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# Non-Contact Multi-Sensor Fingerprint Collection – Phase II
**11/2014 - 4/2015**

**FINAL REPORT**

**For:**
**ManTech International Corp.**

**Jeremy M. Dawson, Ph.D. - PRINCIPLE INVESTIGATOR**
**Christopher Robison – Collection Staff Lead**

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## 1. Project Overview

The purpose of this data collection was to obtain data to enable the evaluation of non-contact fingerprint devices. In addition, human factors information was collected from operators performing the data collection to assess the operability of the prototype devices and how the general public interacted with these devices. The target number of participants for this collection was 400. An initial cohort of data was provided after ~200 participants were collected, followed by a second cohort of the remaining data. Data collection took place between 12/1/2014 and 4/2/2015, with 450 participants providing data.

The following is a description of the data collection effort, a summary of data collected and participant demographics, and operator feedback from WVU staff members.

## 2. Data Collection

Data collection was performed on the WVU Evansdale Campus. The collection utilized livescan and non-contact fingerprint devices provided by ManTech. An indoor laboratory space (164 ESB Addition) was used as the collection area, with all sensors and rolled ink impressions collected in the same space. Data was collected from each device and assembled in a common data repository on a regular basis.

### *2.1 Fingerprint Devices*

Data collection was performed using seven different fingerprint devices (both livescan and non-contact systems), as well as rolled ink impressions on a standard 10-print card. Table 1 lists the devices used in this data collection, along with the data collected from each device. *Note: The Single-finger non-contact system from FlashScan 3D was slated to be included in this data collection. However, it developed an operational issue prior to the start of collection. It was sent to FlashScan for repair, but was not returned.*

**Table 1:** Fingerprint device details.

| Vendor | Sensor | Collection Type | Data Collected |
|---|---|---|---|
| 1. CrossMatch | Guardian R2 | Livescan, contact | Left & right hands, slaps & rolls |
| 2. L1/Morpho | TouchPrint 5300 | Livescan, contact | Left & right hands, slaps & rolls |
| 3. CrossMatch | SEEK Avenger | Mobile, contact | Livescan equivalent to 10-print card |
| 4. Northrup Grumman | BioSled | Mobile, contact | Livescan equivalent to 10-print card |
| 5. MorphoTrak | MorphoIDent | Mobile, Contact | Left & right hands, slaps only |
| 6. Advanced Optical Systems (AOS) | ANDI On-The-Go | Portal, contactless | 4 fingers on right hands only |
| 7. MorphoTrak | Finger-on-the-Fly | Livescan, contactless | Left & right hands, 4 fingers only |
| 8. IDair | InnerID (on iPhone) | Mobile, contactless | Left & right hands, finger photos |

Images of these devices are shown in Fig. 1.

**Figure 1:** Fingerprint devices (from top left): CrossMatch Guardian R2, L1/Morpho TouchPrint 5300, CrossMatch SEEK Avenger, Northrup Grumman BioSled, MorphoTrak MorphoIDent, Advanced Optical Systems (AOS) ANDI On-The-Go, MorphoTrak Finger-on-the-Fly. The IDair InnerID (on iPhone) system was not available for photograph.

### *2.2 Collection Site*

The laboratory space housing the various collection equipment was approximately 24x24ft, with the collection area encompassing ~12x24ft of this space. Three standard lab benches were used to acquire data from the 8 different sensors used in this collection. The first bench housed the MorphoIDent, BioSled, and InnerID devices, along with a laptop for data transfer from these devices. The second bench housed the SEEK Avenger and Finger-On-The-Fly (FOTF) devices, and the control laptop for the FOTF system. The third bench housed the Guardian and TouchPrint devices and their control laptop, as well as the control laptop for the ANDI On-The-Go (OTG) system. The OTG system was located adjacent to the collection area to allow the participant to gain a walking start before interacting with the system. A plywood riser with ink plate and card bracket for inked fingerprint impression collection was placed on a nearby counter surface. A sink was available in the room for cleanup, as well as standard ink remover pads. The restrooms were located nearby for additional hand-washing if needed. Fig. 2 illustrates the arrangement of the equipment in the laboratory used for the data collection.

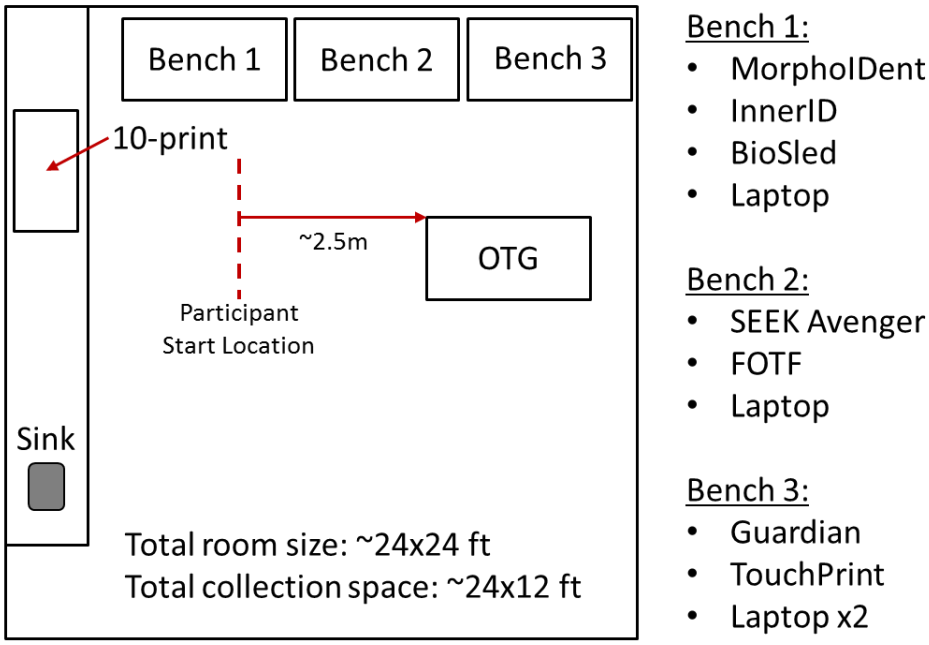


**Figure 2:** Collection laboratory and station arrangement.

*2.3 Data Types & Organization*

Each participant in the data collection provided two sequential sessions of fingerprints for each sensor. Inked prints were collected once and scanned at 500 and 1000ppi. The file structure of the data is as follows:

10 print cards
- Subject ID_Date_WVU Collection ID
  - 500
    - .eft file x1, .bmp images x14
  - 1000
    - .eft file x1, .bmp images x14

Andi OTG
- Subject ID_Date_WVU Collection ID
  - Session 1 & 2 folders
    - Binary .bmp images x4
    - Grayscale .bmp images x4

BioSled
- Subject ID_Date_WVU Collection ID
  - Session 1 & 2 folders
    - BioSled system files x16
    - .bmp images x16

Crossmatch SEEK avenger
- Subject ID_Date_WVU Collection ID
  - Session 1 & 2 folders
    - .eft file x1
    - .bmp images x14

FPII Guardian
- Subject ID_Date_WVU Collection ID
  - Session 1 & 2 folders
    - Sensor date folder
      - .bmp images x13

innerID
- Subject ID_Date_WVU Collection ID
  - Session 1 & 2 folders
    - .bmp images x10

L1 TouchPrint
- Subject ID_Date_WVU Collection ID
  - Session 1 & 2 folders
    - .bmp images x13

Morpho FOTF
- Subject ID_Date_WVU Collection ID
  - Session 1 & 2 folders
    - Unsegmented .bmp images x4
    - Segmented .bmp images x16

MorphoMobile
- Subject ID_Date_WVU Collection ID
  - Session 1 & 2 folders
    - .bmp images x10

The syntax of each fingerprint image filename is as follows:

SubjectRID_CollectionDate_CollectionNumber_SensorName_Slap/RollIdentifier_SessionNumber_Finger/SlapIdentifier.EXT

The numerical values in the 'Slap/RollIdentifier' and 'Finger/SlapIdentifier' fields are determined based on the NIST standard(s) for fingerprint capture and archiving (Publicly Available). To keep file path lengths at a minimum, each sensor has been abbreviated with a 3 letter code in the 'SensorName' field. Table 2 defines each abbreviation.

**Table 2:** Sensor codes used in file naming convention.

| Code | Definition |
|---|---|
| 10P | Ten Print Card (Scanned at 1000 & 500 dpi) |
| IID | InnerID (iPhone App) |
| MFF* | Safran Morpho Finger on the Fly |
| CSA | CrossMatch SEEK Avenger |
| BIO | Northrup Grumman BioSled |
| OTG | ANDI On the Go (OTG) |
| L-1 | L-1 scanner |
| CG2 | CrossMatch Guardian 2 |
| SMM | Safran Morpho Mobile MorphoIDent |
| **Note:* The session IDs for this device will appear as <X-Y> where X denotes which session data was being collected and Y denotes the individual passes of the subject's hand through the device per session. | |

Due to operator error and sensor malfunction, some data may be missing or corrupted. A list of missing data was included with the dataset upon delivery to ManTech. In instances where a

particular sensor was malfunctioning or away for repair, collection was continued and this data will be missing from the subject's data record.

### *2.4 Collection Procedure*

The following is a description of the collection procedure the participant experiences from consent to remuneration. It is written as an instructional document describing to staff members the standard operating procedure of each data collection station. Total time through the collection was 45 minutes to 1 hour.

#### 2.4.1 Consent

Greet the participant and provide the consent form. Explain each section of the consent form, including all locations on the form that need to be initialed, dated, or signed. Ensure that your explanation includes the following:

- The purpose of the study is to collect data for biometrics research funded by ManTech International and the National institute of Justice.
- Data collection consists of fingerprints captured by multiple electronic fingerprint devices and on paper with ink.
- Participation is strictly voluntary; they may opt out of the process at any time.
- Inform the participant that they will be receiving gift cards upon completion of data collection and that if they choose to not complete the study they will not receive the gift cards.

Once the participant has read and completed the consent form, ask if they have any further questions and direct them to the Enrollment workstation.

#### 2.4.2 Enrollment

Once the participant has arrived at the Enrollment Workstation, ask them for a photo ID to verify their identity. Participants may already be in the Enrollment database from another study, so ask if they have participated before. If they have participated before they will already have an RID number, if not they will need a new RID generated in the system. Using the Enrollment interface, search the database to see if the basic information (name, date of birth, etc.) exists in the database. Searching the database can be completed by using the participant's first or last name, date of birth, or all three. Typically it is most efficient to search by last name and identify the correct person based on the date of birth that appears after searching. If the participant already has an RID in the system, make a note of the RID for use while completing the enrollment process. If the participant is not in the system proceed to enter new data for the participant. Once you have completed the enrollment form, print the barcode and save the information. Instruct the participant to proceed to the fingerprint collection laboratory.

#### 2.4.3 Sensor Workflow

The prototype devices were typically initialized at the beginning of each collection day, and operated continuously until all appointments scheduled for that day were completed. Each participant provided data in two sessions per visit. Data was collected from all sensors in one session, then repeated in the same sequence for the second session. For sensors with built in quality assessment, if fingerprint capture failed three times in a row with no visible quality

issues, the last image was accepted and collection was continued. Inked fingerprints were collected after all livescan images were captured to ensure that the participants' fingers were clean for livescan collection. The following is a description of the standard operating procedures for each sensor used in the data collection.

2.4.3a – Northrup Grumman BioSled

1. Unplug any USB cables from the system
2. Tap BioSled software icon
3. Select CAR tenprint format for fingerprinting
4. Select Demographics menu and enter subject RID in the name field and select the save icon
5. Select the fingerprint menu
6. The device will prompt for two finger slaps starting with the left little and ring fingers (Fig. 3).

**Figure 3:** BioSled in operation.

7. Once all 6 slap captures are completed, the device will prompt for finger rolls starting with the right thumb.
8. Place the subject's right thumb on the Sherlock sensor and make sure that their finger is touching both the sensor and the bezel surrounding the sensor pad. When placed correctly, a red line will appear indicating the device has started to capture.
9. Roll the subjects thumb toward their body until the roll is complete. The line will turn green when a satisfactory print has been captured. The device will then prompt for the next finger.
10. Repeat steps 8 & 9 for each finger on the subject's right and left hands
11. When finger capture is completed, select the save button for the fingerprint images and then again to save the whole session.
12. Repeat steps 4 – 11 for the second capture session.
13. Once both sessions have been captured, plug a mini USB cable into the device and connect the cable to a windows PC.
14. Mount the device as a media device and access the phone's root directory.
15. Navigate to the BioMob folder and (need folder name) select the two most recent session folders. If there were more than two participants stored on the device, check with the transaction review list in the BioMob software.

2.4.3b – MorphoIDent

1. Begin fingerprint capture by pressing the green ‘check’ button the device’s fingerprint scanner with light up red indicating it is ready to capture (Fig 4).

**Figure 4:** MorphoIDent ready to capture.

2. Have the subject place their right index finger on the platen until the device vibrates. *NOTE:* If the print is of poor quality, the device will prompt the operator to attempt a recapture or to accept the low quality print. If the subject’s prints do not show up well on the scanner, a striped pattern will flash across the fingerprint image. When this happens, have the subject replace their finger on the platen.
3. Have the subject place their left index finger on the platen until the device vibrates.
4. Repeat steps 1-3 for the remaining fingers starting with Right finger followed by left.
5. After 5 captures, the device will be in a state where it is ready to download its images to a computer running the MorphoMobile 2.0 software.
6. Connect the device to the computer and the software will automatically download the images and convert them to .nst files.
7. Open the %Temp/MorphoMobile/Bodega/Repository/ folder and copy the five folders to C:\MantechFingerprints\Morphomobile\SubjectRID\Session\. If the subject ID folder or session folders do not exist, create them and then paste the fingerprint files into their respective location.
8. Open a text file and list which CAP#### file corresponds to which pair of fingers. Also note which hand was captured first by writing R > L or L < R.
9. Repeat 1-8 for the second session

2.4.3c – Morpho Finger-On-The-Fly

1. Start the FOTF software with the default settings (Fig. 5).
2. Begin capture by clicking the enroll button followed by the green start button.

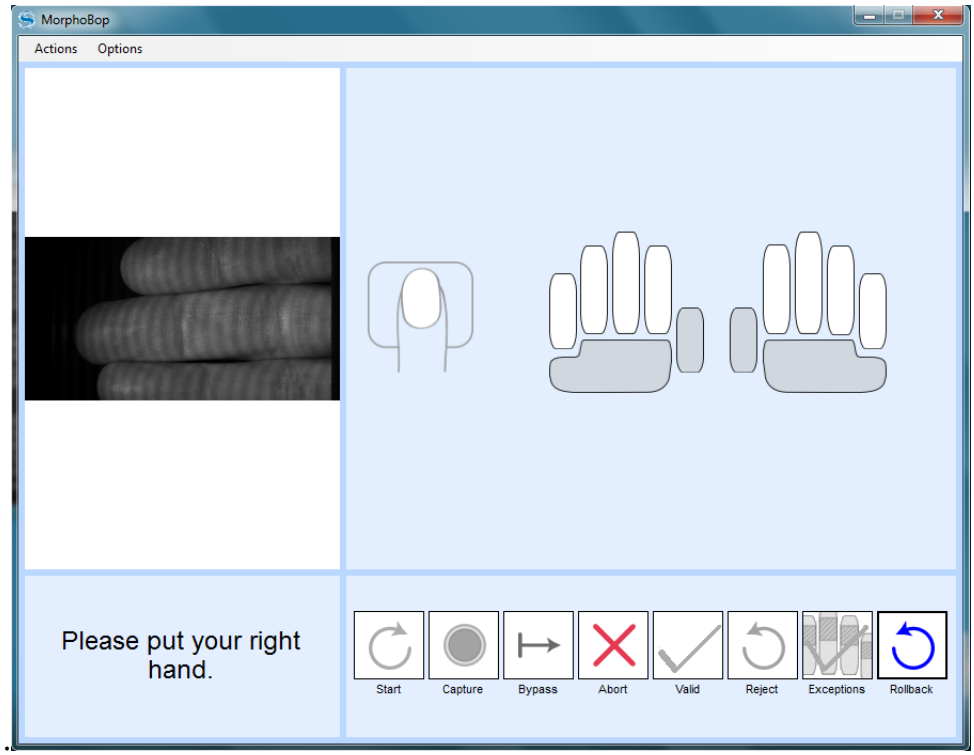


**Figure 5:** FOTF user interface.

3. Have the subject swipe their right hand through the device in the direction indicated above the platen (Fig. 6).

**Figure 6:** FOTF in operation.

4. Repeat step 3.
5. Repeat 3-4 for the left hand.
6. After capture is completed, a review screen will appear, allowing the fingerprints to be evaluated (Fig. 7). When finished, close the review window and a box will prompt to save the session. Click yes and proceed to scan the subject's RID number and click submit. The files will be moved to a session folder within the subject's ID folder.

**Figure 7:** FOTF evaluation screen.

7. Repeat steps 1-6 for the second session.

2.4.3d – IDair InnerID

1. Start the InnerID app
2. Have the participant hold their right index finger steady, line up the oval shape over the fingerprint and touch the screen to capture.
3. Check the image to see if there is any noise or blur causing artifacts to the processed image, if so, recapture.
4. Repeat 1-3 for the remaining fingers moving from index to little followed by thumb and repeat the same for the left hand.
5. Connect the device to a computer using the lightning cable provided and give the computer permission to access files.
6. Copy the image files over to C:\MantechFingerprint\InnerID\subjectID\Session\
7. Repeat 1-6 for the next session.

2.4.3e – ANDI OTG

1. Start up the ANDI OTG monitoring software. The system dialog box on the computer desktop will give a message of ‘got heartbeat,’ indicating it is ready for operation.
2. Instruct the subject to pass their 4 right fingers through the green box as they walk past the device (Fig. 8).

**Figure 8:** ANDI OTG in operation.

3. After the subject passes their fingers through the capture region, the fingerprint images that were captured will show up in preview windows on the desktop (Fig. 9).

**Figure 9:** ANDI OTG image preview.

4. Once capture has completed, copy the images in the OTG folder to: C:\mantechFingerprints\ANDI OTG\subject ID\session
5. Repeat steps 2-4 with the subject's right 4 fingers for the second session.

2.4.3f – CrossMatch SEEK Avenger

1. On the SEEK Avenger mobile computer desktop, select ‘MOBS’
2. From within the ‘MOBS’ program, select Enrollment.
3. Select the ‘CAR’ folder.
4. Select ‘Personal Information’
5. Select ‘Arrest’
6. Select ‘Arrest Segment’ Tab
7. Scan subject’s ID and select save twice
8. Select ‘Enrollment.’
9. Select ‘Fingerprints.’
10. Select ‘Capture,’ as shown in Fig. 10.

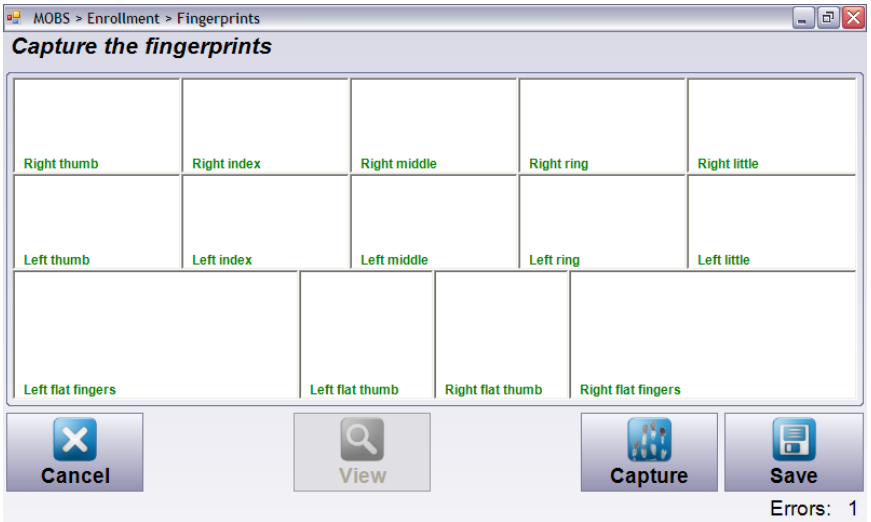


**Figure 10:** MOBS fingerprint capture interface.

11. The participant will place right index and right middle fingers on the platen to capture the slaps.
12. The participant will then place right ring and right little fingers on the platen to capture the slaps.
13. The participant will then place right and left thumb on the screen to capture the slaps.
14. The participant will then place the right thumb flat on the platen. The staff member will roll the thumb from nail to nail to capture the rolled fingerprint image.
15. Repeat step 10 for all four fingers on the right hand.
16. Repeat steps 7-11 for the left hand.
17. If, at any time, partial or low quality prints are captured, you may go back and recollect a new image. If print quality has been assured, select ‘Save’ as shown in Fig. 11.

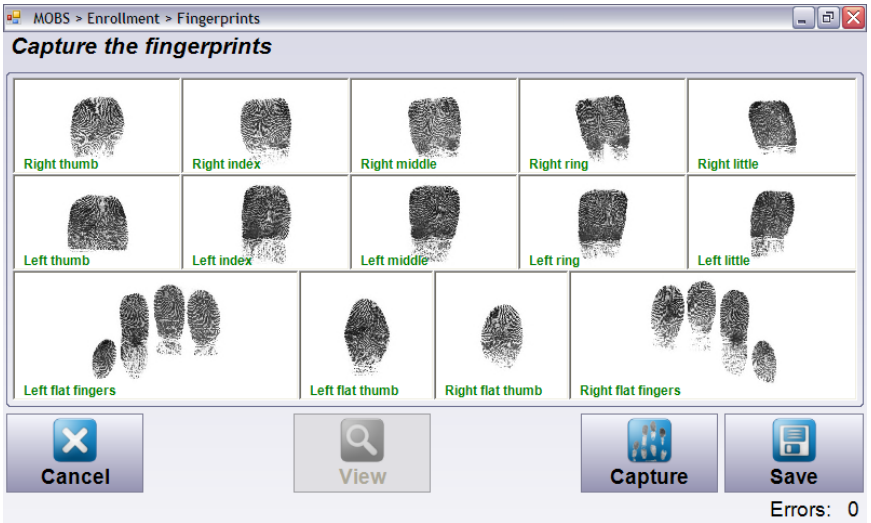


**Figure 11:** Completed MOBS fingerprint capture. The 'Save' option is located in the lower right.

18. Select 'Save' again on the next screen.
19. From there, a new notification will pop up. Select 'Later.'
20. Navigate back to the SEEK II Desktop.
21. Select 'Computer.'
22. Select 'My Computer.'
23. Select 'C Drive.'
24. Select 'Documents and Settings.'
25. Select 'All Users.'
26. Select 'Application Data.'
27. Select 'Cross Match Technologies.'
28. Select 'MOBS.'
29. Select 'Pendings.'
30. Rename the most recent file with the format 'RID_DATE_SESSIONNUMBER.eft.' Since the random ID is manually entered, double check the number to ensure no errors are made in file naming.
31. Repeat steps 2-26 for session number 2. Collection with this device is now completed. If necessary, clean the platen of the device using lift tape.

2.4.3g – CrossMatch Guardian R2

1. Select the 'ManTechData' folder on the Desktop.
2. Create a folder labeled 'CrossmatchR2' inside the participant's RID folder. Use the barcode scanner to scan the RID number when naming the folder.
3. Inside the 'CrossmatchR2' folder, create two separate folders labeled '1' and '2.'
4. Start the CrossMatch software by clicking on the CrossMatch L-SCAN Essentials icon on the computer desktop.
5. Select the 'Save Images' radio button shown on the left side of Fig. 12.

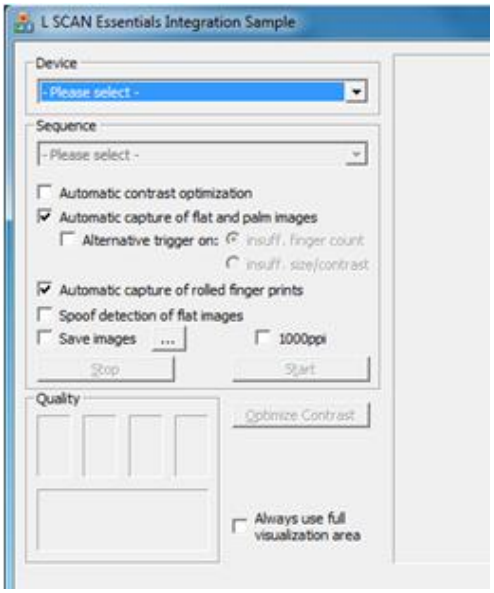


**Figure 12:** Guardian fingerprint collection interface.

6. Select the Save images radio button, and then select the '…' box, shown in Fig. 12.
7. Select the folder '1' that you created in step 4.
8. Select the 'Always use full visualization area' radio button, shown at the bottom of Fig. 12.
9. The participant places both thumbs on the platen to capture the thumb slap (Fig 13(a)).
10. The participant places the right four fingers on the platen to capture the right slap (Fig 13(b)).
11. The participant then places the left four fingers on the platen to capture the left slap (Fig 13(c)).
12. Place the participant's right thumb on the platen and roll the thumb, nail to nail, to capture the rolled fingerprint. A general demonstration of this is shown in Fig 13(d).
13. Repeat step 11 for all fingers on the right hand, beginning with index and ending with little.
14. Repeat step 11 for all fingers on the left hand, starting with the thumb and ending with little.
15. Once the rolled left little capture is completed, repeat step 6 to change the folder to '2' created in step 4.
16. Repeat steps 7-15 for collection session 2. Collection with this device is now completed. If necessary, clean the platen of the device using lift tape.

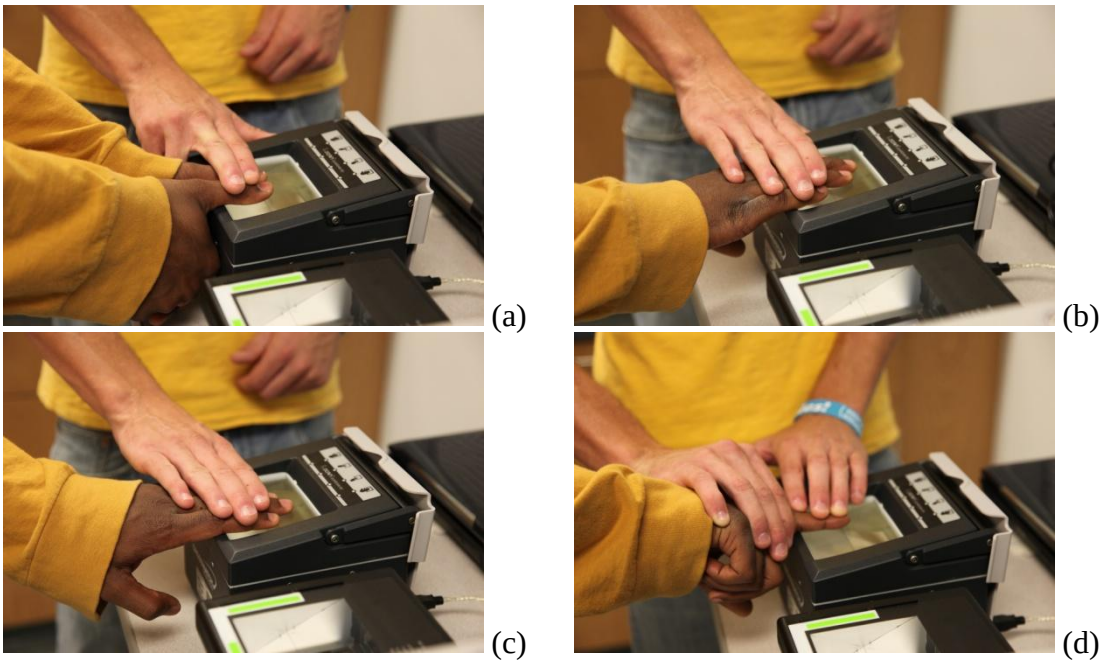


**Figure 13:** Fingerprint collection using Crossmatch Guardian R2: (a) thumb slap, (b) right slap, (c) left slap, and (d) rolled prints.

2.4.3h – L1 Touchprint

1. Click on 'Fingerprint Capture' on the Desktop.
2. Select the "L-1 TouchPrint 5300" radio button in the user interface, shown in Fig. 14.

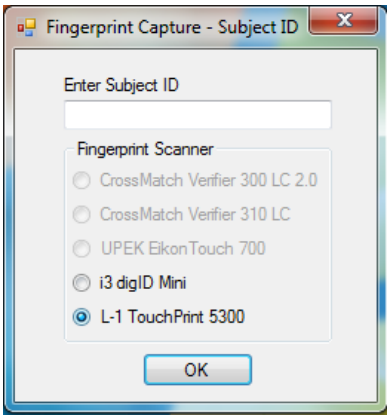


**Figure 14:** TouchPrint capture interface initiation.

3. Place the cursor in the field labeled "Enter Subject ID" and scan the RID using the barcode scanner.
4. Click 'OK' to initialize the capture interface.
5. Place the participant's right thumb in the middle of the platen, similar to the Crossmatch Guardian sample shown in Figure 10. Roll the thumb from nail to nail to complete fingerprint capture.
6. Proceed to the right index finger, and roll as described in step 5 for the remaining fingers on the right hand

7. Repeat steps 5 & 6 for the left hand
8. Once each individual fingerprint is captured, the participant places both thumbs on the machine to capture the thumb slap.
9. The participant then places the right four fingers on the machine to capture the right slap.
10. The participant repeats step 9 with the left four fingers to capture the left slap.
11. Once all fingerprints are captured, the operator performs any necessary re-captures and clicks 'Save.'
1. The process is repeated for the second session of fingerprints. Collection with this device is now completed. If necessary, clean the platen of the device using spray cleaner and a lint-free cloth.

### 2.4.4 Collection Completion

After the participant has provided fingerprints at all of the stations, provide directions to the bathroom (or lab sink) in case they wish to wash their hand more thoroughly, and instruct them to proceed to the remuneration office to receive their gift cards.

### 2.4.5 Post Processing

The data collected was stored on each station's laptop computer, where it was then compiled onto the storage server in weekly backup operations. With all the data compiled, a script was written to rename and re-order the data according to the hierarchy listed in section 2.3. Preparing the MorphoIDent data required more effort than expected to extract .bmp files from the device. First, an Apache based AFIS server was connected to the MorphoMobile2.0 software in order to decrypt the data stored on the device as it is transferred to the computer. Once transferred, the fingerprint images were stored in .nst files which can be opened with NISTPack's TransactionEdit software. To extract these image files, the data was split among 4 workstations and each file was manually exported from the .nst files into .bmp format. Once all the files had been exported, a Matlab script was used to reorganize and rename the files according to the format listed in section 2.3.

Data was delivered to ManTech in two releases. One took place after the collection of data from ~200 participants, and the second after the final total of 450 was achieved. Prior to each of these data releases, the data was evaluated and a list of quality issues or missing data was compiled and supplied along with the release.

The ten-print cards could not be delivered due to IRB restrictions on data transfer. Because of this, ManTech supplied the WVU team with an FBI-certified flat-bed scanner (Epson Perfection V700) and Aware AccuScan card scanning software to create electronic records of the ten-print cards. Cards were scanned at both 500 and 100ppi, and an .eft record and individual .bmp images were created for each participant at both resolutions. Card scanning was performed on a daily basis using a computer located in guest office on the same floor as the collection lab. The card scanning procedure is as follows:

1. Open 'CSScanDemoEFT.exe' located on the computer's Desktop.
2. Once the GUI is loaded, the designated scanner should be changed to 'Epson Perfection V700' in the drop down selection list.

3. The layout file then needs to be chosen by following the following steps in the Windows 7 OS:
    a. Browse
    b. select C drive
    c. Choose ‘program files(x86’
    d. Choose ‘Aware’
    e. Choose ‘AccuScan’
    f. Choose ‘Samples’
    g. Choose ‘Samples’
    h. Choose ‘acuscan_fbi_criminal_alt2.xml’
4. Place ten print card in scanner.
5. Click ‘Scan’ in the scanning software interface (Fig.15). Note that the default resolution is 500ppi.

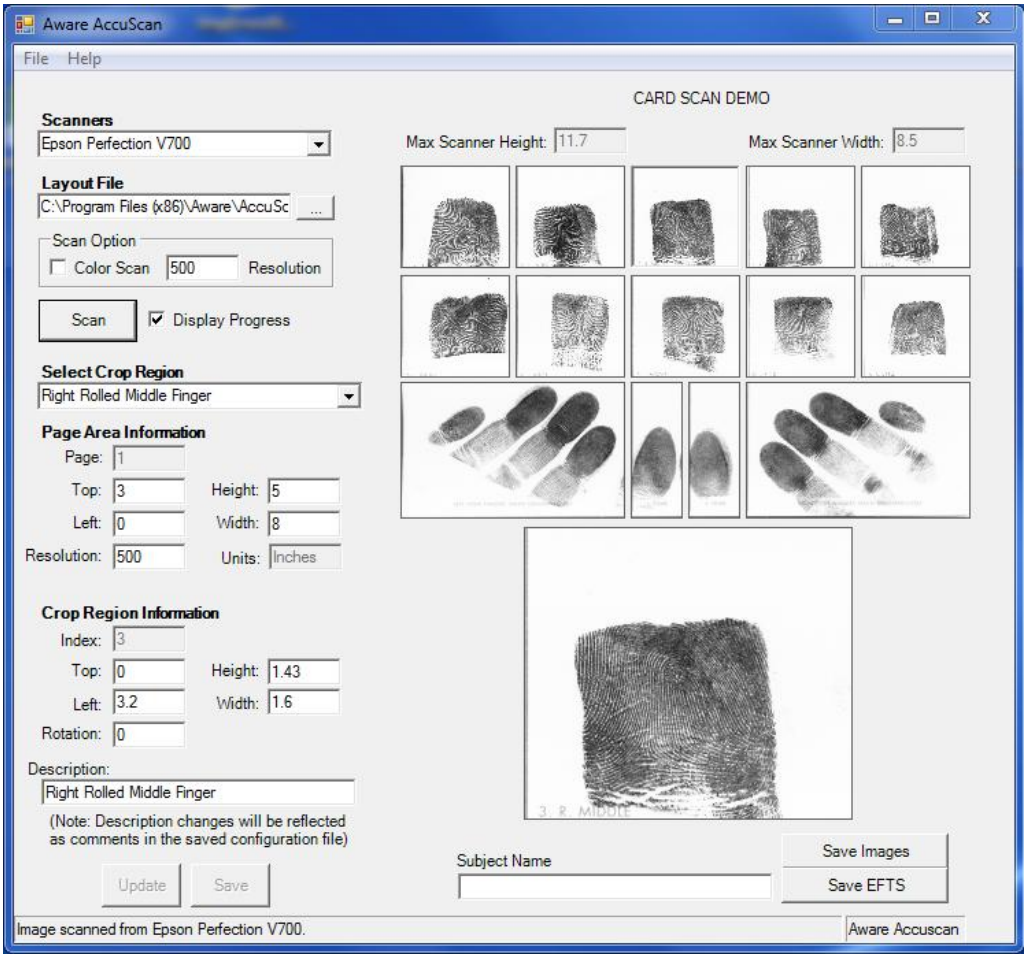


**Figure 15:** AccuScan scanning interface.

6. Click ‘Save Images.’
7. Save in ‘ManTech Ten Print Data’ in a folder named according to participant’s RID number located in the date collected. Use the barcode scanner to scan the barcode in the envelope along with the ten print card to avoid number entry errors.

8. Save files using the naming convention ‘RID_DATE_500.bmp.’ Again, the barcode scanner can be used to retrieve the RID and date.
9. In the same naming convention from step 8, put the file name in the Subject name area, click ‘Save EFTs,’ and save the data in the same folder as above.
10. Change the scanner resolution to 1000ppi in the ‘Scan Option’ field.
11. Under ‘Page Area Information,’ change the resolution to 1000.
12. Click ‘Update’ near the bottom of the window.
13. Repeat steps 5-8.
14. Save files the naming convention ‘RID_DATE_1000.bmp.’ Again, the barcode scanner can be used to retrieve the RID and date.
15. Repeat step 9 using the naming convention from step 14.

**3. Collection Demographics**

Figs. 16-20 provide information on cumulative participation in the data collection and a breakdown of ethnicity, age and gender. Fig. 16 indicates that participation peaked in February 2015. Collection activities were suspended for two periods in December 2014 and March 2015 due to closure of the university for winter and spring breaks. Low participation in January was due to inclement weather for most of that month, one instance of which caused a 2-day closure of the university. Fig. 17 shows steady growth in participation throughout the project period, despite university closures. Fig. 18 indicates that Caucasians make up over half of the participants at 51.6%, followed by Asian Indians (11.4%) and Hispanics (8.9%). This ethnicity distribution shows higher than normal Hispanic participation, most likely due to higher participation from the community rather than student population. Fig. 19 indicates that the majority of participants were in the 20-29 age range, making up 77.9% of the total, with the next highest groups in the 30-39 (11.0%) and 18-19 (5.9%) age ranges. Fig. 20 shows that male & female participation was almost equal for Hispanic and Caucasian participants, with male participation being higher for all other ethnicities.

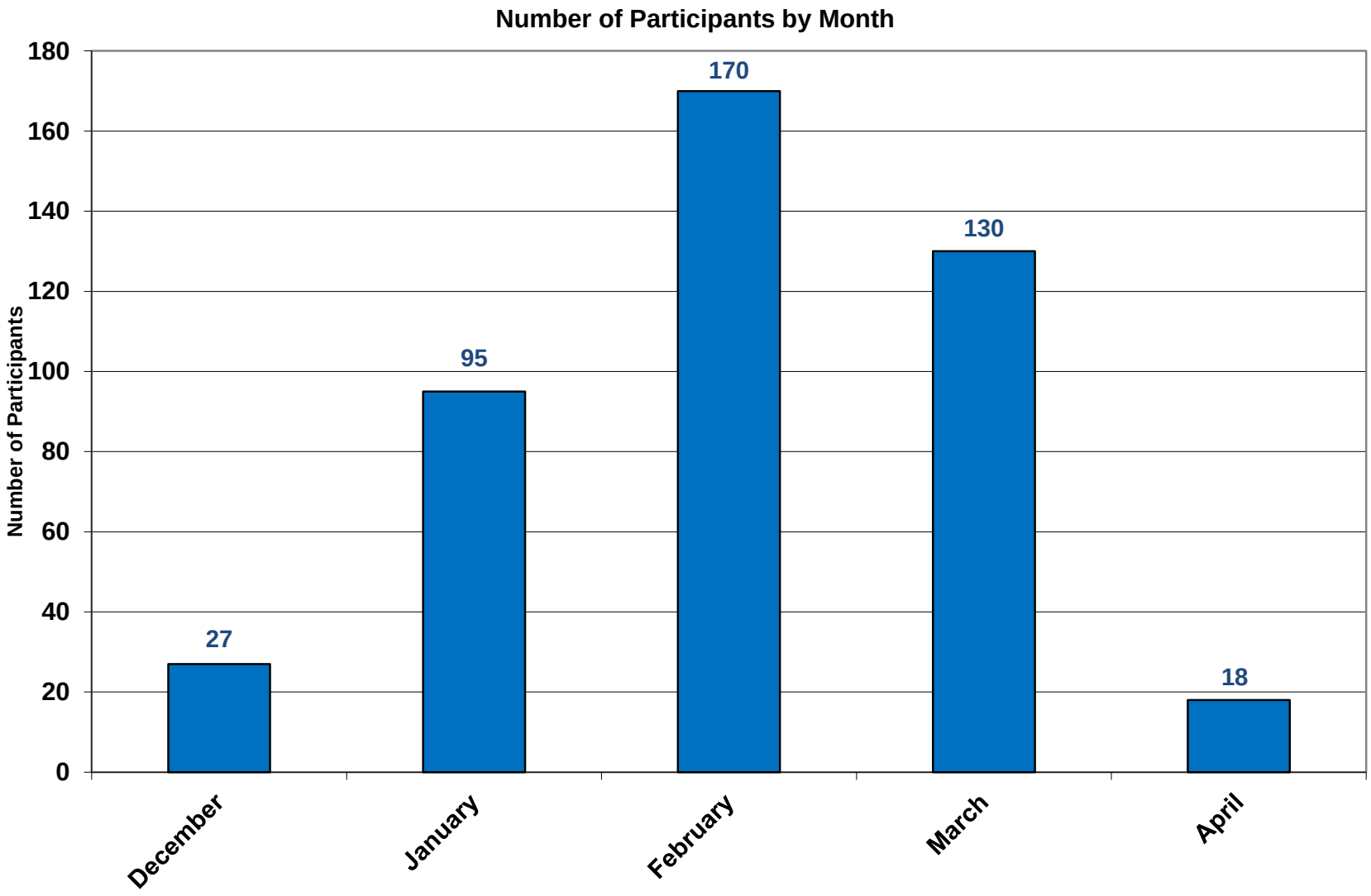


**Figure 16:** Number of participants by month.

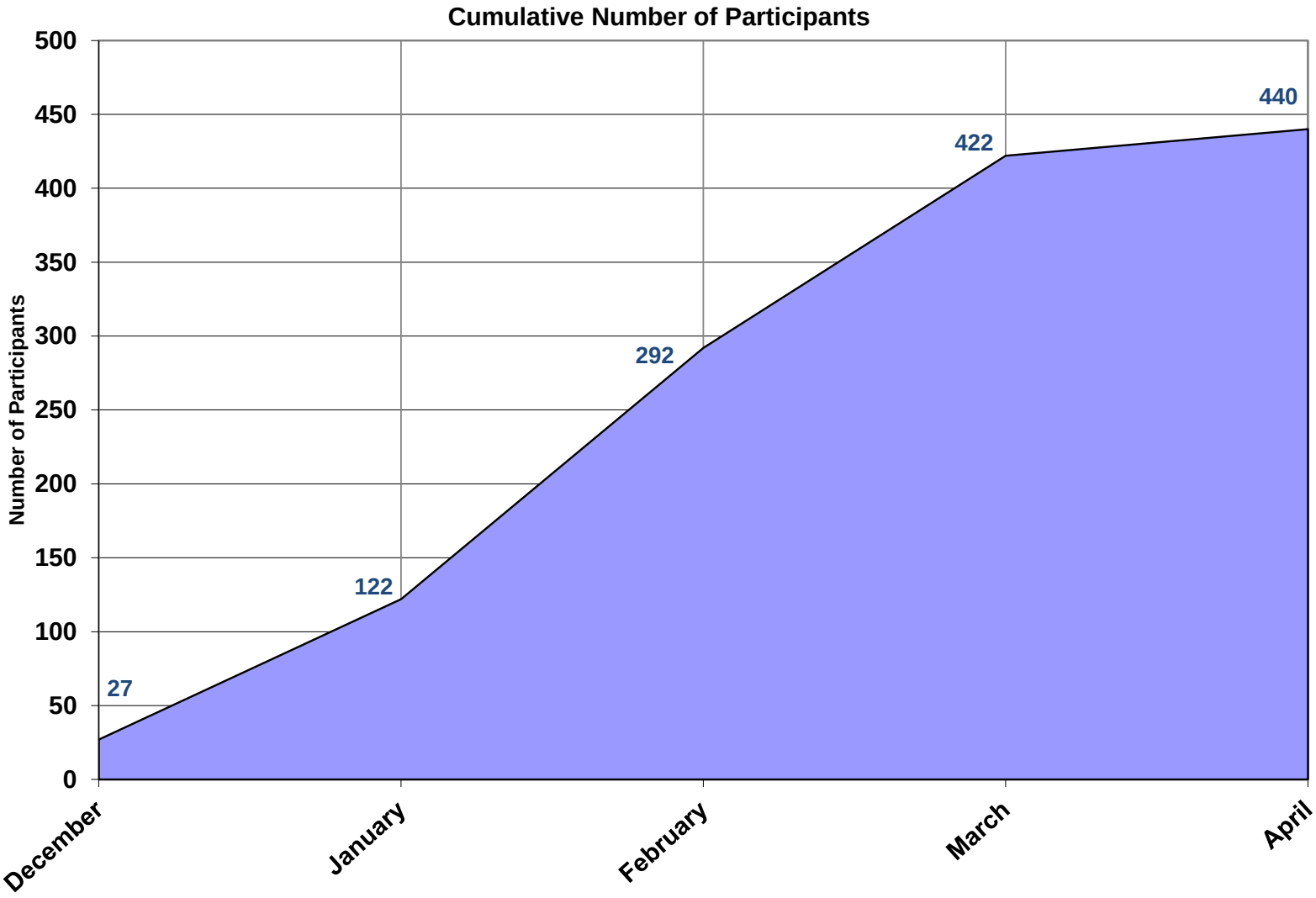


**Figure17:** Cumulative participation.

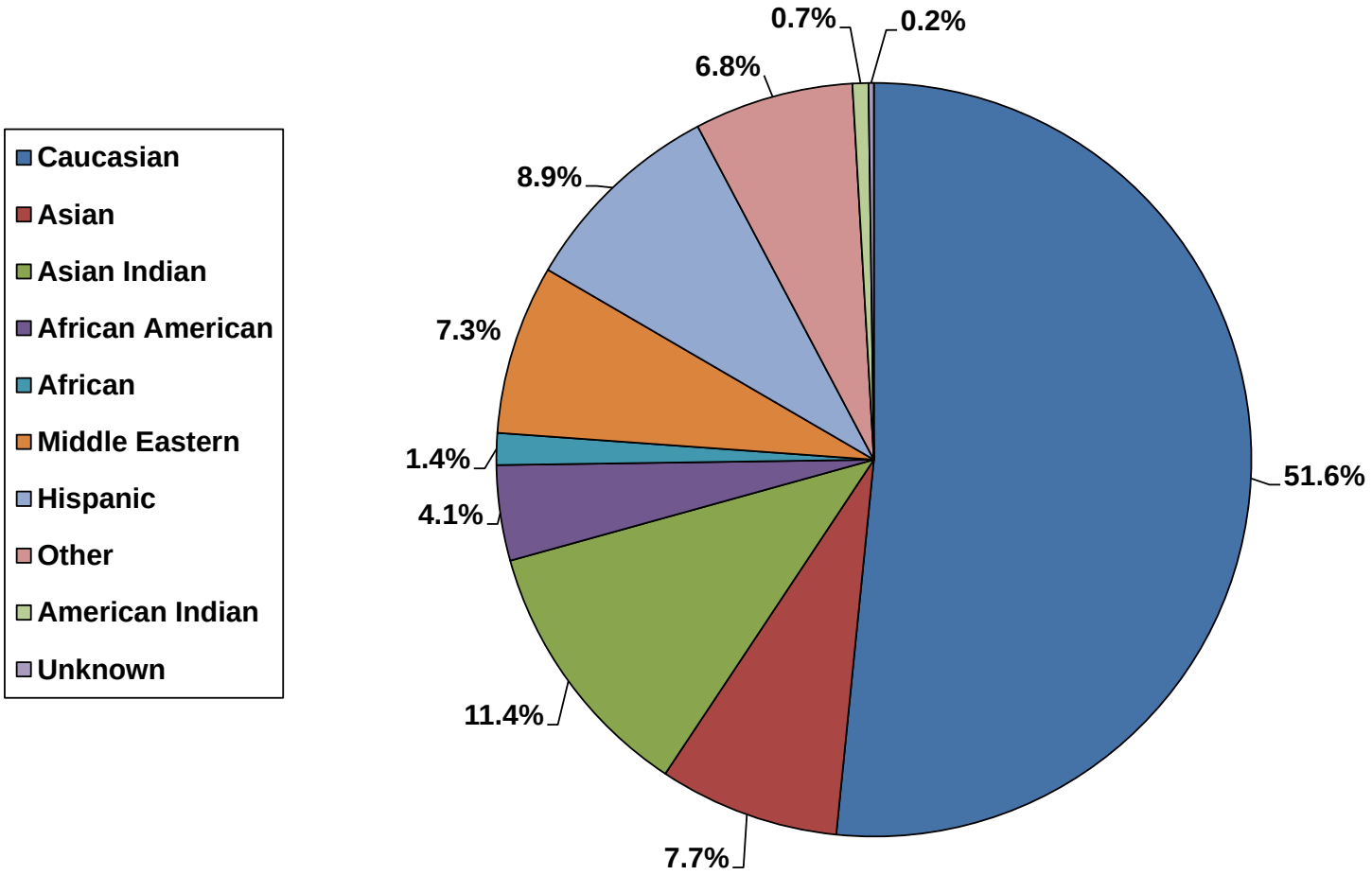


**Figure 18:** Participant ethnicity.

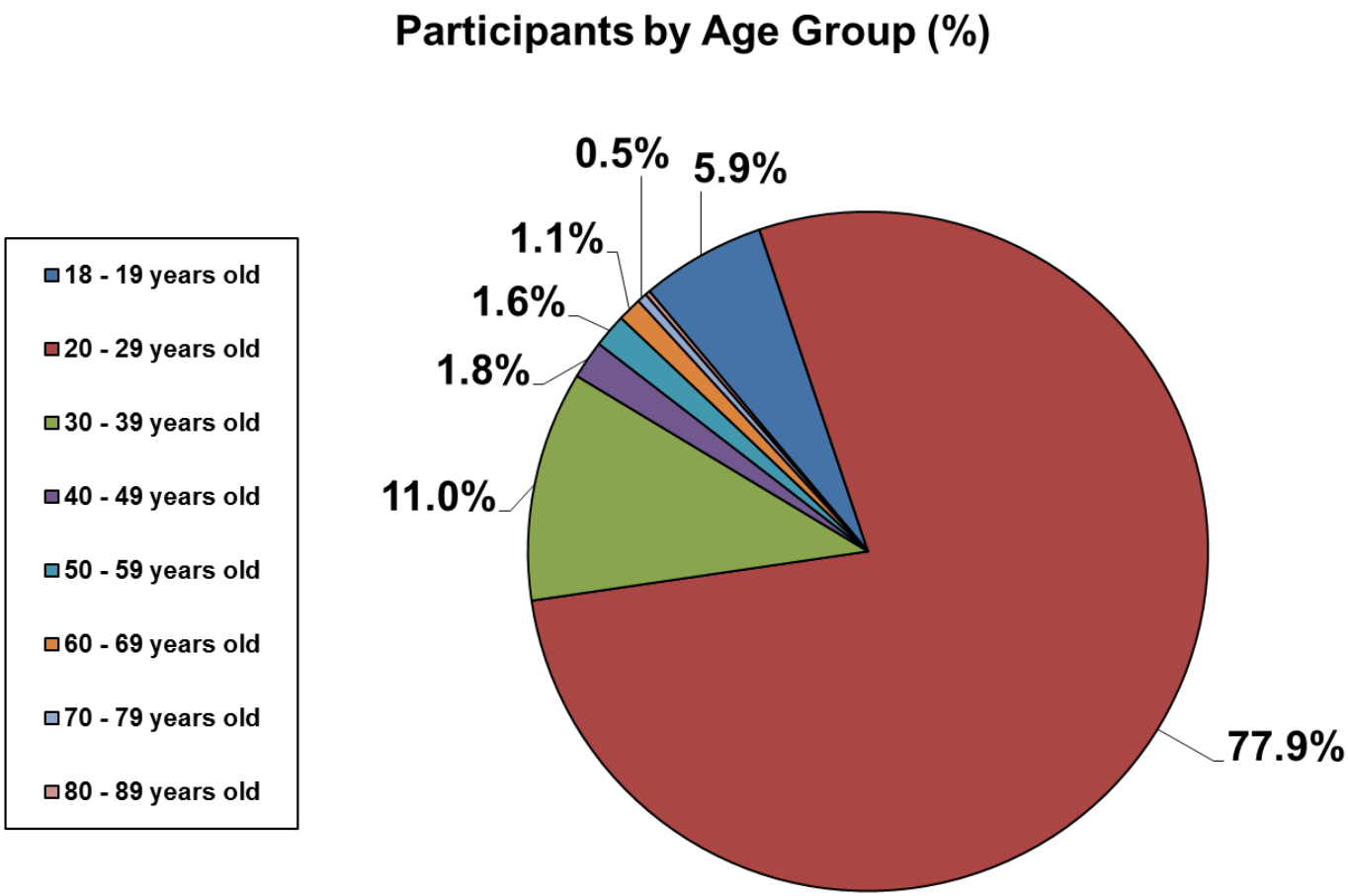


**Figure 19:** Participant age.

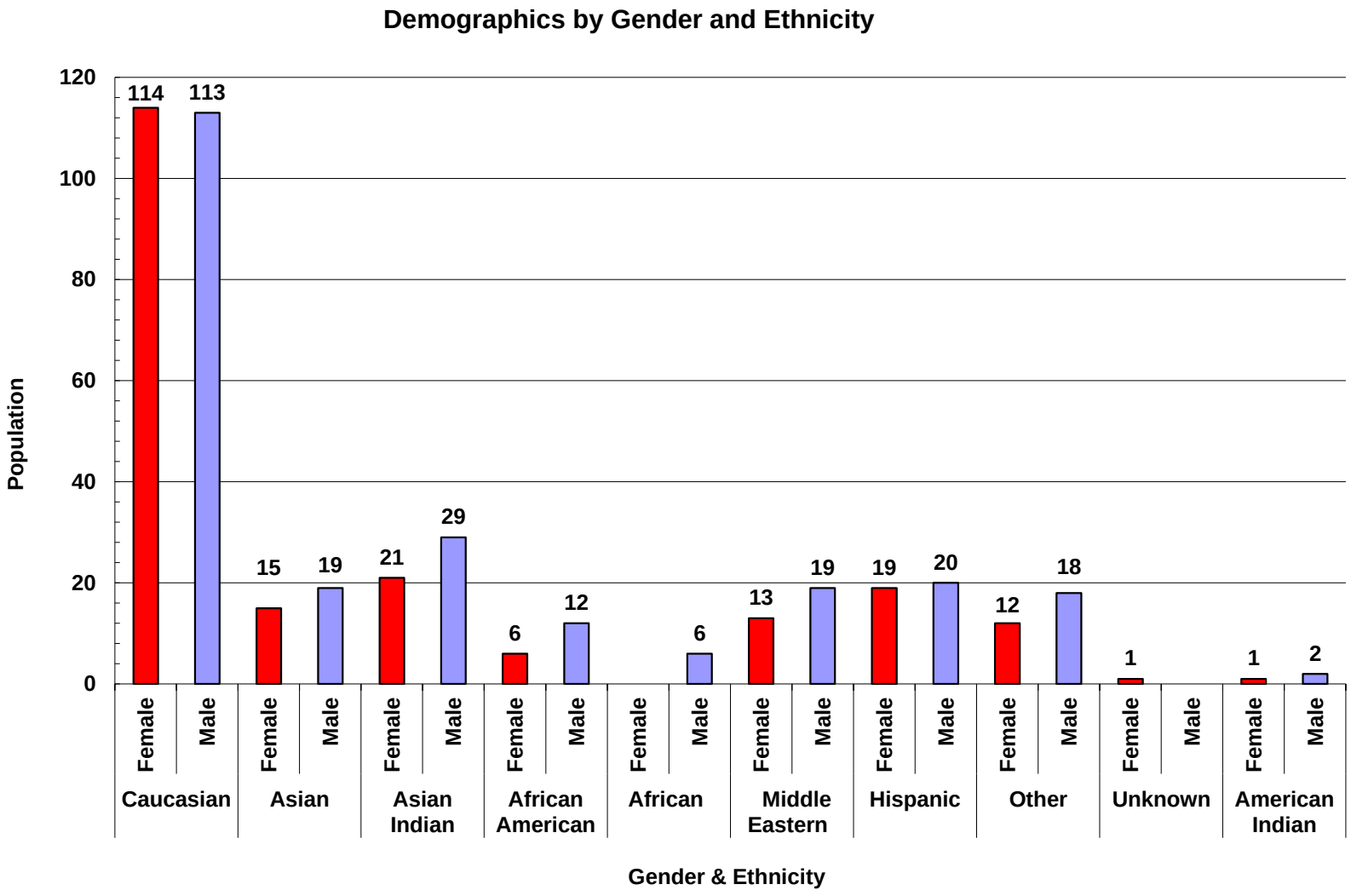


**Figure 20:** Breakdown of gender & ethnicity.

## 4. Device Issues and Operator Feedback

### *4.1 Device Issues*

This section provides a list of issues encountered with the fingerprint devices used in this data collection effort, and, if possible, steps taken to overcome them.

*BioSled:* Individuals who had smaller than average fingers (Usually petite women) found it difficult for the device to register their print well enough to begin capture. The device's battery may only last about 5-7 hours if left unplugged during collection hours. The device would not initialize the Sherlock sensor if the USB charging cable was plugged into the device. This is most likely related to the Android OS rather than the NG software, although it became an inconvenience towards the end of a collection day due to the very limited battery life. The software would sometimes crash without warning and lose a participant's session if not saved. Likewise, if a session is left open and the device goes into rest mode, the session is also lost. Finally, the Sherlock sensor would sometimes not recognize a fingerprint unless the subject or operator "shorted" the conductor bar to the sensor by sliding their finger along the device's edge where the sensor meets the bezel.

*MorphoIDent:* The IDent device has a very hard time capturing the fingerprints of individuals with very dry and/or cracked fingertips. From a lack of clarity in documentation, the MorphoIDent device would only store the fingerprint images in an encrypted file format. With help from the Morpho California office, the problem identified was that the local AFIS server software provided by Morpho was not communicating properly with the device software. Due to this communication issue, over 80% of the fingerprint images captured needed to be reloaded into the MorphoMobile software and decoded by the AFIS server. This was a labor-intensive manual operation, for this data collection. However, the issue is likely due to the device being used in a stand-alone setting and not integrated with an operational AFIS.

*Morpho Finger-On-The-Fly:* Subjects with darker skin tones were much more difficult to capture. For some, multiple re-captures were attempted, and were never of high enough quality to be captured by the device. The sample enrollment software would sometimes crash when several subjects were captured consecutively. The circumstances of the errors were sporadic and the cause was not determined. Subjects with long fingernails would cause distortions to the final image.

*CrossMatch SEEK Avenger:* The 'MOBS' software would sometimes crash unexpectedly when capturing a subject's prints. Upon restarting the system, MOBS would crash on startup, and an error prompt would appear stating that a file was missing or corrupt (Fig. 21). After moving/renaming the file in question, MOBS would then run without issue. This error was very uncommon but happened enough times to warrant mentioning.

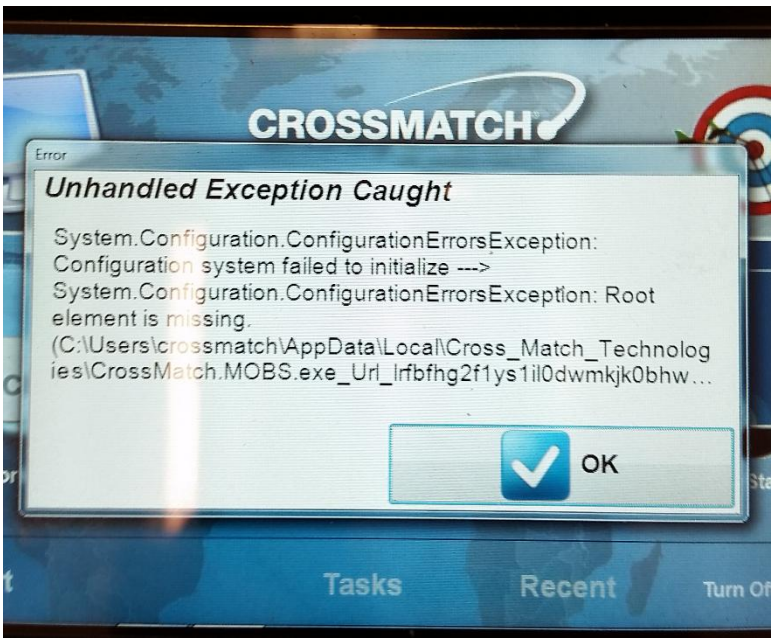


**Figure 21:** CrossMatch SEEK Avenger error message.

*ANDI OTG:* The ANDI system would not capture a participants fingerprints at what seemed to be random intervals. The problem would be more likely to happen if the system had been sitting idle for an extended period of time (3+days). Upon restarting the system, the system would sometimes return to normal operation. However, as the problem persisted, the system would more frequently remain non-responsive. As with the Morpho Finger-On-The-Fly, subjects with long fingernails would cause distortions to the final image.

*InnerID:* The app would sometimes crash, causing a loss of the most recent image captured. Also, the system did not have any form of customized file/subject naming scheme, so the capture pattern for each subject needed to be consistent. In low light settings, it was too difficult for the operator and participant to hold the device and fingers steady enough to capture, resulting in a noisy or poor quality binarized image. This device developed an uncorrectable issue midway through the collection. It was sent back to IDair for repair, but was not returned.

### *4.2 Operator Feedback*

The operators who performed the bulk of the data collection over the project performance period were asked to provide feedback on their experience using the non-contact devices alongside other commercial fingerprint acquisition devices. They were to also comment on how the general public adapted to using the varying types of sensors included in the collection. They provided a written description of their interaction with the various devices during the data collection process. Anonymized, unedited responses from these operators are provided below.

*Operator 1*

> The BioSled software on the Samsung galaxy S4 was one of the more contrary devices. There were instances where the BioSled would randomly not save data. Many times while a participant was rolling their prints, the device timed out, causing us to have to restart the application and losing their data. This sensor would also take bad images if the participant's hands were sweaty.

The Seek Avenger and BioSled were very similar in the how they retrieved the data, since they have the same sensor. However, due to the software differences, the Seek Avenger was one of the most difficult sensors, giving us errors regularly. The four major errors that we received were; “Finger Shifted”, Poor Quality”, “Print Not Wide Enough”, and “Segmentation Error”. This sensor was tricky at times, since it would act as if it were recording the print and as soon as the participant lifted their finger off of the scanner the print would disappear, causing the participant to have to rescan. A nice thing about this device is that it would recognize whether the correct fingers were on the scanner or not. Since this device has the same scanner as the BioSled, this device also didn’t work well with sweaty hands.

The MorphoIDent proved to be very reliable and through the duration of this collection, we didn’t have any issues.

The Finger on the Fly device was one of the operator and participant favorites. It rarely gave problems, except when the participant was of very dark skin color, in this occurrence, the scanner sometimes would not capture their prints.

The Guardian R2 was one of the least user-forgiving devices that we had as it could be very contrary. On occasion this device would take partial rolling print images, each would have to be retaken, causing the operator to manually go into the file and replace the image. To get the replacement image, the operator had to start a whole new session.

The L1 was very user-forgiving and extremely easy to clean. This was also one of the most participant friendly devices, as it made it very easy to retake prints.

The ANDI was very simple and quick to use, we never had any major issues with it. The ANDI did show to have some hardware issues, but those were not due to participant/sensor interaction.

Due to the malfunction of the iPhone 5C we were using with the InnerID software application, we didn’t get to collect quite as much data with it. From the little that we did get to use it, it showed to be a very touchy device. My own experience with the device was rather difficult since I do not have the steadiest of hands, this made it very hard to get a good picture. I had to keep retaking until I received a clear image.

*Operator 2*

In the course of three months and after using both prototypes and newly released products I believe there are advantages and disadvantages with each type of product. Starting with the released products [MorphoIDent, Seek Avenger, Guardian R2, and L-1], some products were more user friendly than others and had seemingly less problems. Released products that were user friendly include: MorphoIDent, Guardian R2 and L-1. These products were easy to operate and volunteer subjects were able to navigate quickly and efficiently through these products. The only issues with Guardian R2 was if a mistake in capturing a fingerprint had occurred, the product would sometimes restart from the beginning as opposed to allowing a single fingerprint to be recaptured. Following up with user friendly released products, a released product that was not user friendly was Seek Avenger. One of the major issues with Seek Avenger was the product rejecting fingerprints of good quality along with its inability to capture fingerprints even with pressure on both the finger bar and fingerprint pad.

The prototype products [InnerID, BioSled, Finger on the Fly, and ANDI], like the released products, had both its advantages and disadvantages. Easy to operate and user friendly prototype products includes InnerID and ANDI along with the previously stated Finger on the Fly. The ANDI system, aside from Finger on the Fly and MorphoIDent, was probably the easiest product to use along with the most user friendly. The only prototype product that had its disadvantages was BioSled. BioSled would constantly stop its function and would have to be restarted and after performing this task it would still have a tendency to not restart function. Another issue was its inability to capture fingerprints on occasion which required the operator to move ahead to next finger(s) and refer back to the previous, uncaptured finger(s). Unlike Seek Avenger, this was easier to capture fingerprints when function was in working order and allowed the operator to review fingerprints and recapture if necessary. As expected when working with both the released and prototype products, there were advantages and disadvantages which would be expected but overall these products, once corrections could be made, would be beneficial in both the public and private sector.

*Operator 3*

ANDI: The ANDI was easy for both the operator and participants to use. At times it would not capture all the prints as participants would separate their fingers too much or not have enough separation for the software to differentiate the fingers. Every once in a while ANDI would stop capturing images or the flash would stop firing.

GUARDIAN: The Guardian was easy to for the participants to use. It was more difficult to recapture a print if the software thought it was acceptable, as you had to create a temp folder and do another session to get the print needed.

L1: The L1 was easy for both the operator and participant to use. Compared to the guardian it is was a lot easier to recapture a print if needed.

Finger on the Fly: Finger on the Fly had difficulty capturing prints from people with dark skin. Also, if they swiped their hand in a diagonal motion or changed the speed they moved their hand over the sensor while capturing. At times I noticed that it saved the left hand prints in the right hand format.

Seek Avenger: The Seek Avenger was easy for the operator to use as it checked for errors in the participants prints as they rolled their fingers. The participants had difficulty with the sensor as they would lift their finger up mid roll or didn't have a large enough surface area to start the capture.

BioSled: The BioSled was difficult for both the operator and participant. Farley, often the sensor would not detect the participant's fingers on the sensor and we had to rub the bar with our finger to get it to capture. Also, it would still capture the participants' prints even if they were incomplete due to them lifting their finger off the bar mid roll.

MorphoIDent: The MorphoIDent was easy for both the operator and participant to use.

InnerID: The participants had difficulty keeping their hand steady to capture a clear print. It was also hard to keep the phone steady to get a clear print. It appeared at times that the camera went out of focus right before it captured the participant's prints.

*Operator 4*

While I did not participate in the ManTech fingerprint project to a great extent, I still had the opportunity to operate most of the machines, including ANDI, MorphoIDent, Seek Avenger, BioSled, Finger on the Fly, and Guardian R2. I found most of these sensors easy to learn, however, I feel that certain improvements can be made on them.

Some of the sensors were very sensitive to movement. For example, the Seek Avenger often gave a "sequence error" or sensed that the finger was shifted while being rolled. This was beneficial to an extent, however, these errors would sometimes show up when the fingerprint seemed to be completely fine. In addition to this, the sensor would occasionally not register a participant's fingerprint, but this could be easily fixed by moving a finger along the bottom of the sensor, as well as ensuring that the participant's finger was always in contact with the bottom of the sensor. Aside from this, I felt that the Seek Avenger was easy to operate and produced high quality fingerprints.

On several of the sensors, saving the data or retaking a fingerprint seemed to be inefficient. Some of the sensors did not have an option to retake a fingerprint, so after the set of fingerprints was finished, a temporary folder had to be created so that the image could be retaken, placed in this folder, and copied into the original folder. The original fingerprint that had to be retaken was then deleted from the folder, and the temporary folder was deleted. Having an option to retake a fingerprint either right after it is taken or after all of the fingerprints have been completed would make for a quicker process.

One other small problem that I believe could be improved upon is allowing the MorphoIDent to charge while being used. In addition, the ANDI prototype would occasionally have completely black images show up rather than the participant's fingerprints. I think that improvements such as those listed above would produce a quicker, more efficient fingerprint collection.

*Operator 5*

Working with the prototypes and the released instruments, I noticed that some were much easier to use than others. To begin with, the released products: MorphoIDent, Seek Avenger, Finger on the Fly, Guardian R2, and the L-1 were all relatively easy to work with aside from the Seek Avenger. The Seek Avenger had difficulty taking prints even when they were of excellent quality. I also experienced multiple times where the instrument would shut down, the screen would turn upside down, or it would say "poor quality" when the print was excellent. The Finger on the Fly only had problems when the participants skin color was "too dark" otherwise there were no other major problems with the Finger on the Fly. It was very user friendly. The Guardian R2 also worked wonderfully 99% of the time and was very user friendly. The only problems I experienced was when the cable connecting the instrument to the laptop was touched the program would shut down and have to be restarted. I experienced no technical problems with the MorphoIDent or the L-1 thereby making them the best-released product strictly going off of technical problems and user friendliness.

The prototypes: InnerID, BioSled, and ANDI also varied for user friendliness. The innerID was easy to use, if you had steady hands. If your hands were not steady than you had to retake photos multiple times and then go back into the photo album to delete the bad photos. The BioSled had the most technical problems out of all of the instruments. The BioSled took any print whether it was good or bad which was helpful because some participants had wrinkly hands or scars and the other instruments would deny the print multiple times. It was also bad because participants with sweaty hands or those who rushed the roll had to redo the print multiple times and it would not recognize that the prints were bad. The ANDI was the easiest of the prototypes to use because participants could just walk through it. The only problem I encountered was if a participant did not hold their pinky up high enough or did not separate their fingers it would miss some of their fingers.

The qualities of the prints were good on the ANDI, L-1, MorphoIDent, Guardian R2, Finger on the Fly, and InnerID consistently. The Finger on the Fly had problems catching the edges of the print but with some work I believe that the Finger on the Fly can have the quality and quantity that the ten prints have. On the other hand, the BioSled and the Seek Avenger need work on the sensor. They do not adequately capture participants with sweaty hands and depending on where the sensor is to be used that may need to be addressed.

*Operator 6*

The commercial devices used in this study, including the MorphoIDent, Seek Avenger, L-1, Guardian R2, and Finger on the Fly, all worked very well, except for the Seek Avenger. The seek avenger would repeatedly crash in the middle of a collection. Occasionally restarting the program would fix it, but other times we were forced to skip over it while it was being repaired. Not only did it shut down regularly, but the scanner would often times reject full rolled prints that seemed to be of good or excellent quality and there would be no explanation as to why. Also, the Avenger would say there was a "Sequence Error" even when the correct fingers were placed on the scanner. Finger on the Fly was a great piece of equipment and hardly ever had any problems. It was very user friendly and was by far the fastest off all collection devices we studied. One of the only problems I experienced was that participants with darker skin tones would have a difficult time with the Finger on the Fly. The device would reject those fingers and force us to repeat the collection several times. MorphoIDent was by far the most user friendly of the devices. In my experiences with it, the device never had any technical difficulties and was very easy to handle. The Guardian R2 was also very user friendly, although there were several times when the device would shut down in the middle of a collection due to certain error codes. Usually, once I restarted the program, it continued to work just fine. The L-1 was a personal favorite and took very high quality prints. The program is very user friendly and never crashed while I was using it. The only problem I noticed with the device was that if the participant's hands were very sweaty, the prints would be very light in color and more difficult to examine.

The prototypes, including the InnerID, BioSled, and ANDI, were also very user friendly. The ANDI was extremely impressive and requires little effort from either the participant or operator. I would estimate about 90% of the time the ANDI captured all four finger of the participant on the first trial. The majority of trials where the ANDI did not capture a finger was due to the participant bumping into the cutout or holding their fingers too close together. Even though InnerID only worked for about half of the collection, I thought it was a very user friendly and simple device. It certainly requires a steady hand and proper

lighting, but it was very quick and being able to see the picture I took before moving on was very beneficial. The BioSled was not as user friendly as the other prototypes. The BioSled would crash occasionally and required a hard restart of the device before continuing. Also, when attempting to recapture prints of poor quality, the screen would sometimes not show the newly captured fingerprint and would instead still show the poor quality print.

Overall I think all of these products have the potential to be very useful in the private and public sectors. All of the devices have the ability to capture very high quality prints when operated by well-trained personnel.