identify the most appropriate or pleasing tones.

This report describes four main results.

1. Audio tones are effective for locating the device. The visually impaired participants had little or no difficulty locating the fingerprint scanner mockup using tones.
2. Textured surfaces can be used for determining proper hand placement. All but one participant were able to position their hand appropriately.
3. Audio tones and haptic input are effective in providing an indication of duration.
4. In order for the duration indicator to be effective the indicator must be associated with a process.

The finding that the duration of the scan must be associated with a *process* has broad implications for fingerprint devices. In previous usability tests we observed users struggling to determine *when* to place and remove their hands from the device. The results of this study suggest that the indicators used were not perceived as indicative of the capture process. Further testing is required to determine how best to represent the process and the duration of the scan to the larger population of fingerprint users.

Finally, this study was specifically designed to study interaction with fingerprint devices for those with visual impairments. But how will people with differing abilities use fingerprint devices? Users may be too diverse for a biometric device to provide enough information to all users. Instead of the users adapting to the device, the device could adapt to the user. Additional research is required to explore the usefulness of adaptive technologies for biometric applications.

2 Introduction

The Department of Homeland Security's (DHS) United States Visitor and Immigrant Status Indicator Technology (US-VISIT) is a biometrically-enhanced identification system primarily situated at border points of entry such as airports and seaports. US-VISIT processing currently applies to most non-citizens entering the United States, regardless of country of origin and mode of transportation. The US-VISIT program has a number of committees and programs that are developing processes to meet the functional performance criteria and technical standards of Section 508 of the Rehabilitation Act (United States Code Title 29 Section 794d), as amended in the Workforce Reinvestment Act of 1998. Section 508 applies to US-VISIT when it procures, develops, maintains, or uses Electronic and Information Technology (EIT) products. Under Section 508, Federal agencies must give employees with disabilities and members of the public "access to and use of information and data that is comparable to the access to and use of" information and data available to Federal employees without disabilities [1].

Research is required to understand how people with disabilities interact with biometrics devices in order to support US-VISIT's efforts to specify requirements and processes for complying with Section 508. Studying the interaction of people with disabilities and biometric devices will help identify new and improved requirements for biometric device developers and will improve the implementation and processes for US-VISIT programs for people with disabilities.

Previous usability studies performed by the NIST Biometrics Usability team examined how to present instructional information to users [2]. Users accustomed with leaving two index fingerprints at US-VISIT may not be familiar with the ten slap fingerprint capture process. The study compared three methods of presenting instructions to users. Observing 300 users interacting with a fingerprint scanner, iris, and face cameras identified significant shortcomings that could be magnified for users with disabilities. These findings became the basis of this follow-up study[1] that examines how users with visual impairments interact with fingerprint scanners.

3 Methodology

Although the Biometrics Usability team has performed extensive research on Section 508 and Web applications with persons with visual disabilities [3,4], we had no experience or personal

[1] These tests were performed for the Department of Homeland Security in accordance with section 303 of the Border Security Act, codified as 8 U.S.C. 1732. Specific hardware and software products identified in this report were used in order to perform the evaluations described in this document. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products and equipment identified are necessarily the best available for the purpose.

understanding of what the visual disability issues would be when using an electronic fingerprinting device. We decided to first interview several people with visual disabilities to better understand the user population and their needs.

Based on the feedback of the interviews an exploratory or formative study was conducted to investigate how users with visual disabilities locate a fingerprint device, position a hand on a fingerprinting device, and identify the start and the end of a fingerprint scan.

4 Participants

Ten volunteers out of a pool of 17 contacts who had participated in previous usability-accessibility research participated in the interviews and the follow-up study. All interviewees were federal government employees, with a visual impairment. Four of the participants self - declared as having “low vision” and six self-declared as “blind”. Additional information about the participants is presented in Appendix C.

Each participant was provided with the background for the study and asked the following questions:

1. Have you ever been fingerprinted? What was that experience like?
2. What cues would you recommend to help make the fingerprint process more independent or accessible?
3. Have you had any experience with iris scanning? How would you recommend that iris scanning be addressed?
4. Are there any other biometric processes that you have experienced?
5. Would you like to participate in a usability study that will refine the design of digital fingerprint scanning in an effort to define requirements for making the process more accessible?

Each of the ten participants had experience with paper and ink rolled prints. In order to collect these prints each was assisted by an administrator who had asked for a hand, explaining that they were putting a finger onto an ink pad and that they would then roll the finger on the paper. This process was repeated for each finger of each hand. Four participants had used a digital fingerprint scanner. Again, each was assisted by an administrator placing the appropriate fingers on the scanner. One participant recalled presenting each finger individually on a small scanning surface.

All but one participant, who had some vision, had suggestions on how to improve the process for independence and accessibility. The suggestions fell into three categories. First, six participants suggested tactile cues such as contrasting surfaces or raised markings or notches for placing and positioning fingers. Three participants recommended audio cues such as beeps to indicate the end of the procedure. Verbal directions with manual guidance from the operator was suggested by three of the participants. The individual responses are presented in Appendix C.

None of the participants had any experience with iris scans but offered comments and recommendations on the process as enumerated in Appendix D. Although all of the participants were intrigued by the possibility of iris scans, most believed it would be impossible due to multiple factors such as opaque prosthetic shells, artificial eyes, and anaridia (absence of the iris).

None of the participants had any other experiences with biometric devices. All were excited about the opportunity to participate in usability testing of biometric devices and volunteered for the second phase of the study.

5 Study

Based on our interviews, we chose to investigate three factors of the interaction between "livescan" (i.e., fully electronic capture) fingerprint sensors and the visually impaired:

1. locating the scanning device,
2. properly placing a hand on the scanner,
3. determining the duration of a fingerprint scan..

We were also interested in the participants' opinions on the usefulness of different tones in a biometric context.

5.1 Participants

This study included 12 participants—the ten from the telephone interviews and two colleagues of the interviewees. All were federal government employees with some level of visual impairment as described above. All indicated that they had no hearing impairment.

5.2 Equipment

Since there was no available commercial fingerprint scanner where we could control all of the necessary parameters for this study, the equipment consisted of a mockup of a fingerprint scanner. The scanner mockup was 8.5 mm x 9 mm x 30 mm (see Figure 1 Fingerprint Scanner Mockup).

Inside the clear acrylic box, a speaker was mounted on the front and a vibration unit near the top. Overlaying the top surface was a sheet of Gila Decorative Window Film (crackled glass) to provide a textured surface. The window film was cut to the size of the top surface with a section cutout toward the front of the box (see Figure 2 Fingerprint Scanner Texture Placement). This cutout allowed the smooth surface of the box to be exposed.

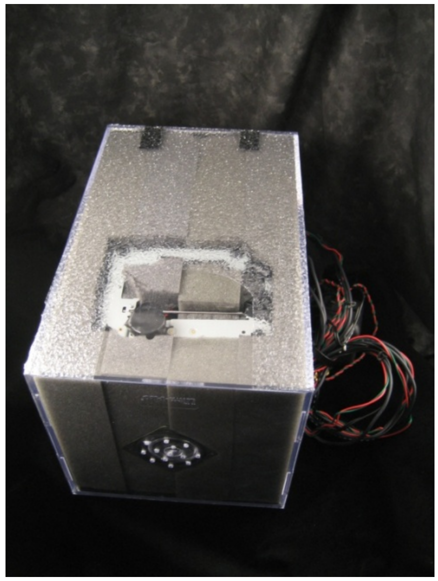

Figure 1 Fingerprint Scanner Mockup

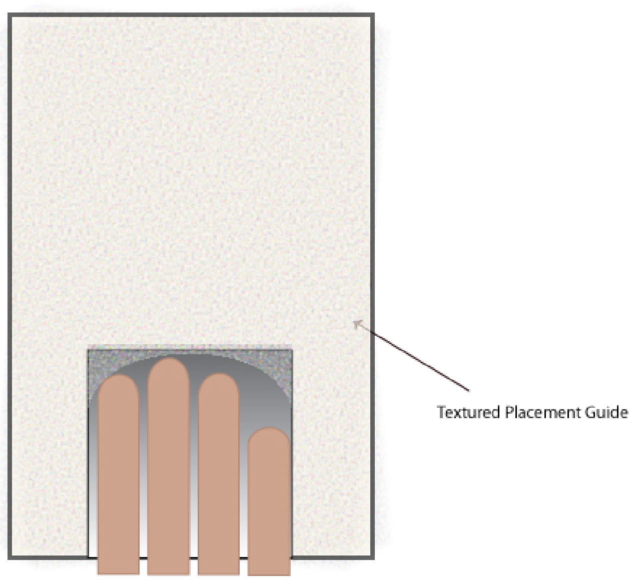

Figure 2 Fingerprint Scanner Texture Placement

5.2.1 Fingerprint Scan Process Indicators

We investigated two different methods to indicate the fingerprint scanning process, tones and vibration.

5.2.2 Tones

First, a tone was selected as a location indicator. This tone had a duration of 0.15 seconds or less, and repeated at one-second intervals in accordance with the Manual on Uniform Traffic Control Devices [5].

Three different tones were developed for indicating the scanning process.

Indicator Tone 1: A one second tone at 1000 Hz

Indicator Tone 2: A three second tone at 1000 Hz

Indicator Tone 3: There were two "variations on a theme" for Tone 3

> Tone 3a: An eight second series of tones separated by one second to one half seconds in decreasing intervals, a short pause, then two quick beeps

> Tone 3b: An eight second series of tones separated by one second to one half seconds in decreasing intervals

In conjunction with the tones developed for the scanning process, we selected six tones that are commonly used by the visually impaired community as indicators. These were:

- A crosswalk button locator tone used in Prisma Teknik's Accessible Pedestrian Symbols (APS)[6]
- A crosswalk crossing set of rapid beeps used in Prisma Teknik's APS
- A crosswalk crossing "cuckoo" sound used in Mallory Sonalert APS
- A crosswalk crossing "chirp" sound used in Mallory Sonalert APS
- Another type of crosswalk crossing "chirping" used by Novax Industries APS
  The locator sound from the above study.

5.2.3 Vibration

A device was placed within the scanner mockup that was turned off and on remotely and created a vibration that could be felt when a hand was placed on the top of the mockup.

5.3 Procedure

The participant was welcomed into the room where the study was to be conducted. The consent form was reviewed and signed. Next, the participant was informed that the purpose of the study was to investigate the use of electronic fingerprint scanning with people with differing levels of visual acuity. He or she was told that there was a mockup of a scanner, "a little bigger than a shoebox" on a table in front of him/her. This mockup was going to emit a sound and that the participant should locate the scanner using this sound and place one hand on top of the mockup where he/she thought the hand should be placed. The participant was also told that once he/she placed his/her hand on the scanner he/she should press down on the scanner and that the scanner would indicate, in some way, both that a scan had begun and that the scan had ended. The participant was asked to inform the study conductor when they thought the scan had begun and then lift his/her hand when the scan had ended. First, the participant was to locate the sensor mockup by a tone. Second, he/she was to use the textured surface to identify where he/she should place his/her hand for the scan. Finally, the participant was asked to inform the facilitator when the scan began and when it ended. The participant was also informed that there would be three trials of this procedure. This procedure is illustrated in Figure 3. The first four participants received the following indications:

Group 1 (Start Tone & Stop Vibrate, Continuous Tone, Continuous Vibration):

Trial one: Tone 1 indicated the start of the scan and a vibration indicated the end.

Trial two: Continuous Tone 2 indicated the scanning duration.

Trial three: An eight second continuous vibration indicated the scanning duration.

Since we were following a formative testing procedure, the results (see Results) for the first group were analyzed and the indicators were changed for the next group of five participants:

Group 2 (Start & Stop Tone, Continuous Vibration, Speedup Tone A):

Trial one: Tone 1 indicated the start and the stop of the scan.

Trial two: An eight second continuous vibration indicated the scanning duration.

Trial three: Tone 3a indicated the scanning duration.

The results for the second group were analyzed and the indicators were changed for the next group of three participants:

Group 3 (Start & Stop Tone, Continuous Vibration, Speedup Tone B):

Trial one: Tone 1 indicated the start and the stop of the scan.

Trial two: An eight second continuous vibration indicated the scanning duration.

Trial three: Tone 3b indicated the scanning duration.

After the three trials, each group of participants listened to six tones and gave their opinions on how appropriate they thought the sound would be in a biometric application.

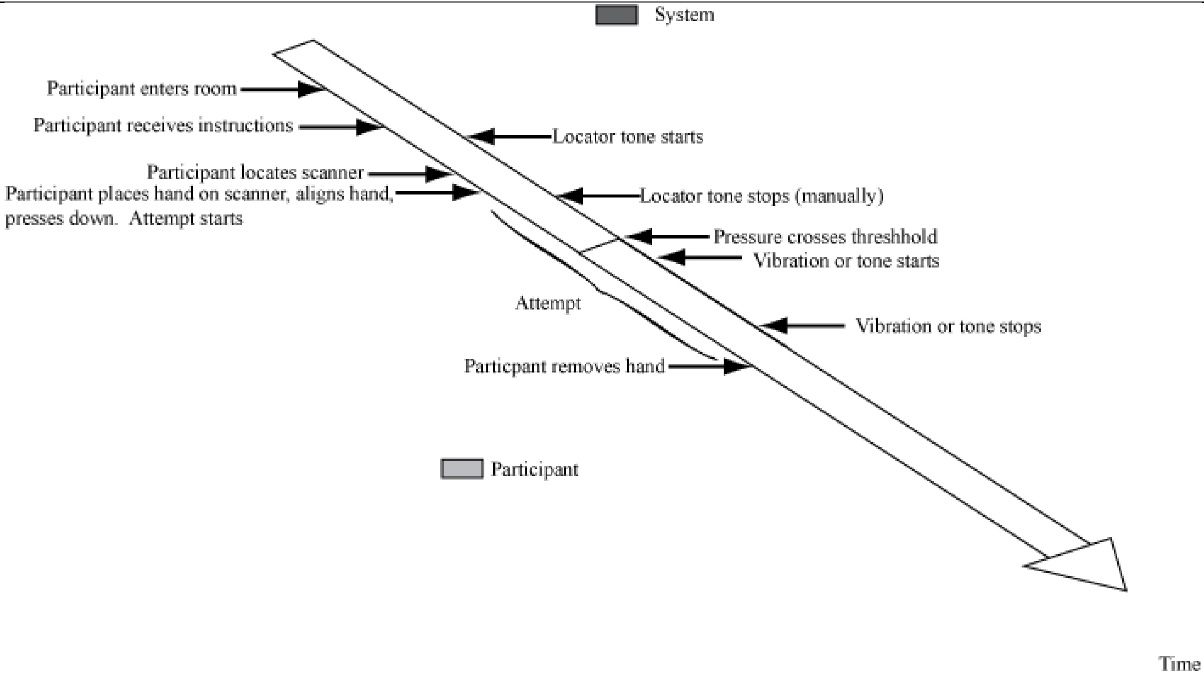

Figure 3 Fingerprint Scanning Process

6 Results

As presented in Table l, participants successfully located the scanner using the locator tone. Only one participant had any difficulty. In addition, all but one participant were able to correctly position their hand on the scanner using the textured surface.

Table 1 Location and Hand Placement with Scanner

Group	Participant number	Vision	Located	Placement
1*	1	None	OK	OK
	2	None	Ok	Ok
	3	None	Ok	Ok
	4	None	Ok	Ok
2†	5	Low	Ok	Ok
	6	None	Ok	Ok
	7	None	Ok	Ok
	8	None	Ok	Ok
	9	None	Ok	Ok
3‡	10	Low	Ok	Ok
	11	Low	With difficulty	Ok
	12	None	Ok	No

* Start Tone & Stop Vibrate, Continuous Tone, Continuous Vibration
† Start & Stop Tone, Continuous Vibration, Speedup Tone A
‡ Start & Stop Tone, Continuous Vibration, Speedup Tone B

Table 2 Group One shows that for the first group in trial one only one out of the four participants understood that the vibration indicated the scan was over. Likewise, only one participant understood that the cessation of the beeping indicated that the scan had ended in trial two. However, in the third trial all but one participant understood that the stopping of the vibration indicated the end of the scan.

Given the participant's difficulty in understanding these cues we modified the test for the second group. Trial one was changed from a vibration indicating the end of the scan to a second beep. The constant beeping in trial two was replaced with Tone 3a as a new trial three (with group one's trial three as the new trial two).

Table 2 Group One (Start Tone & Stop Vibrate, Continuous Tone, Continuous Vibration)

Participant number	Vision	Trial One		Trial Two		Trial Three	
		Start beep	End vibrate	Start beeping started	End beeping ceased	Start vibration started	End vibration ceased
1	None	Ok	Unclear	Ok	Ok	Ok	Ok
2	None	Ok	No	No	No	Ok	No
3	None	Ok	Ok	Ok	No	Ok	Ok
4	None	Ok	Unclear	Ok	No	Ok	Ok

Group two's results(as shown in Table 3) show that the ending beep in trial one and the accelerating beeping in trial three were not very effective. Participants were apparently mislead by the gap before the final two beeps in tone 3a. Even participant 9, who correctly interpreted the tone, mentioned that it could be misleading. The constant vibration throughout the scan in trial two was correctly indentified (participant eight's data was lost due to equipment malfunction).

Table 3 Group Two (Start & Stop Tone, Continuous Vibration, Speedup Tone A)

Participant number	Vision	Trial One		Trial Two		Trial Three	
		Start beep	End beep	Start vibrate	End vibrate ceased	Start beep	Accelerated beep ceased
5	Low	Ok	Ok	Ok	Ok	Ok	no (gap)
6	None	Ok	No	Ok	Ok	Ok	no (gap)
8	None						
9	None	Ok	No	Ok	Ok	Ok	ok (gap)

For the final group of three participants we removed the gap before the final two beeps for the accelerated beeping condition. All participants correctly identified the scan duration in the vibration and accelerating beeping condition. Two of the three participants could identify the scan duration when the scan began and ended with a single beep (see Table 4 Group Three).

Table 4 Group Three (Start & Stop Tone, Continuous Vibration, Speedup Tone B)

Participant number	Vision	Trial One		Trial Two		Trial Three	
		Start beep	End beep	Start vibrate	End vibrate ceased	Start beeping	Accelerated beep ceased
10	Low	Ok	Ok	Ok	Ok	Ok	Ok (no gap)
11	Low	No	No	Ok	Ok	Ok	Ok (no gap)
12	None	No	Ok	Ok	Ok	Ok	Ok (no gap)

As shown in Table 5, when presented with the six tones, all participants preferred Tone 6 (the locator tone used in this study).

Table 5 Tone Preference

Group	Participant number	Vision	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6
1*	1	None	Just OK	No	No	No	No	OK (best)
	2	None	OK	No	Just OK	No	Ok	OK (best)
	3	None	Ok	Ok	Ok (best)	Ok	Ok	OK (best)
	4	None	No	No	No	No	No	Ok
2†	5	Low	No	No	Ok	Ok	Ok	Good
	6	None	No	Ok	Ok	Ok	Good	Best
	8							
	9	None	No	Ok	No	No	Ok	Ok
3‡	10	Low	Ok	No	Just ok	No	No	Ok
	11	Low	No	Ok	Ok	Ok	Ok	Ok
	12		Ok	No	No	No	No	Ok

1. A crosswalk button locator tone used in Prisma Teknik's Accessible Pedestrian Sysmbols (APS)
2. A crosswalk crossing set of rapid beeps used in Prisma Teknik's APS
3. A crosswalk crossing "cuckoo" sound used in Mallory Sonalert APS
4. A crosswalk crossing "chirp" sound used in Mallory Sonalert APS
5. Another type of crosswalk crossing "chirping" used by Novax Industries APS
6. The locator sound from the this study

* Start Tone & Stop Vibrate, Continuous Tone, Continuous Vibration
† Start & Stop Tone, Continuous Vibration, Speedup Tone A
‡ Start & Stop Tone, Continuous Vibration, Speedup Tone B

7 Discussion

7.1 Locating

The visually impaired participants in this study had little or no difficulty locating the fingerprint scanner mockup. This finding is encouraging as it implies that audio cues would be an effective method to indicate the location of a biometric device in an operational setting.

The tone preference results (see Table 5) provide clues as to the characteristics of an appropriate locator tone. When looking at the participants' comments on the tones, commonly desired attributes appear. Tone 6 (the tone used in this study) was universally liked. Participants commented that this tone sounded "more like an electronic device" and would be "more distinct from background sounds". However, a few participants wanted the locator tone to be louder. Tones 3, 4, and 5 were all variations on a bird chirping. Participants were mixed in their opinions on these tones. These tones were rated as easily heard, but concerns were expressed about these tones being confused with real bird calls. However, participant 3, an expert on audible cues for the visually impaired, highly rated the bird call tones. She felt that the "falling third" tonal drop would draw people's attention and would be good if someone had hearing loss in one of the frequencies used.

When asked, participants reported that they judged the tones on how easily the tone could be heard in a noisy ambient environment and how distinct it was from other noises. At the same time, participants wanted the tone not to be "annoying", "distracting" or too loud. Another common finding was that participants wanted the locator tone to sound only until they learned where the scanner was located. Once the location was determined and remembered, they preferred that the locator tone not sound. There was an implication that the scanner should be able to determine who needed the locator tone.

Given the complex requirements of what comprises a locator tone (how loud it should be, and how often it should sound) more detailed research could be performed in this area.

7.2 Hand Placement

Only one participant was unable to position a hand on the smooth area within the textured surface of the scanner mockup. This participant did have some vision and was able to see into the scanner (since it was made of clear acrylic) and see the speaker and vibration assembly. The participant reported that it appeared she would be reaching into the scanner and was therefore unwilling to place her hand on any operating equipment. All other participants reported that they had little or no difficulty determining where to place their hands and that the textured surface was easily differentiated. Interestingly, many participants expressed that even people with lessened tactile sensitivity (such as caused by diabetes) would still be able to distinguish between the textured and smooth surfaces.

7.3 Scan Duration

Three groups of participants experienced three different scan duration indicators.

In the first group of participants (Start Tone & Stop Vibrate, Continuous Tone, Continuous Vibration), the majority did not recognize that the scan had ended when a vibration was felt. We had initially thought that a vibration would cause the participants to pull their hand away from the machine in surprise of the unexpected vibration. This did not turn out to be the case. Instead, participants were confused by the mismatch between the two different signaling modes (i.e., from audible to haptic). In the second trial of the first group, participants were uncertain what the cessation of the steady beeping meant. In their remarks some mentioned waiting for something to happen after the beeping stopped. Participants did not make a strong connection between the scanning process and the beeping.

In the third trial of the first group, all but one of the participants correctly identified when the simulated scan was over. The vibration had a strong association with the process of scanning. One participant commented on how the vibration made him think of a machine-like process, like the vibration made from the scanning mechanism. Although most of the participants correctly indicated when the scan was complete, many said that they had "guessed" at the meaning of the vibration stopping. Nevertheless, this guesswork proved to be correct.

The second group of participants (Start & Stop Tone, Continuous Vibration, Speedup Tone A) again received three different indicators of the scanning process. Since the trial with the vibration indicating the end of the scan faired so poorly, it was replaced with a trial consisting of a starting beep and an ending beep. Although in group one the participants suggested that they might understand better if the starting and stopping indicators were of the same type (e.g., both beeps), this behavior was not observed with the second group.

Trial two for the second group of participants consisted of the same vibratory indicator as in group one's trial three. Again, the steady vibration during the simulated scan was understood well.

The third trial for group two was a series of beeps during the simulated scanning process. As we listened to the previous two groups' comments, we wanted an indicator sound that was more representative of a process. A house alarm arming system indicator was used as a model. The arming indicator was a series of beeps with progressively less time between beeps to indicate the approaching time of the alarm activation. As this accelerating beeping was deemed to be indicative of requiring an action on the part of the listener, we constructed a series of beeps based on the alarm system. At the end of the arming system indicator there was a pause followed by two beeps to indicate that the system was now armed. This gap proved to be very confusing to the participants. Most participants assumed the scan had ended before the two final beeps.

Group three (Start & Stop Tone, Continuous Vibration, Speedup Tone B) had the same trials as group two but for the third trial the final two beeps were removed. When these beeps were removed, all participants correctly identified the end of the simulated scan. As with the results from group two, the steady vibration was better understood than the start and end beep trial.

8 Summary

In this study we examined the use of audio, haptic, and tactile input to assist users with visual disabilities interact with fingerprint devices. Specifically we focused on input for locating the scanning device, for properly placing a hand on the scanner, and for determining the duration of a fingerprint scan. We found that audio tones are effective for locating the device. Textured surfaces can be used for determining proper hand placement. Finally, audio tones and haptic input are effective in providing an indication of scan duration. However, we found that in order for the duration indicator to be effective the indicator must be indicative of a process. For example, consider the progress bar in many computer applications. Our finding that a single tone at the beginning and end was confusing to participants is consistent with this hypothesis. This finding has much broader implications for fingerprint devices.

In previous usability tests [2], we have observed many users struggling to determine when to place and remove their hands from the fingerprint device. Users were not certain when the process started and ended based on the lights. Based on results from this accessibility testing, this is likely due to the fact that for the study participants these lights were not indicative of the process. Further testing is required to determine how best to represent the process and the duration of the scan to the larger population of fingerprint users.

We also noticed that many of the participants of this accessibility study were very concerned about other types of disabilities. Several participants commented that the audio tones would not be appropriate for users with hearing impairments. This test was specifically designed to study interaction with fingerprint devices for those with visual impairments. However, their concerns raise the bigger question of how will people with differing abilities use fingerprint devices? Users may be too diverse for a biometric device to provide the necessary information for all users.

One size does not necessarily fit all. Instead of the users adapting to the device, the device could adapt to the user. A user should be able to take their personal profile to the system and the system should be able to use that profile to customize itself to meet the individual's needs. Consider the following scenario: As a user approaches the biometric sensors, a signal is sent to the system that indicates a user's desires or requirements. The system acts on the signal, enabling or disabling various features based on the user's requirements. When the user is ready to present his/her biometrics, the system has been automatically configured in a personalized fashion. Thus for someone who has a visual impairment the system might use tones; for someone with a hearing impairment the system might use lights.

Such adaptive technologies have potential beyond Section 508 accessibility requirements [7]. For example, consider an unattended physical access control point, such as a biometrically enabled door, and a user that has expressed a distrust (for example from some perceived safety concerns) for a particular biometric (e.g., a false belief that an iris camera may damage their eyes). If an access badge was outfitted with a signaling technology, then such a system could read a user's preferences from a distance, and prepare a substitute modality, such as a fingerprint. Adaptive capabilities could also be extended beyond purely biometric needs -- consider an adaptive system at an unattended airport tarmac entry/exit point. A longer-range radio frequency identification (RFID) badge could broadcast that a particular category of transportation worker that moves heavy equipment needs to have the electronic door held open longer so they can enter and exit without fear of a door prematurely shutting [8].

Additional research is required to determine the usefulness of adaptive technologies for biometric applications.

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Acknowledgements

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APPENDIX A

Demographic Questionnaire

3. Handedness

- ☐ Right Handed
- ☐ Left Handed
- ☐ Ambidextrous

4. Height

☐ Feet ☐ Inches

5. Country of Origin

☐

6. Profession

☐

APPENDIX B

Instructions

We're studying the use of electronic fingerprint scanning of people with differing levels of visual acuity. We are going to go a different room. In this room there will be a table approximately (5') in front of you. On this table there's a mockup of a fingerprint scanner, a little bigger than a shoebox.

After entering the room, the scanner will start to emit a tone. Using this tone, I would like you to locate the scanner. On top of the scanner, there is an area where the image of your fingerprints would be taken, if this was an operational scanner.

After locating the scanner, I would like you to position four fingers of one hand (index, middle, ring, and little finger) on top of the scanner were you think the fingerprint image will be taken. Your fingers should be positioned so that none of them are touching a textured surface. They should only be on a smooth surface.

Once you feel that your fingers are correctly on the platen, tell us. Afterwards, press down on the scanner, the scanner will indicate that the scan has begun. It will also indicate the scan is over.

Throughout this process, I would like you to talk out loud about what is going on. So when you hear the locator tone, please tell me your impressions of it. Tell me about locating the scanner, placing your hand appropriately, and when the scan starts and when the scan ends. Your opinions on this process are very important to us and they will influence our future research in this area.

After the scanning, I would like to play a few tones for you to get your opinions of them as to how effective they might be for locating biometric devices.

APPENDIX C

Table 6 Participant Interview Responses: Fingerprint

Participant	**What cues would you recommend to help make the fingerprint process more independent or accessible?**	**Visual Impairment**	**Tactile Cues**	**Audio Cues**	**Verbal Cues**
1	Recommended use of a mold that a person could feel and would help clue a visually impaired individual as to how to position their fingers for the most effective scanning. Participant indicated that this technique (molding tactile layouts) was useful for layouts for keyboards	Totally blind and wears an opaque prosthetic shell over eyes	X		
2	Recommended the use of some form of tactile surface that would accommodate hands of different sizes..	Blind	X		
3	Recommended tactical guides, suggesting that the scanning surface have indentations that would indicate were the fingers	Totally blind	X		

	should be placed. Another suggestion was that the scanning surface should have contrasting surface-textures. The surface would be smoother were the fingers should be placed, or, the surface could have notches where the fingers should be placed.				
4	Recommended that we could train the individually impaired individual with how to place their hands. Additionally, the participant suggested that tactical/raised markings on the scanning surface would be helpful. Participant also suggested that the scanner should beep after its scan process is completed.	Totally blind, one eye is artificial	X	X	
5	Recommended clear audible directions, a beep indicating completion of the scanning . Also the scanning surface should be larger and some form of tactile indications would be helpful.	Totally blind and wears opaque prosthetic shells over eyes	X	X	
6	Recommended verbal directions, along with manual guidance of hands.	Low vision, due to anaridia and glaucoma.			X
7	Recommended verbal directions, along with a	Legally blind, but			X

	small amount of manual guidance of hands.	small amount of vision and could probably locate where to place hand on scanner			
8	No recommendations (this participant had some vision and could identify the scanning surface.) Sliding fingers over the scanning pad felt awkward but was accommodating..	Legally blind, 2300 vision in one eye (glaucoma in this eye) and totally blind in the other			
9	This participant did not find the experience of using the digital scanner that difficult, but audio cues to indicate the end of the scanning process would be helpful . Concern was expressed about the required forms which were completely inaccessible.	Totally blind, two artificial eyes		X	
10	Recommended verbal cues. Also, multiple inputs such as both verbal and large imprints.	Low vision suffers from strabismus (commonly known as cross-eyes)	X		X

APPENDIX D

Table 7 Participant Interview Responses: Iris

Participant	How would you recommend that iris scanning be addressed?
1	This participant is blind and wears an opaque prosthetic shell (something like contact lenses) which would prevent scanning of the iris. Iris scanning for the visually impaired would require very clear instructions such as look directly ahead and continue with the directional guides until the eyes are in scope.
2	This participant had no suggestions
3	This participant is blind, and the only way that the iris scanning might work would be to use a face mask or chin support.
4	This participant is totally blind and one eye is artificial which would prevent scanning of that eye. However, with proper directions, his other eye would be scannable with appropriate directions
5	This participant is blind and wears opaque prosthetic shells preventing scanning of the iris.
6	This participant has low vision, due to anaridia and glaucoma and had no recommendations.
7	No suggestions
8	No suggestions
9	This participant has two artificial eyes and was concerned about the design of systems that may prevent easy participation of individuals with eye injuries or missing limbs.
10	This participant has low vision, due to strabismus (commonly known as cross-eyes). Large visual aids and contrasting colors would be helpful.