Neurotechnology+0001

Neurotechnology

Proprietary Fingerprint Template (PFT) Evaluation III

Last Updated: 09 December 2019

Contents

1 Participation Information

1.1 Names

Information in this section is provided by the participant.

- **Participant Name:** Neurotechnology
- **PFT III Identifier:** `Neurotechnology+0001`
- **Feature Extractor:**
  - **Marketing Name:** MegaMatcher
  - **CBEFF Product Owner:** `0x0031`
  - **CBEFF Algorithm Identifier:** `0x0100`
- **Template Matcher:**
  - **Marketing Name:** MegaMatcher
  - **CBEFF Product Owner:** `0x0031`
  - **CBEFF Algorithm Identifier:** `0x0100`

1.2 Dates

- **Application Date:** 07 November 2019
- **First Submission Date:** 21 November 2019 (as version `0000`)
- **Final Submission Date:** 03 December 2019 (as version `0001`)
- **Validation Date:** 03 December 2019
- **Completion Date:** 09 December 2019

1.3 Libraries

Testing completed using CentOS Linux release 8.0.1905 (Core).

Table 1: Information regarding library and configuration files provided as part of `Neurotechnology+0001`.

Filename	MD5 Checksum	Size
libpftiii_Neurotechnology_0001.so	`cf499ef6e8bfad3c4d62021329001c48`	10.2 Mb
libmkl_tiny.so	`78499860662633254ebdff4168be8b60`	24 Mb
libiomp5.so	`2de0b9ab4a5b58d0174de20891b78775`	2 Mb
Fingers.ndf	`757e46ce629f299ec80e0e9ec3c78ce0`	7.6 Mb

2 Timing Sample Dataset

A fixed sample of images randomly selected from the PFT III datasets are used to assess whether or not an implementation adheres to the minimum timing requirements set forth in the PFT III test plan. This sample is also used to provide an estimate on template size. The images and comparisons are identical to the "1K Sample Evaluation" from NIST's PFT II evaluation, with the exception of the "IARPA N2N" dataset, which is new in PFT III. Table 2 shows information about the maximum dimensions and resolutions of the images in each of the timing sample datasets.

Table 2: Maximum dimensions in pixels and capture resolution in pixels per inch (PPI) for the images in each of the subsets comprising the timing sample dataset.

	AZ	LA County	DHS 2	POE+BVA	IARPA N2N
Max Dimensions (pixels)	800 x 800	412 x 1 000	368 x 368	500 x 500	1 600 x 1 500
Resolution (PPI)	500	500	500	500	1 000

2.1 Template Size

Figure 1 and Table 3 show the distribution of file sizes of templates. Failures of any kind reported during template generation result in NIST code writing 0 byte files. These files are excluded from the template size analysis in this section.

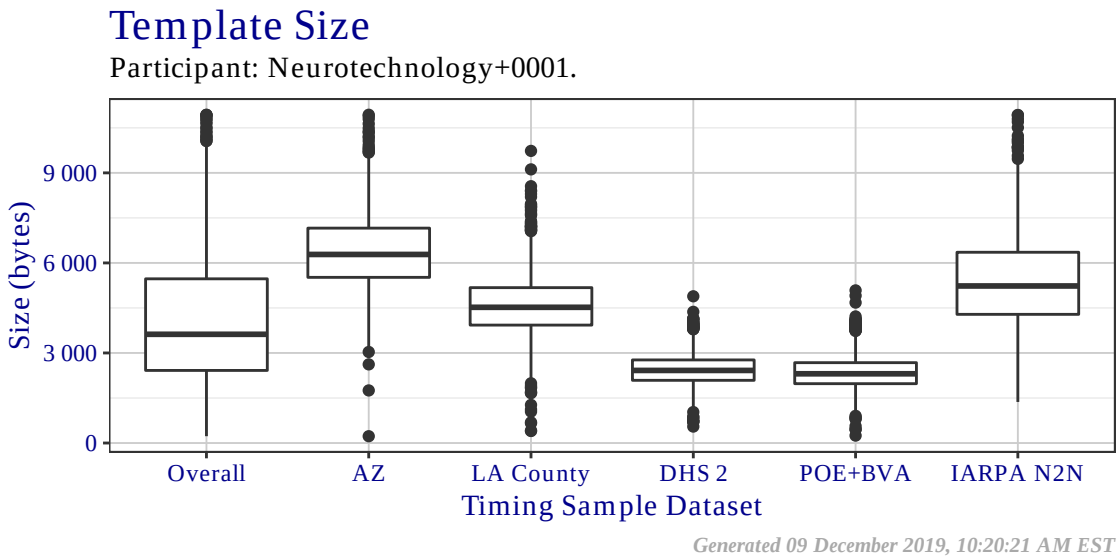

Figure 1: Box plots of template sizes in bytes of templates created from a fixed sample of data from the PFT III evaluation. An overall plot is shown, as well as individual plots per data origin. Tabular versions of this data are shown in Table 3.

Table 3: Sizes in bytes of templates created from a fixed sample of data from the PFT III evaluation. The bottom row, *Failures*, shows the number of failures to create a template, which are not included in these statistics. Box plots of this data are shown in Figure 1.

	Overall	AZ	LA County	DHS 2	POE+BVA	IARPA N2N
Min	**227**	227	402	549	248	1 368
25 %	**2 418**	5 519	3 928	2 089	1 977	4 287
Median	**3 622**	6 282	4 521	2 418	2 306	5 232
Mean	**4 045**	6 351	4 574	2 439	2 348	5 455
75 %	**5 470**	7 158	5 176	2 768	2 677	6 355
Max	**10 937**	10 937	9 733	4 889	5 085	10 930
Failures	**0**	0	0	0	0	0

2.2 Template Creation Time

Figure 2 and Table 4 show the distribution of durations of time consumed when creating templates. Failures of all kinds are incorporated into these statistics, since this time would be observed by the end user of a template creation algorithm.

Times are measured by running a single process on an isolated compute node equipped with an Intel Gold 6140 CPU.

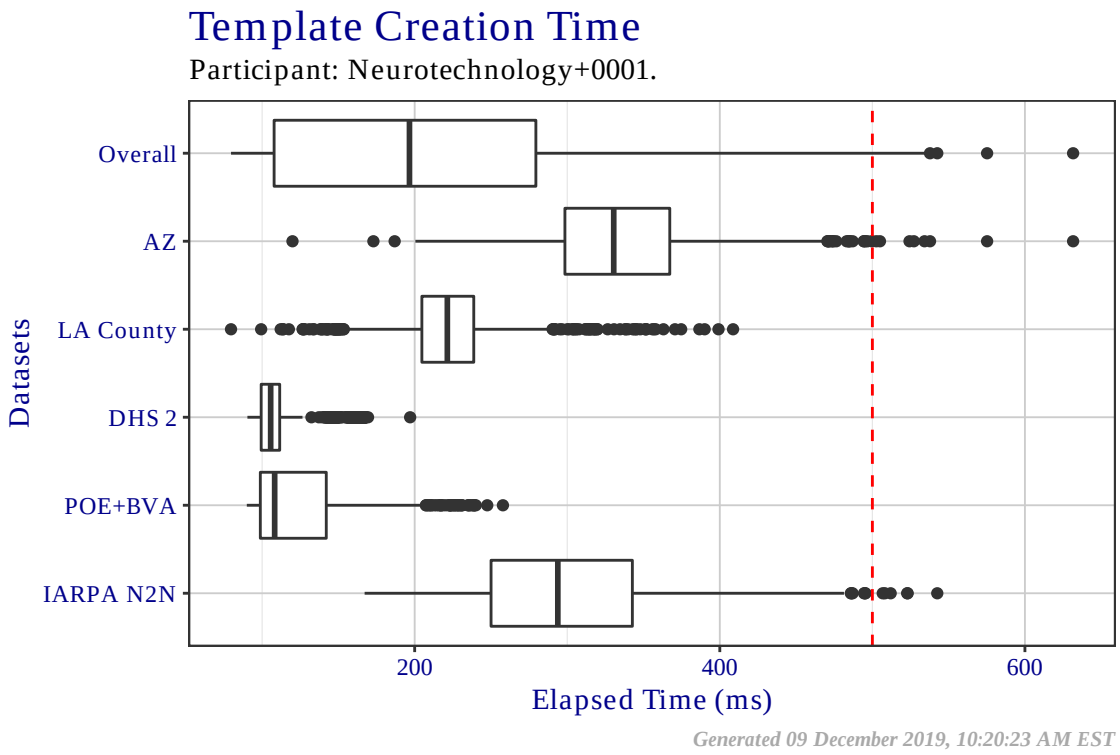

Figure 2: Box plots of elapsed milliseconds when creating templates from a fixed sample of data from the PFT III evaluation. All times are used, even if a failure occurred. Tabular versions of this data are shown in Table 4.

Table 4: Elapsed milliseconds when creating templates from a fixed sample of data from the PFT III evaluation. All times are used, even if a failure occurred. The bottom row, *Failures*, shows the number of failures to generate a template. Failures *are* included in these statistics. Box plots of this data are shown in Figure 2.

	Overall	AZ	LA County	DHS 2	POE+BVA	IARPA N2N
Min	**79.6**	119.9	79.6	90.4	90.0	167.2
25 %	**107.8**	298.5	204.7	99.4	98.8	250.1
Median	**196.6**	330.5	221.4	105.6	108.2	293.8
Mean	**204.0**	334.4	220.7	108.4	120.2	300.9
75 %	**279.4**	367.2	238.7	111.5	142.0	342.7
Max	**631.6**	631.6	408.7	197.0	257.8	542.5
Failures	**0**	0	0	0	0	0

2.3 Template Comparison Time

Figure 3 and Table 5 show the distribution of durations of time consumed when comparing templates. Failures of any kind are incorporated into these statistics, since this time would be observed by the end user of a template comparison algorithm.

Times are measured by running a single process on an isolated compute node equipped with an Intel Gold 6140 CPU.

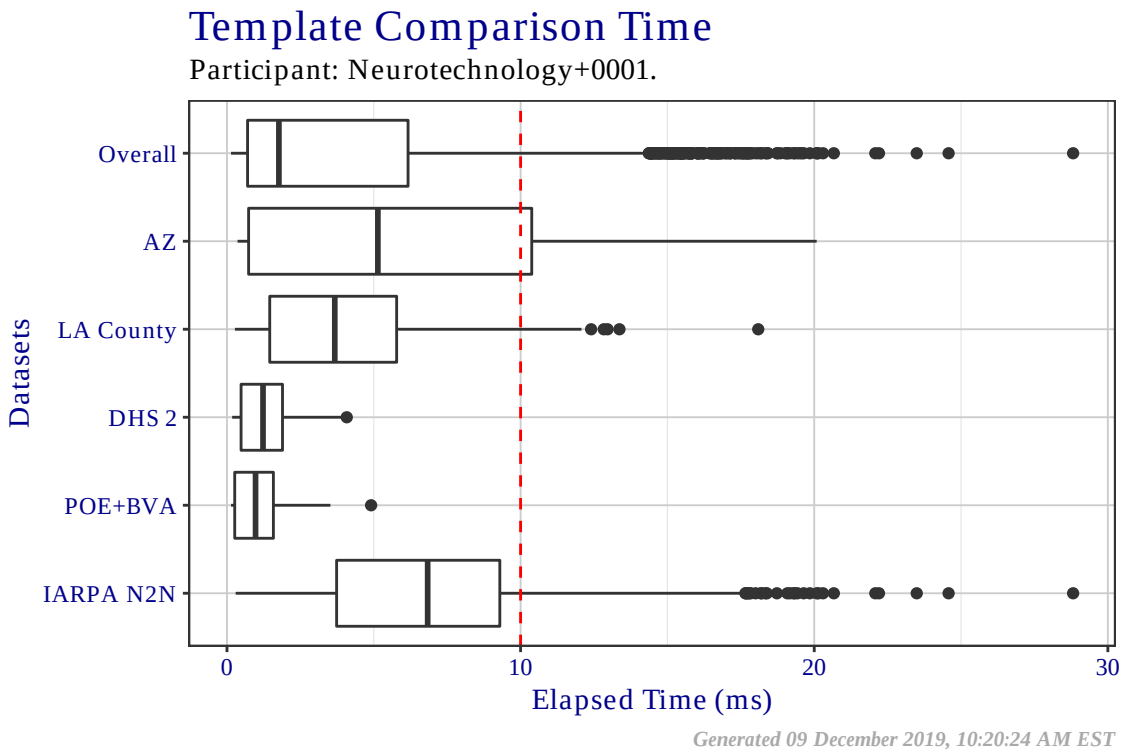

Figure 3: Box plots of elapsed milliseconds when comparing two templates from a fixed sample of data from the PFT III evaluation. All times are used, even if a failure occurred. Tabular versions of this data are shown in Table 5.

Table 5: Elapsed milliseconds when comparing two templates from a fixed sample of data from the PFT III evaluation. The bottom row, *Failures*, shows the number of failures to compare. Failures *are* included in these statistics. Box plots of this data are shown in Figure 5.

	Overall	AZ	LA County	DHS 2	POE+BVA	IARPA N2N
Min	**0.1**	0.4	0.3	0.2	0.1	0.3
25 %	**0.7**	0.7	1.5	0.5	0.3	3.7
Median	**1.8**	5.1	3.7	1.2	1.0	6.8
Mean	**3.7**	5.8	3.8	1.2	1.0	6.8
75 %	**6.2**	10.4	5.8	1.9	1.6	9.3
Max	**28.8**	20.1	18.1	4.1	4.9	28.8
Failures	**0**	0	0	0	0	0

3 PFT III Datasets

Although large tests, both PFT and PFT II only used *subsets* of data available from the Arizona Department of Public Safety, the Los Angeles County Sheriff's Department, and the Department of Homeland Security. For PFT III, NIST is using new subject comparisons from each of these datasets. Additionally, PFT III adds comparisons of public and sequestered data collected as part of the Intelligence Advanced Research Project Activity (IARPA)'s Nail-to-Nail (N2N) Challenge.

Table 6: False non-match rate values at specific false match rates for all comparisons from all fingers in the PFT III AZDPS dataset

FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
0.007	0.0054	0.0037

3.1 Arizona Department of Public Safety

The Arizona Department of Public Safety (AZDPS) dataset consists of plain and rolled impressions of all ten fingers. Figure 4 and Table 6 show the detection error tradeoff (DET) curves of all fingers not compared in other PFT tests. This data is separated by finger position in Figure 5 and Table 7 and again by impression type in Figure 6 and Table 8. Values made by combinations of fingers were generated by summing the individual similarity scores for comparisons of the individual finger and dividing by the number of values added. This technique is known as *sum fusion*.

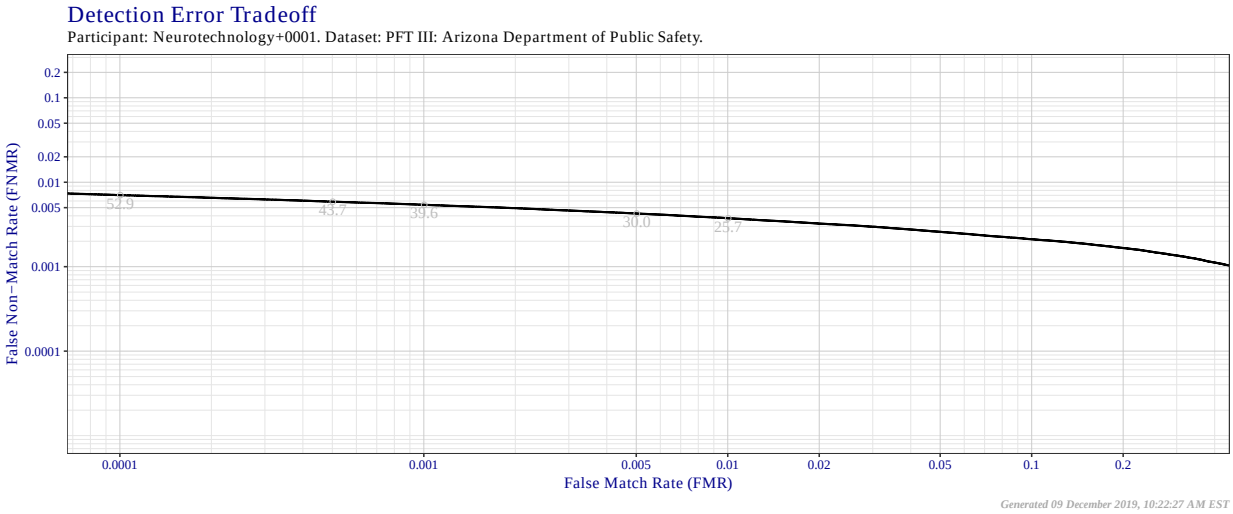

Figure 4: Detection error tradeoff of all comparisons from all fingers in the PFT III AZDPS dataset. Numbers in gray indicate the similarity threshold.

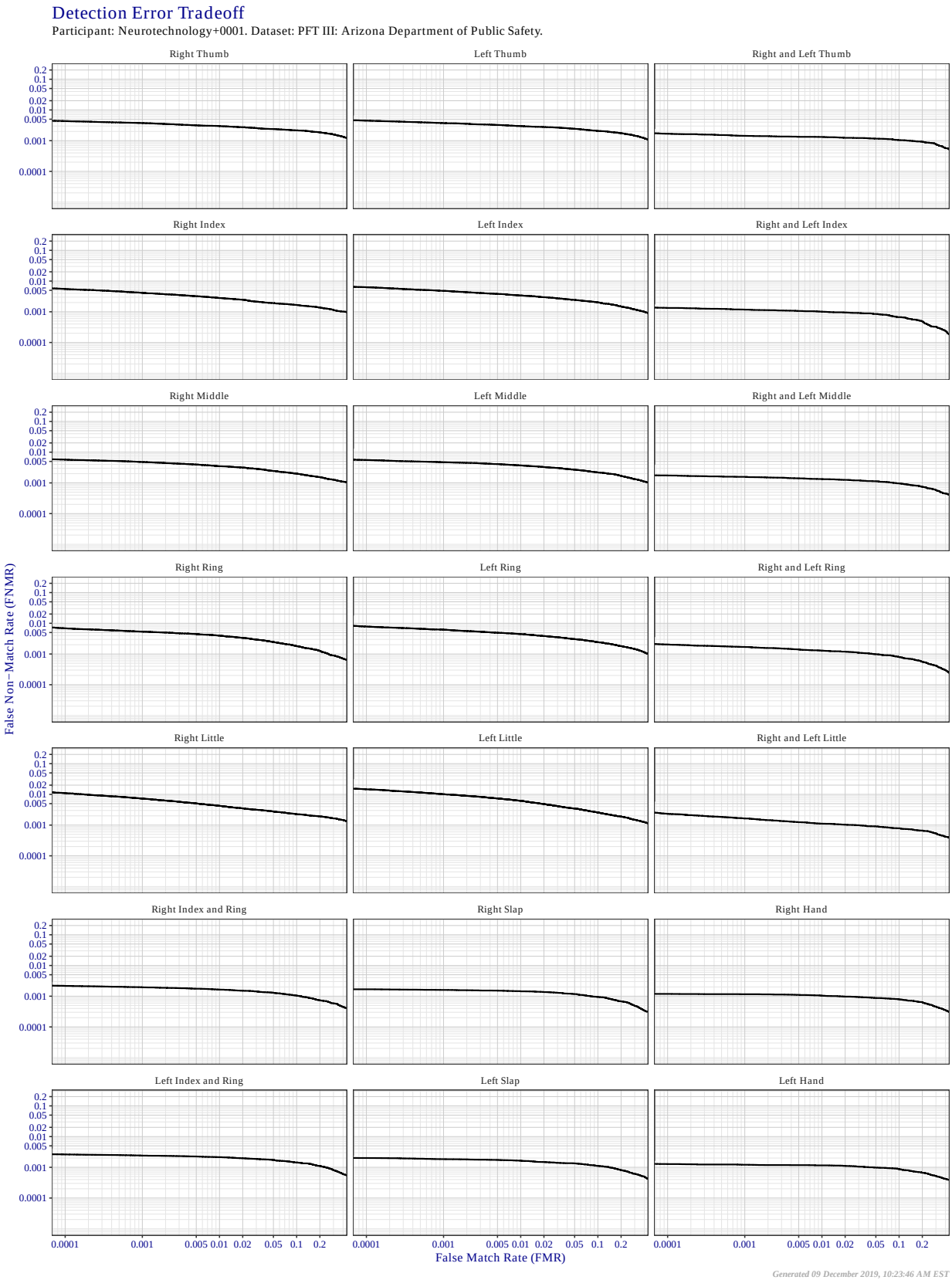

Figure 5: Detection error tradeoff of all comparisons from all fingers in the PFT III AZDPS dataset, separated by finger position. Combined finger positions were generated by sum fusion.

Table 7: False non-match rate values at specific false match rates for all comparisons from all fingers in the PFT III AZDPS dataset, separated by finger position. Combined finger positions were generated by sum fusion.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
R Thumb	0.0043	0.0037	0.0030
R Index	0.0055	0.0041	0.0028
R Middle	0.0057	0.0048	0.0035
R Ring	0.0069	0.0053	0.0040
R Little	0.0110	0.0073	0.0043
L Thumb	0.0045	0.0037	0.0030
L Index	0.0063	0.0048	0.0034
L Middle	0.0056	0.0047	0.0037
L Ring	0.0078	0.0062	0.0044
L Little	0.0146	0.0101	0.0062
R & L Thumb	0.0017	0.0014	0.0013
R & L Index	0.0013	0.0012	0.0010
R & L Middle	0.0018	0.0016	0.0013
R & L Ring	0.0020	0.0017	0.0013
R & L Little	0.0023	0.0016	0.0011
R Index & Ring	0.0022	0.0020	0.0016
L Index & Ring	0.0026	0.0024	0.0021
R Slap	0.0017	0.0016	0.0014
L Slap	0.0020	0.0018	0.0016
R Hand	0.0012	0.0012	0.0010
L Hand	0.0013	0.0012	0.0012

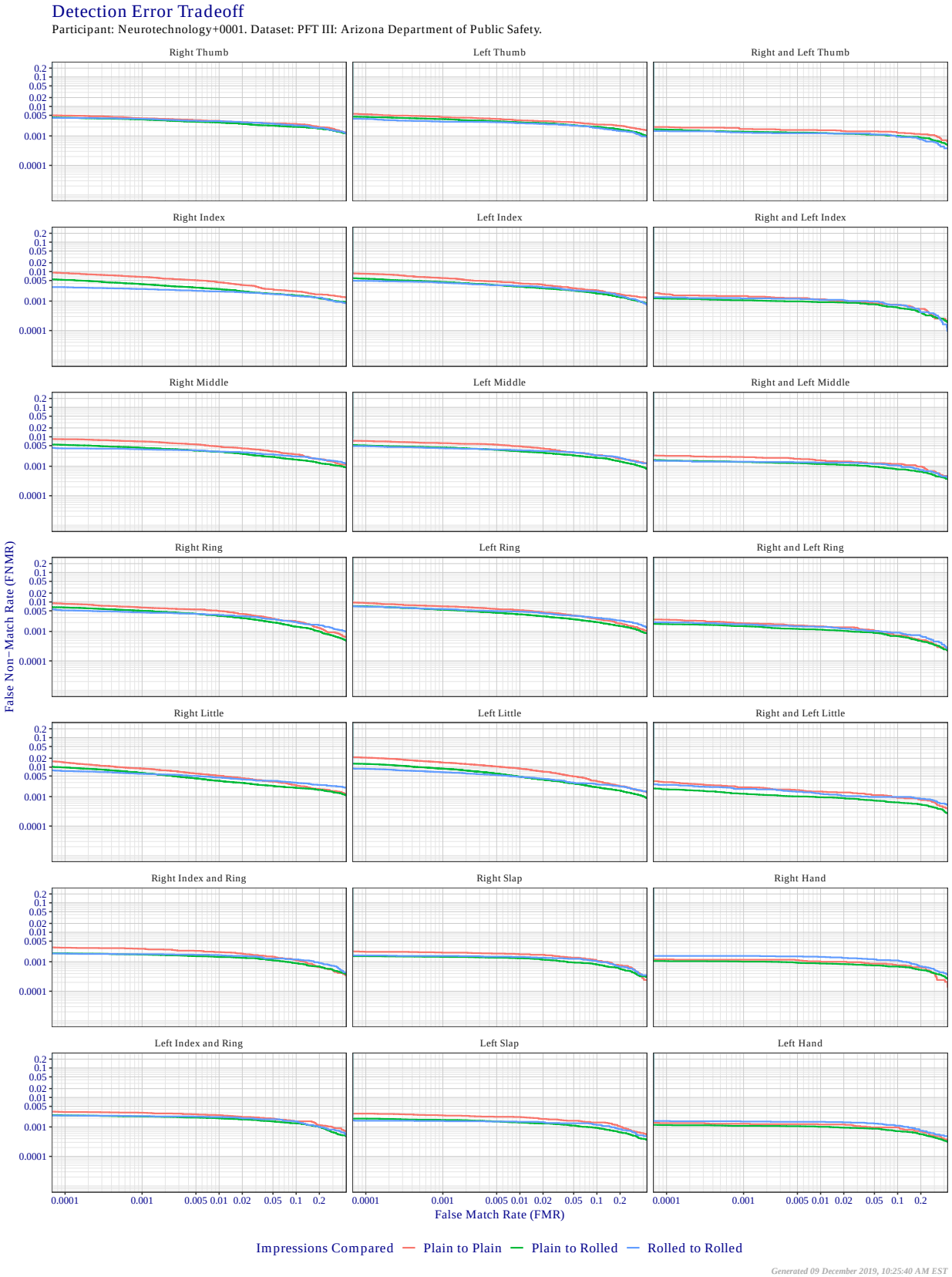

Figure 6: Detection error tradeoff of all comparisons from all fingers in the PFT III AZDPS dataset, separated by finger position and impression type. Combined finger positions were generated by sum fusion.

Table 8: False non-match rate values at specific false match rates for all comparisons from all fingers in the PFT III AZDPS dataset, separated by finger position and impression type. Combined finger positions were generated by sum fusion.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
Plain to Plain			
R Thumb	0.0049	0.0040	0.0033
R Index	0.0089	0.0066	0.0043
R Middle	0.0082	0.0070	0.0047
R Ring	0.0087	0.0065	0.0049
R Little	0.0146	0.0090	0.0051
L Thumb	0.0054	0.0043	0.0034
L Index	0.0085	0.0060	0.0040
L Middle	0.0072	0.0061	0.0048
L Ring	0.0092	0.0071	0.0052
L Little	0.0211	0.0143	0.0090
R & L Thumb	0.0020	0.0017	0.0016
R & L Index	0.0017	0.0015	0.0012
R & L Middle	0.0023	0.0021	0.0016
R & L Ring	0.0025	0.0019	0.0015
R & L Little	0.0031	0.0021	0.0015
R Index & Ring	0.0030	0.0028	0.0021
L Index & Ring	0.0032	0.0030	0.0025
R Slap	0.0022	0.0020	0.0018
L Slap	0.0028	0.0025	0.0022
R Hand	0.0012	0.0012	0.0010
L Hand	0.0013	0.0013	0.0012
Plain to Rolled			
R Thumb	0.0042	0.0036	0.0029
R Index	0.0053	0.0038	0.0026
R Middle	0.0053	0.0042	0.0031
R Ring	0.0065	0.0050	0.0034
R Little	0.0098	0.0063	0.0034
L Thumb	0.0044	0.0037	0.0029
L Index	0.0058	0.0044	0.0031
L Middle	0.0051	0.0043	0.0032
L Ring	0.0071	0.0055	0.0038
L Little	0.0129	0.0089	0.0047
R & L Thumb	0.0016	0.0014	0.0013
R & L Index	0.0012	0.0011	0.0009
R & L Middle	0.0016	0.0014	0.0012
R & L Ring	0.0018	0.0015	0.0012
R & L Little	0.0018	0.0013	0.0009
R Index & Ring	0.0019	0.0017	0.0014
L Index & Ring	0.0025	0.0023	0.0020
R Slap	0.0015	0.0015	0.0013
L Slap	0.0019	0.0017	0.0014
R Hand	0.0011	0.0010	0.0009
L Hand	0.0012	0.0011	0.0010
R Thumb	0.0041	0.0038	0.0032
Rolled to Rolled			
R Index	0.0030	0.0026	0.0021

R Middle	0.0040	0.0038	0.0032
R Ring	0.0052	0.0044	0.0036
R Little	0.0073	0.0059	0.0044
L Thumb	0.0038	0.0030	0.0027
L Index	0.0049	0.0042	0.0032
L Middle	0.0048	0.0041	0.0035
L Ring	0.0070	0.0057	0.0047
L Little	0.0088	0.0067	0.0047
R & L Thumb	0.0015	0.0013	0.0012
R & L Index	0.0014	0.0012	0.0011
R & L Middle	0.0015	0.0014	0.0013
R & L Ring	0.0020	0.0018	0.0014
R & L Little	0.0025	0.0018	0.0012
R Index & Ring	0.0019	0.0018	0.0017
L Index & Ring	0.0024	0.0023	0.0022
R Slap	0.0016	0.0016	0.0015
L Slap	0.0016	0.0016	0.0015
R Hand	0.0016	0.0016	0.0015
L Hand	0.0016	0.0015	0.0015

Table 9: False non-match rate values at specific false match rates for the PFT III Los Angeles County Sheriff's Department dataset overall.

FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
0.0095	0.0075	0.0056

3.2 Los Angeles County Sheriff's Department

The Los Angeles County Sheriff's Department (LASD) dataset consists of plain and rolled impressions of all ten fingers, captured with a mixture of ink and optical devices. Figure 7 and Table 9 show the DET of all fingers not compared in other PFT subsets. This data is separated by finger position in Figure 8 and Table 10 and again by impression type in Figure 9 and Table 11. Curves made by combinations of fingers were generated by sum fusion.

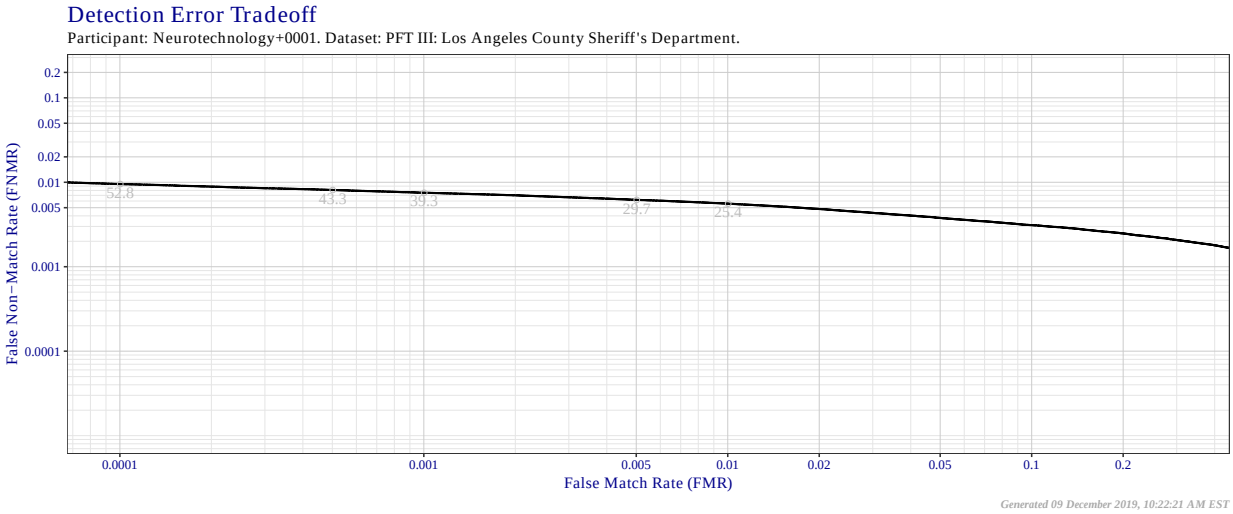

Figure 7: Detection error tradeoff of all comparisons from all fingers in the PFT III LASD dataset. Numbers in gray indicate the similarity threshold.

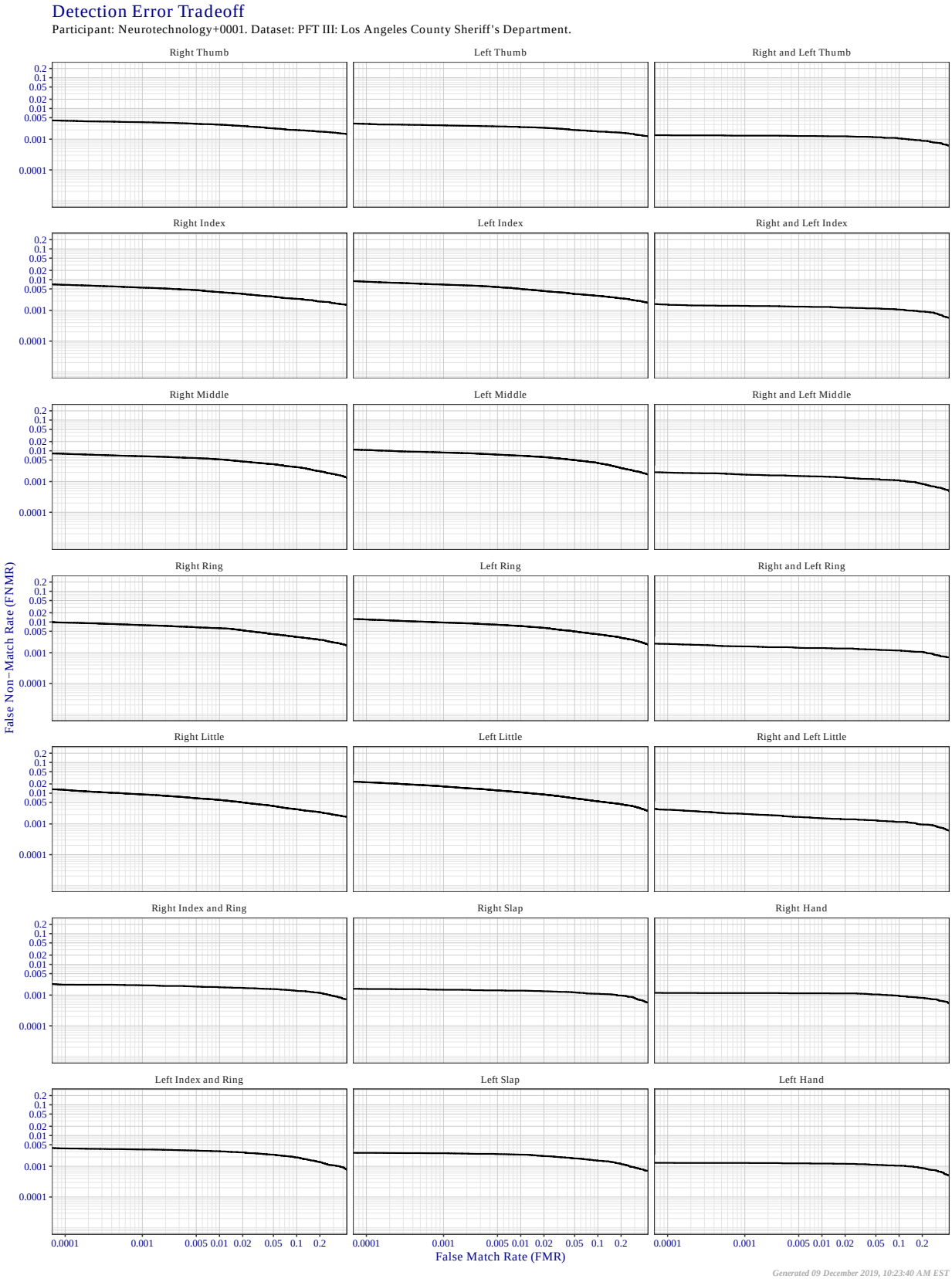

Figure 8: Detection error tradeoff of all comparisons from all fingers in the PFT III LASD dataset, separated by finger position. Combined finger positions were generated by sum fusion.

Table 10: False non-match rate values at specific false match rates for the PFT III LASD dataset, separated by finger position. Combined finger positions were generated by sum fusion.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
R Thumb	0.0040	0.0036	0.0030
R Index	0.0068	0.0055	0.0039
R Middle	0.0080	0.0067	0.0052
R Ring	0.0096	0.0079	0.0063
R Little	0.0128	0.0091	0.0060
L Thumb	0.0031	0.0028	0.0025
L Index	0.0086	0.0069	0.0050
L Middle	0.0106	0.0088	0.0069
L Ring	0.0121	0.0096	0.0074
L Little	0.0227	0.0166	0.0106
R & L Thumb	0.0013	0.0013	0.0013
R & L Index	0.0015	0.0014	0.0013
R & L Middle	0.0020	0.0017	0.0015
R & L Ring	0.0019	0.0016	0.0014
R & L Little	0.0029	0.0021	0.0015
R Index & Ring	0.0022	0.0021	0.0018
L Index & Ring	0.0038	0.0035	0.0031
R Slap	0.0016	0.0015	0.0014
L Slap	0.0027	0.0027	0.0024
R Hand	0.0012	0.0012	0.0011
L Hand	0.0013	0.0013	0.0012

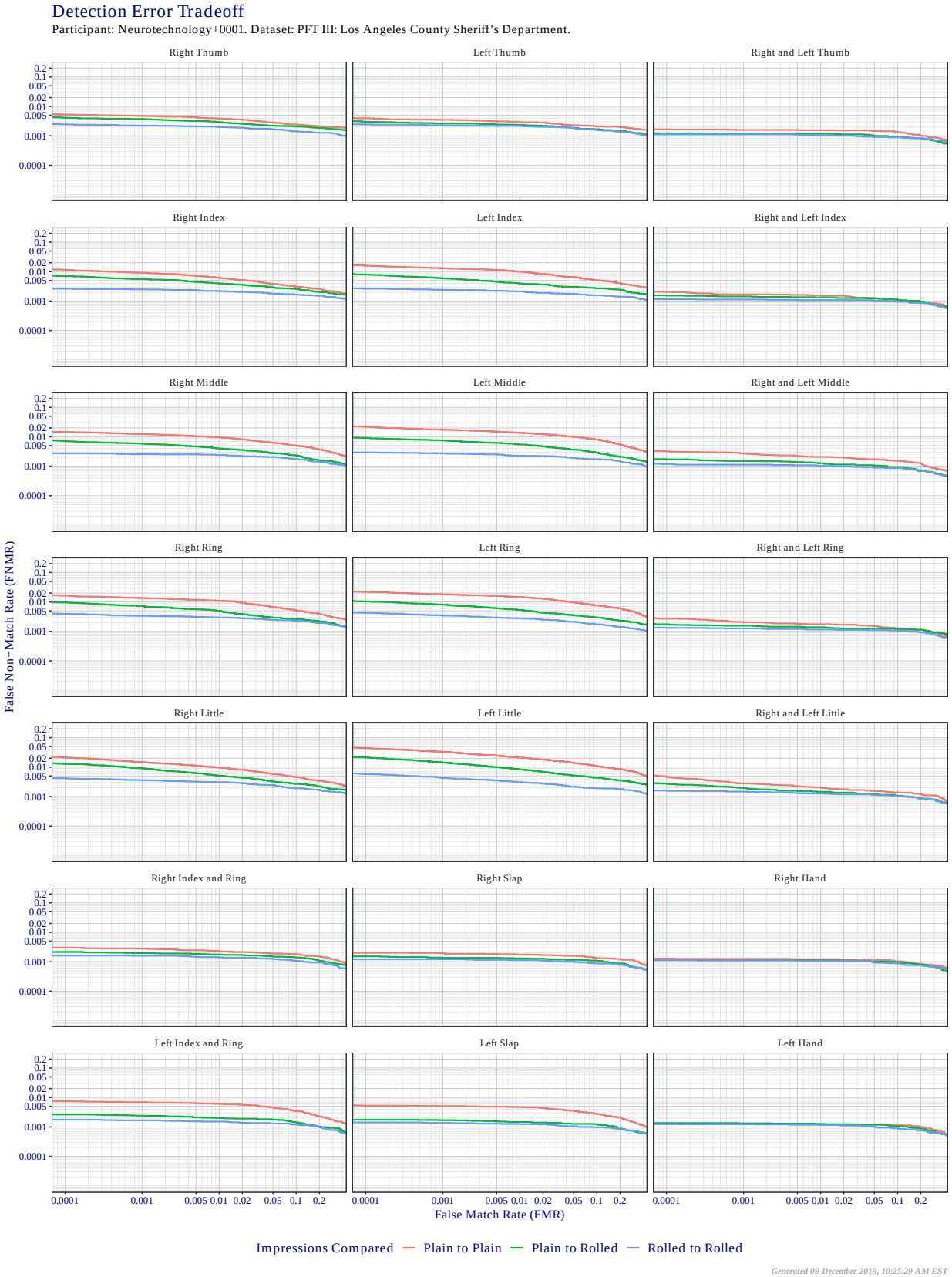

Figure 9: Detection error tradeoff of all comparisons from all fingers in the PFT III LASD dataset, separated by finger position and impression type. Combined finger positions were generated by sum fusion.

Table 11: False non-match rate values at specific false match rates for the PFT III LASD dataset, separated by finger position and impression type. Combined finger positions were generated by sum fusion.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
Plain to Plain			
R Thumb	0.0053	0.0048	0.0039
R Index	0.0117	0.0092	0.0062
R Middle	0.0145	0.0123	0.0096
R Ring	0.0163	0.0136	0.0110
R Little	0.0212	0.0147	0.0097
L Thumb	0.0040	0.0035	0.0030
L Index	0.0160	0.0130	0.0100
L Middle	0.0221	0.0174	0.0137
L Ring	0.0220	0.0180	0.0146
L Little	0.0445	0.0332	0.0211
R & L Thumb	0.0017	0.0016	0.0016
R & L Index	0.0020	0.0017	0.0015
R & L Middle	0.0032	0.0027	0.0021
R & L Ring	0.0027	0.0021	0.0018
R & L Little	0.0048	0.0028	0.0021
R Index & Ring	0.0030	0.0028	0.0023
L Index & Ring	0.0075	0.0069	0.0061
R Slap	0.0020	0.0020	0.0017
L Slap	0.0053	0.0051	0.0047
R Hand	0.0013	0.0013	0.0012
L Hand	0.0013	0.0013	0.0012
Plain to Rolled			
R Thumb	0.0042	0.0037	0.0029
R Index	0.0070	0.0056	0.0040
R Middle	0.0071	0.0059	0.0040
R Ring	0.0096	0.0072	0.0050
R Little	0.0129	0.0091	0.0051
L Thumb	0.0030	0.0026	0.0024
L Index	0.0079	0.0060	0.0040
L Middle	0.0091	0.0076	0.0055
L Ring	0.0104	0.0080	0.0054
L Little	0.0214	0.0143	0.0084
R & L Thumb	0.0012	0.0012	0.0012
R & L Index	0.0015	0.0014	0.0013
R & L Middle	0.0017	0.0015	0.0013
R & L Ring	0.0017	0.0016	0.0014
R & L Little	0.0028	0.0020	0.0015
R Index & Ring	0.0022	0.0020	0.0018
L Index & Ring	0.0026	0.0024	0.0020
R Slap	0.0015	0.0014	0.0013
L Slap	0.0017	0.0017	0.0015
R Hand	0.0011	0.0011	0.0011
L Hand	0.0014	0.0013	0.0013
R Thumb	0.0025	0.0022	0.0020
Rolled to Rolled			
R Index	0.0026	0.0025	0.0022

R Middle	0.0027	0.0025	0.0024
R Ring	0.0040	0.0034	0.0030
R Little	0.0042	0.0036	0.0031
L Thumb	0.0024	0.0023	0.0022
L Index	0.0026	0.0024	0.0021
L Middle	0.0029	0.0027	0.0023
L Ring	0.0043	0.0035	0.0028
L Little	0.0059	0.0043	0.0031
R & L Thumb	0.0011	0.0011	0.0011
R & L Index	0.0012	0.0011	0.0011
R & L Middle	0.0012	0.0011	0.0010
R & L Ring	0.0013	0.0013	0.0012
R & L Little	0.0016	0.0015	0.0013
R Index & Ring	0.0016	0.0016	0.0014
L Index & Ring	0.0018	0.0017	0.0015
R Slap	0.0012	0.0012	0.0011
L Slap	0.0014	0.0014	0.0013
R Hand	0.0011	0.0011	0.0011
L Hand	0.0012	0.0012	0.0012

Table 12: False non-match rate values at specific false match rates for the PFT III POE+BVA dataset overall. Combined finger positions were generated by sum fusion.

FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
0.0058	0.0049	0.0041

3.3 Port of Entry, BioVisa Application

The Port of Entry/BioVisa Application (POE+BVA) dataset consists of plain impressions of index fingers. Figure 10 and Table 12 show the DET of all fingers not compared in other PFT subsets. This data is separated by finger position in Figure 11. Curves made by combinations of fingers were generated by sum fusion.

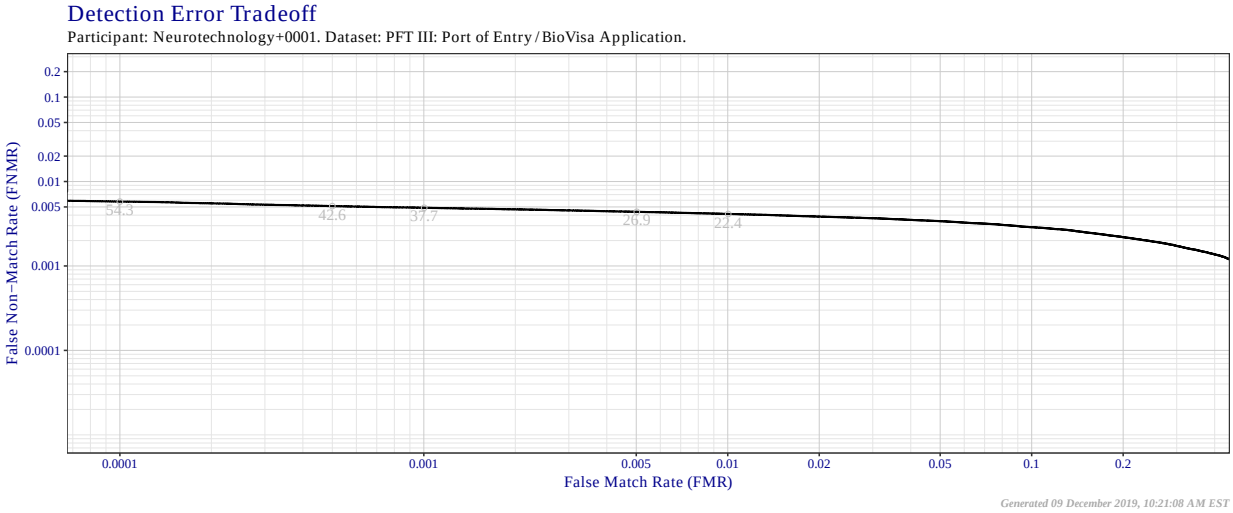

Figure 10: Detection error tradeoff of all comparisons from all fingers in the PFT III POE+BVA dataset Numbers in gray indicate the similarity threshold.

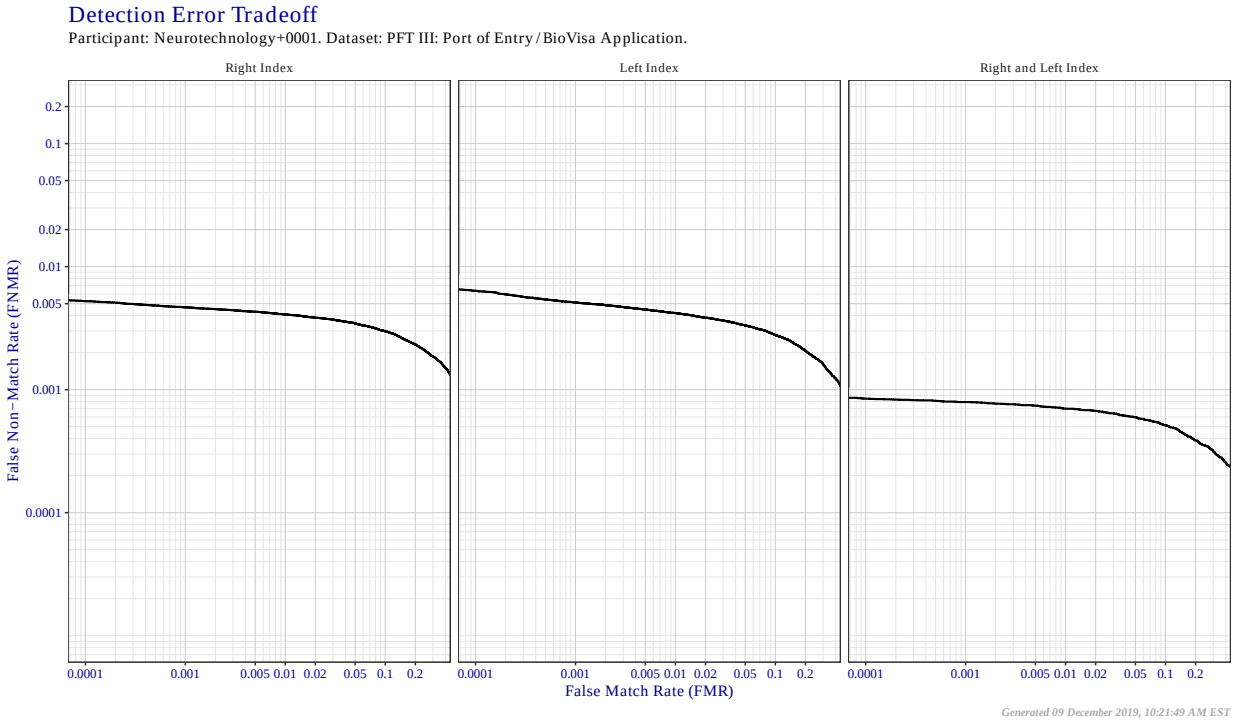

Figure 11: Detection error tradeoff of comparisons from the PFT III POE+BVA dataset, separated by finger position. Combined finger positions were generated by sum fusion.

Table 13: False non-match rate values at specific false match rates for the PFT III POE+BVA dataset, separated by finger position. Combined finger positions were generated by sum fusion.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
R Index	0.0052	0.0047	0.0041
L Index	0.0064	0.0051	0.0042
R & L Index	0.0008	0.0008	0.0007

Table 14: False non-match rate values at specific false match rates for the PFT III VISIT2 dataset overall.

FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
0.007	0.0055	0.0044

3.4 US VISIT #2

The US VISIT #2 (VISIT2) dataset consists of plain impressions of index fingers and are similar to POE+BVA. Figure 12 and Table 14 show the DET of all fingers not compared in other PFT subsets. This data is separated by finger position in Figure 13. Curves made by combinations of fingers were generated by sum fusion.

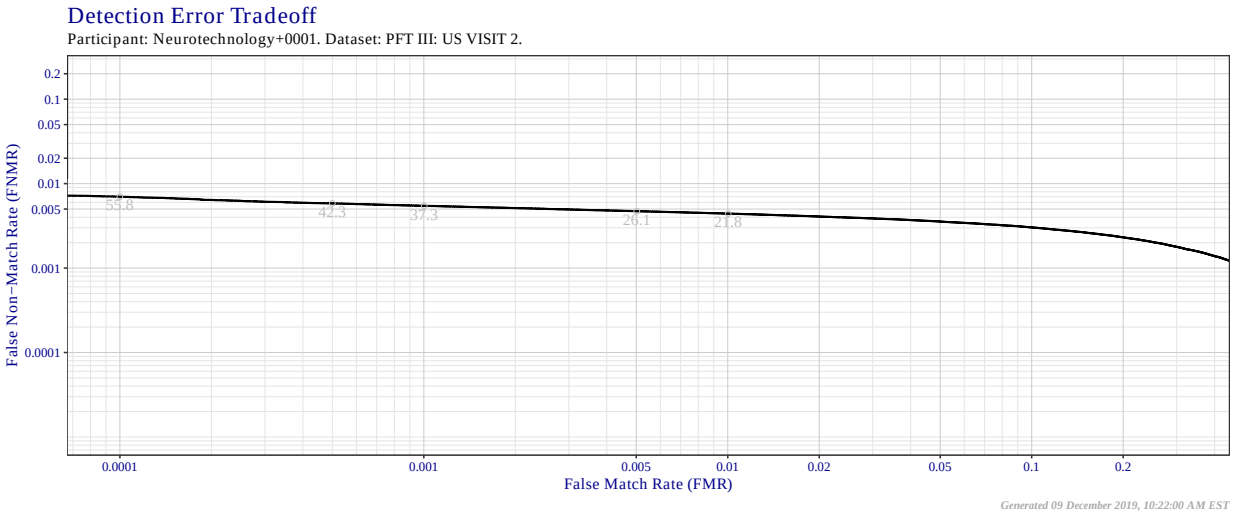

Figure 12: Detection error tradeoff of all comparisons from all fingers in the PFT III VISIT2 dataset. Numbers in gray indicate the similarity threshold.

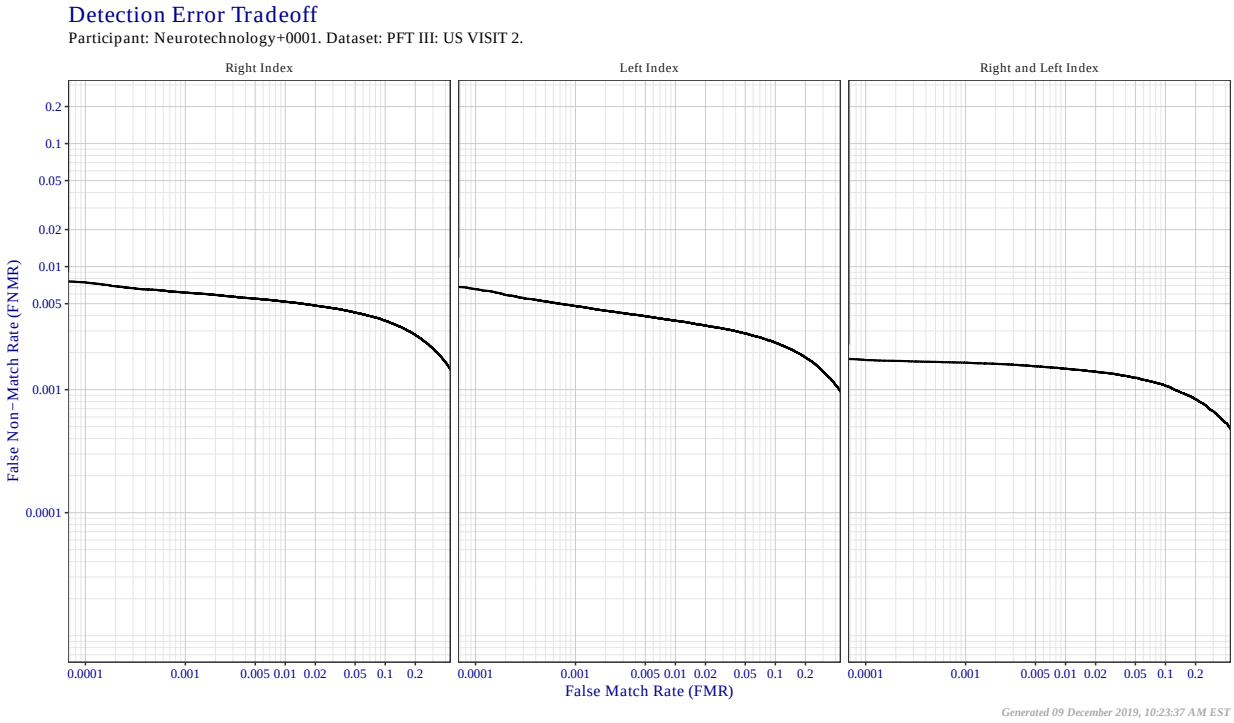

Figure 13: Detection error tradeoff of comparisons from the PFT III VISIT2 dataset, separated by finger position. Combined finger positions were generated by sum fusion.

Table 15: False non-match rate values at specific false match rates for the PFT III VISIT2 dataset, separated by finger position.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
R Index	0.0075	0.0062	0.0052
L Index	0.0066	0.0048	0.0036
R & L Index	0.0017	0.0017	0.0015

3.5 IARPA Nail-to-Nail

In September 2017, IARPA held a fingerprint data collection as part of the *Nail to Nail Fingerprint Challenge*. Participating Challengers deployed devices to capture a rolled-equivalent print. Approximately two-thirds of the ten-print data collected was released to the public as NIST Special Database 302, with the rest being sequestered at NIST for evaluations like PFT III.

Information about the Challenge can be found in NIST IR 8210. Descriptions of the devices described by the device codes in the following figures and tables can be found in NIST TN 2007.

3.5.1 By Device

The following figures and tables show the DET of all comparisons from select devices in the IARPA N2N Challenge. All probe devices imaged natively at 500 PPI, except for **J**, **R**, and **U**, which imaged at 1 000 PPI. The reference device, **V**, also imaged natively at 1 000 PPI. When these higher resolution devices are shown at 500 PPI, they were downsampled using *NIST Fingerprint Image Resampler (NFIR)*.

Figure 14 and Table 16 show results with 500 PPI probes against 1 000 PPI references. Figure 15 and Table 17 show the same probe images against reference images downsampled to the same resolution. Figure 16 and Table 18 show native 1 000 PPI to 1 000 PPI comparisons for supported devices.

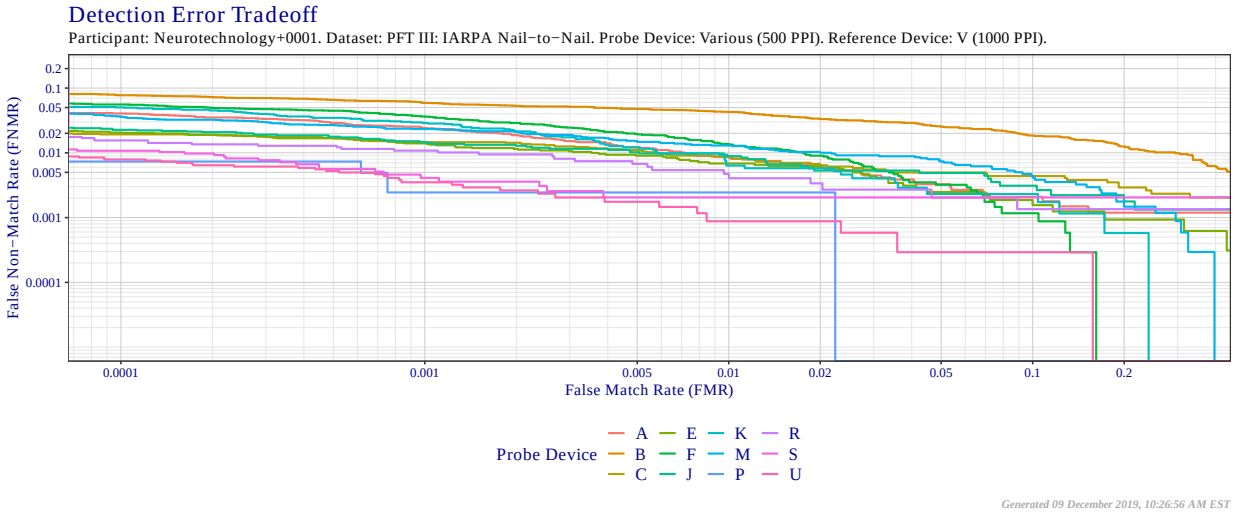

Figure 14: Overall detection error tradeoff of comparisons from the PFT III IARPA N2N dataset, using probe images at 500 PPI and reference images at their native 1 000 PPI resolution.

Table 16: False non-match rate values at specific false match rates for devices deployed in the IARPA N2N Challenge at 500 PPI compared to a 1 000 PPI reference roll.

Device	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
A	0.0405	0.0241	0.0086
B	0.0774	0.0592	0.0430
C	0.0193	0.0146	0.0088
E	0.0205	0.0140	0.0068
F	0.0557	0.0365	0.0137
J	0.0226	0.0146	0.0089
K	0.0503	0.0289	0.0064
M	0.0366	0.0233	0.0130
P	0.0073	0.0024	0.0024
R	0.0155	0.0108	0.0047
S	0.0108	0.0041	0.0021
U	0.0079	0.0035	0.0009

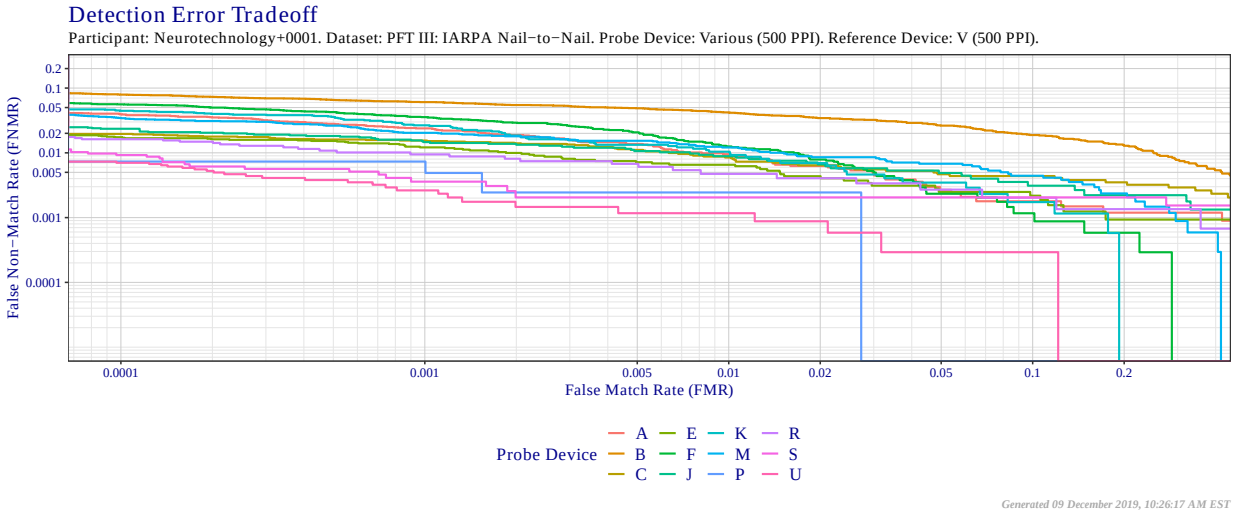

Figure 15: Overall detection error tradeoff of comparisons from the PFT III IARPA N2N dataset, using probe images at 500 PPI and reference images downsampled to 500 PPI.

Table 17: False non-match rate values at specific false match rates for devices deployed in the IARPA N2N Challenge at 500 PPI compared to a downsampled 500 PPI reference roll.

Device	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
A	0.0399	0.0238	0.0095
B	0.0795	0.0607	0.0421
C	0.0196	0.0155	0.0085
E	0.0174	0.0121	0.0065
F	0.0560	0.0356	0.0125
J	0.0235	0.0146	0.0089
K	0.0451	0.0266	0.0104
M	0.0348	0.0204	0.0121
P	0.0073	0.0073	0.0024
R	0.0162	0.0095	0.0047
S	0.0092	0.0036	0.0021
U	0.0070	0.0026	0.0012

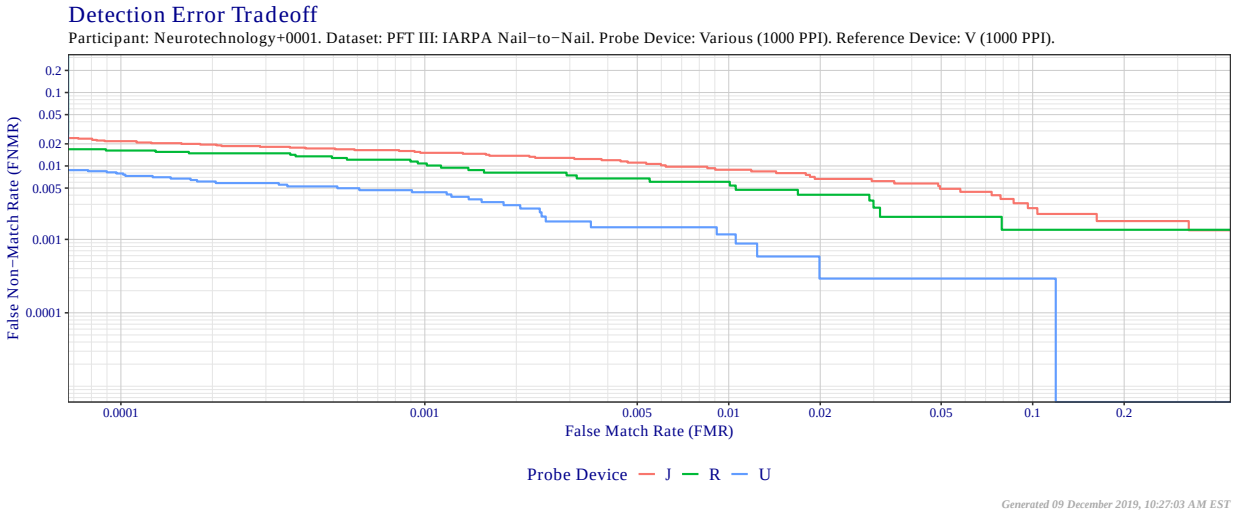

Figure 16: Overall detection error tradeoff of comparisons from the PFT III IARPA N2N dataset for devices that supported native 1 000 PPI to 1 000 PPI comparisons.

Table 18: False non-match rate values at specific false match rates for 1 000 PPI devices deployed in the IARPA N2N Challenge compared to a 1 000 PPI reference roll.

Device	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
J	0.0217	0.0151	0.0089
R	0.0162	0.0108	0.0061
U	0.0079	0.0044	0.0012

3.5.2 Resample Test

PFT III supports encoding of variable resolution images. It is thought that several fingerprint feature extractors downsample imagery to a lower resolution before extracting features. To test this theory, we downsample and compare source and reference imagery both captured natively at 1 000 PPI. All downsampling was performed using *NFIR*.

Images were compared at all combinations of 100, 250, 300, 333, 500, 600, and 1 000 (native) PPI.

Figure 17 and Table 19 show match rates against 1 000 PPI references. Figure 18 and Table 20 show match rates against 600 PPI downsampled references. Figure 19 and Table 21 show match rates against 500 PPI downsampled references. Figure 20 and Table 22 show match rates against 333 PPI downsampled references. Figure 21 and Table 23 show match rates against 300 PPI downsampled references. Figure 22 and Table 24 show match rates against 250 PPI downsampled references. Figure 23 and Table 25 show match rates against 100 PPI downsampled references.

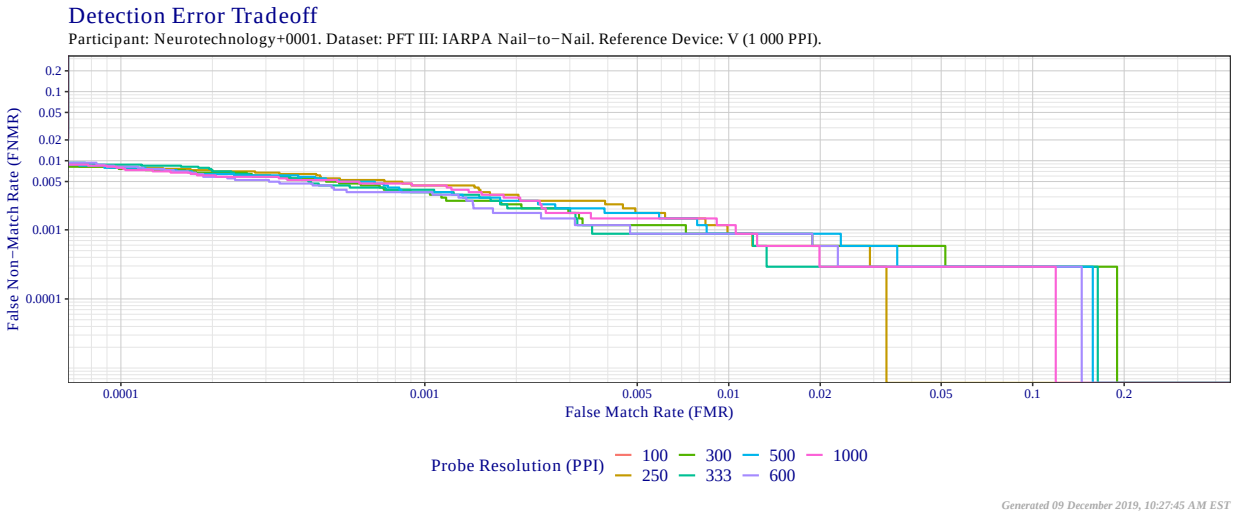

Figure 17: Detection error tradeoff of comparisons from the PFT III IARPA N2N dataset using downsampled probe images of various resolutions as compared to 1 000 (native) images.

Table 19: False non-match rate values at specific false match rates for device U from the IARPA N2N Challenge at various resolutions compared to 1 000 (native) reference rolls from device V.

Probe Resolution (PPI)	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
100	1.0000	1.0000	1.0000
250	0.0082	0.0044	0.0009
300	0.0079	0.0035	0.0009
333	0.0088	0.0038	0.0009
500	0.0079	0.0035	0.0009
600	0.0082	0.0035	0.0009
1 000	0.0079	0.0044	0.0012

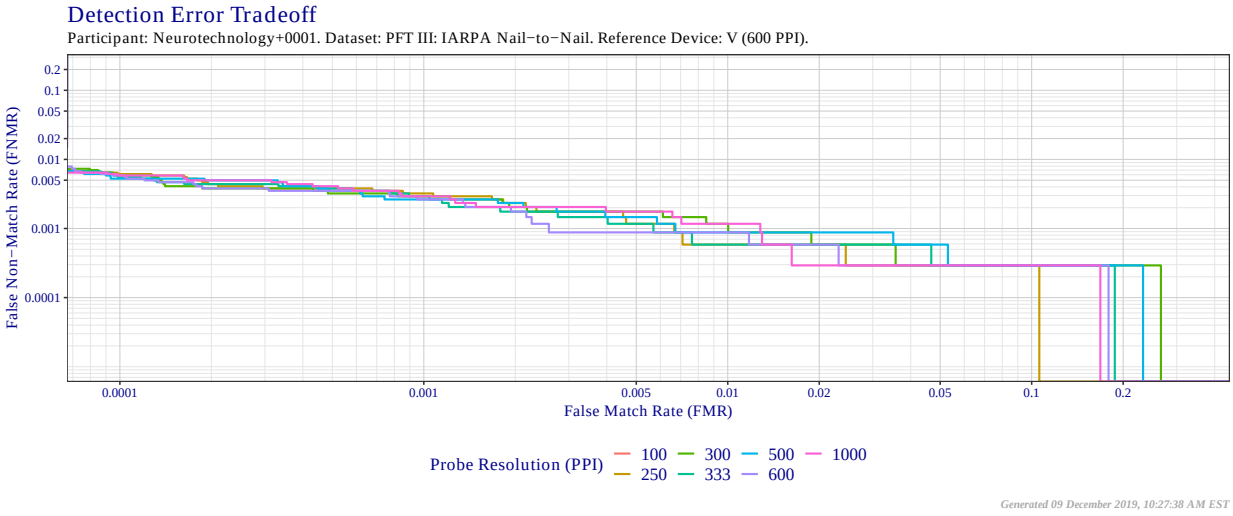

Figure 18: Detection error tradeoff of comparisons from the PFT III IARPA N2N dataset using downsampled probe images of various resolutions as compared to downsampled 600 PPI images.

Table 20: False non-match rate values at specific false match rates for device U from the IARPA N2N Challenge at various resolutions compared to downsampled 600 PPI reference rolls from device V.

Probe Resolution (PPI)	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
100	1.0000	1.0000	1.0000
250	0.0064	0.0032	0.0006
300	0.0061	0.0029	0.0012
333	0.0058	0.0029	0.0006
500	0.0053	0.0026	0.0009
600	0.0058	0.0026	0.0009
1 000	0.0061	0.0029	0.0012

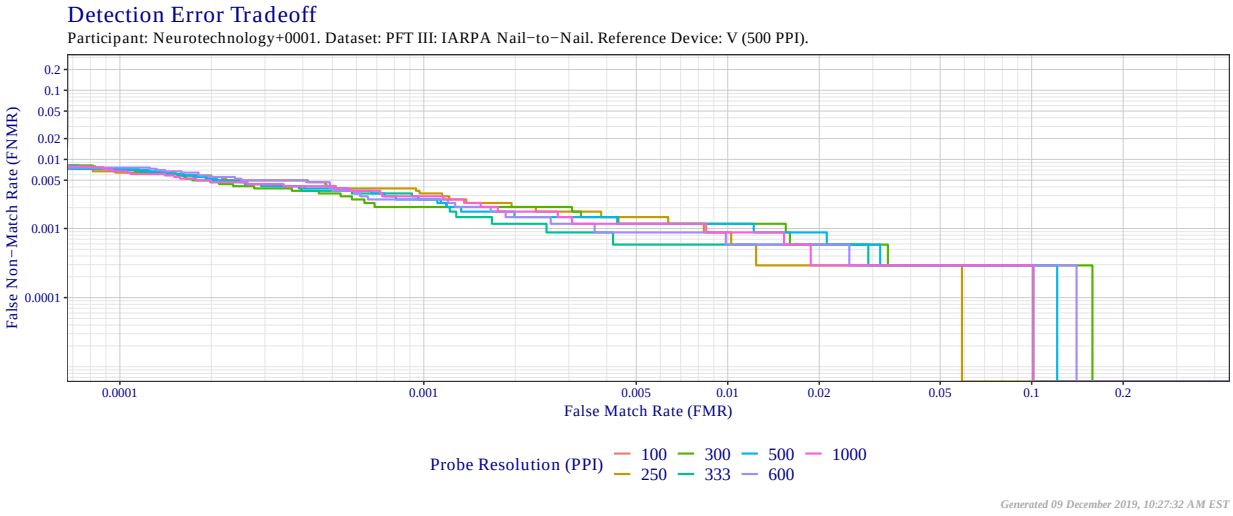

Figure 19: Detection error tradeoff of comparisons from the PFT III IARPA N2N dataset using downsampled probe images of various resolutions as compared to downsampled 500 PPI images.

Table 21: False non-match rate values at specific false match rates for device U from the IARPA N2N Challenge at various resolutions compared to downsampled 500 PPI reference rolls from device V.

Probe Resolution (PPI)	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
100	1.0000	1.0000	1.0000
250	0.0064	0.0032	0.0009
300	0.0073	0.0020	0.0012
333	0.0073	0.0026	0.0006
500	0.0070	0.0026	0.0012
600	0.0076	0.0026	0.0006
1 000	0.0067	0.0029	0.0009

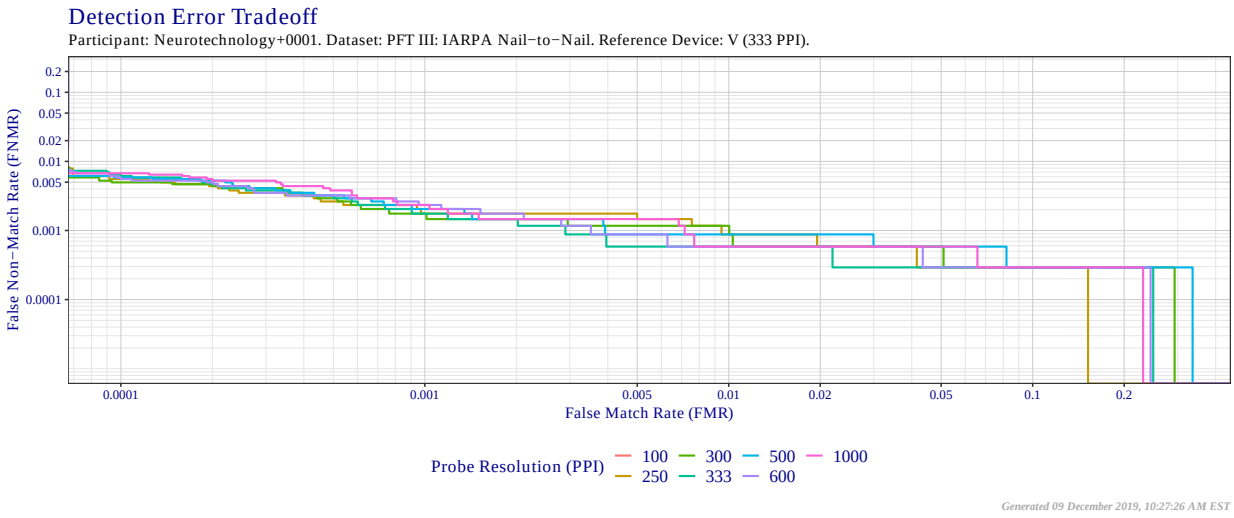

Figure 20: Detection error tradeoff of comparisons from the PFT III IARPA N2N dataset using downsampled probe images of various resolutions as compared to downsampled 333 PPI images.

Table 22: False non-match rate values at specific false match rates for device U from the IARPA N2N Challenge at various resolutions compared to downsampled 333 PPI reference rolls from device V.

Probe Resolution (PPI)	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
100	1.0000	1.0000	1.0000
250	0.0056	0.0018	0.0009
300	0.0050	0.0018	0.0012
333	0.0064	0.0018	0.0006
500	0.0058	0.0020	0.0009
600	0.0058	0.0023	0.0006
1 000	0.0067	0.0023	0.0006

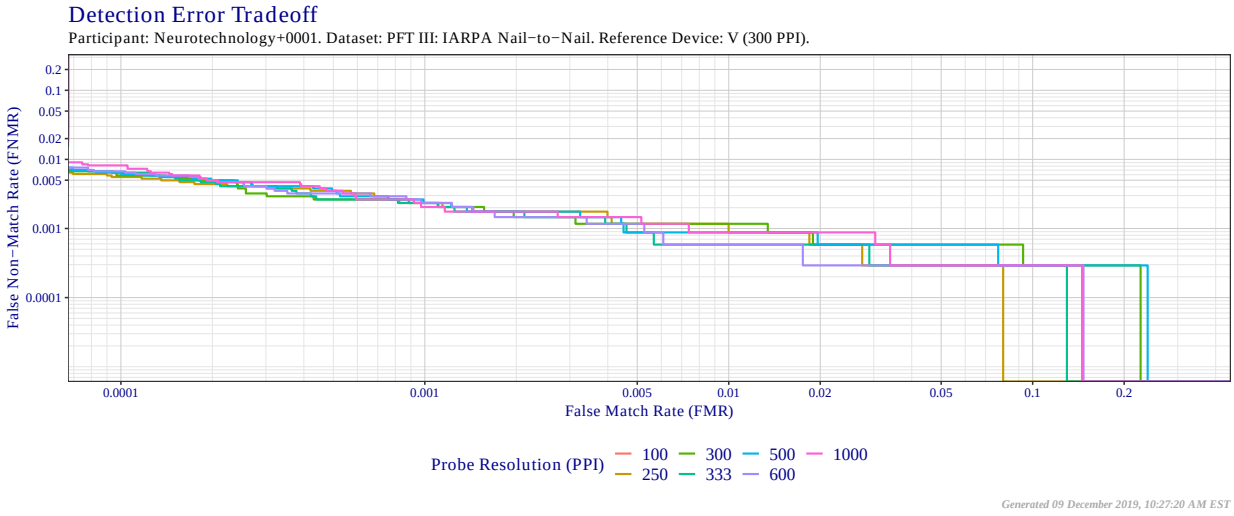

Figure 21: Detection error tradeoff of comparisons from the PFT III IARPA N2N dataset using downsampled probe images of various resolutions as compared to downsampled 300 PPI images.

Table 23: False non-match rate values at specific false match rates for device U from the IARPA N2N Challenge at various resolutions compared to downsampled 300 PPI reference rolls from device V.

Probe Resolution (PPI)	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
100	1.0000	1.0000	1.0000
250	0.0056	0.0023	0.0012
300	0.0058	0.0023	0.0012
333	0.0064	0.0023	0.0006
500	0.0064	0.0023	0.0009
600	0.0067	0.0023	0.0006
1 000	0.0082	0.0020	0.0009

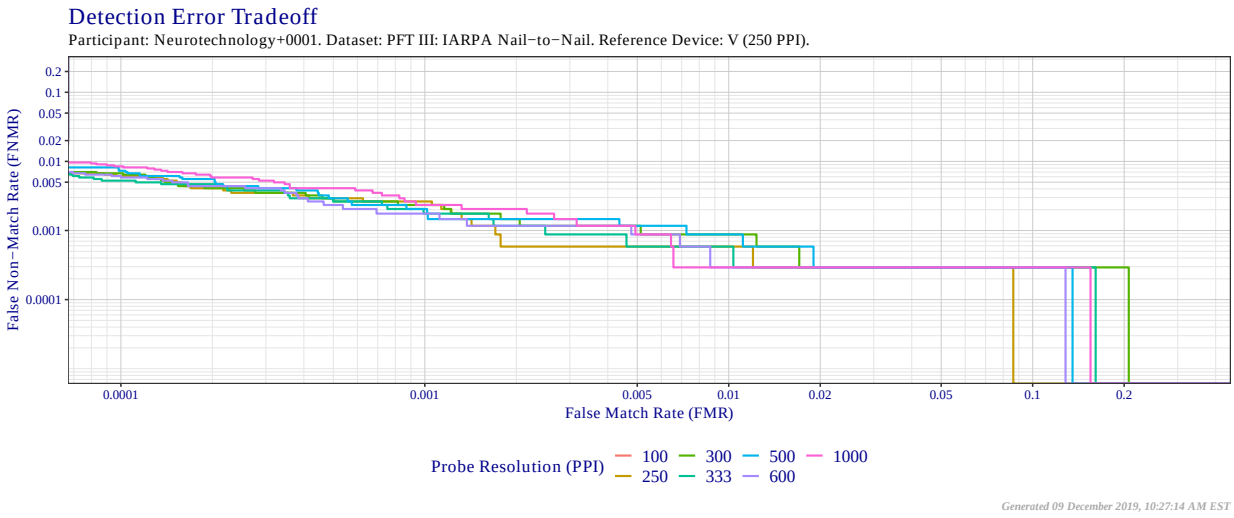

Figure 22: Detection error tradeoff of comparisons from the PFT III IARPA N2N dataset using downsampled probe images of various resolutions as compared to downsampled 250 PPI images.

Table 24: False non-match rate values at specific false match rates for device U from the IARPA N2N Challenge at various resolutions compared to downsampled 250 PPI reference rolls from device V.

Probe Resolution (PPI)	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
100	1.0000	1.0000	1.0000
250	0.0061	0.0026	0.0006
300	0.0067	0.0023	0.0009
333	0.0053	0.0018	0.0006
500	0.0082	0.0020	0.0009
600	0.0061	0.0018	0.0003
1 000	0.0085	0.0023	0.0003

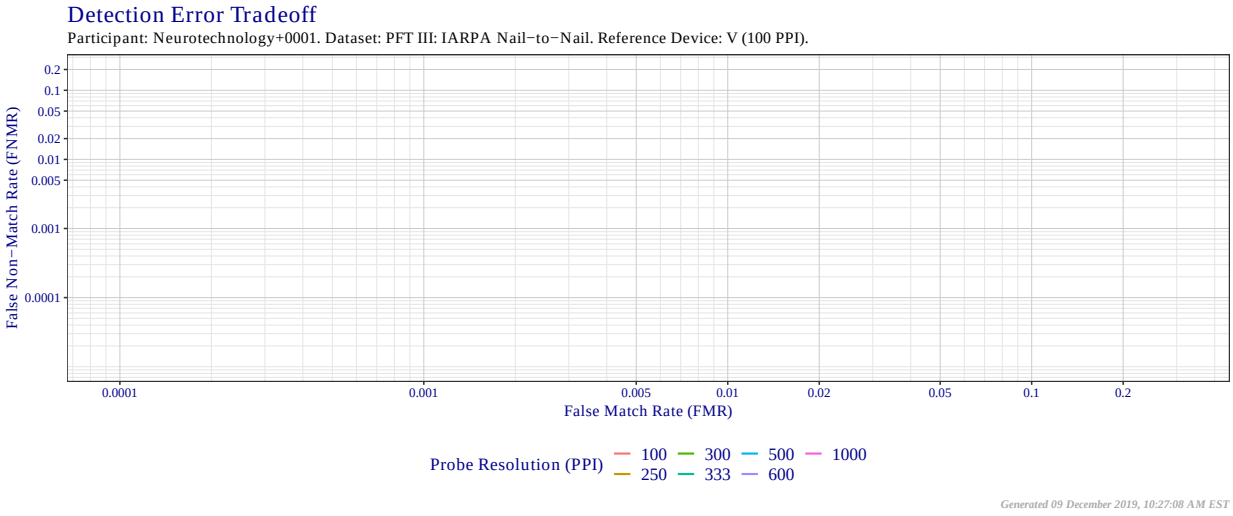

Figure 23: Detection error tradeoff of comparisons from the PFT III IARPA N2N dataset using downsampled probe images of various resolutions as compared to downsampled 100 PPI images.

Table 25: False non-match rate values at specific false match rates for device U from the IARPA N2N Challenge at various resolutions compared to downsampled 100 PPI reference rolls from device V.

Probe Resolution (PPI)	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
100	1	1	1
250	1	1	1
300	1	1	1
333	1	1	1
500	1	1	1
600	1	1	1
1 000	1	1	1

4 Comparison to PFT II

The PFT II evaluation ran at NIST from February 2010 until May 2019. The plots and tables in this section use identical datasets and comparison pairs as PFT II and are directly comparable to results posted on the NIST website for PFT II:

https://nist.gov/itl/iad/image-group/proprietary-fingerprint-template-evaluation-pftii

4.1 All Fingers

Figure 24 and Table 26 shows the DET of all fingers for each dataset evaluated in PFT II. Curves are linked at equivalent score thresholds for specific false match rates on the best performing dataset.

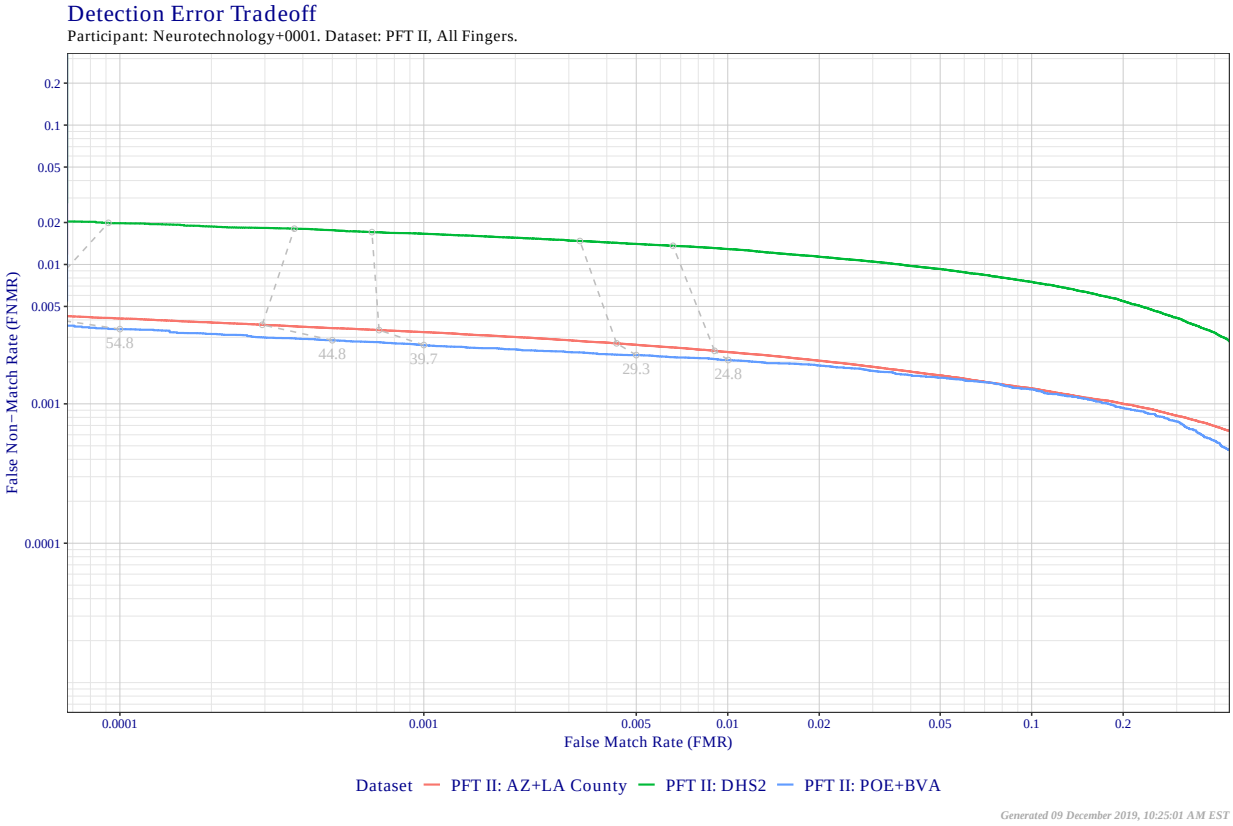

Figure 24: Detection error tradeoff of all comparisons from all fingers in PFT II, separated by dataset. Curves are linked at equivalent score thresholds.

Table 26: False non-match rate values at specific false match rates for the PFT II datasets combined.

Dataset	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
PFT II: AZ+LA County	0.0041	0.0033	0.0024
PFT II: DHS2	0.0198	0.0166	0.0129
PFT II: POE+BVA	0.0034	0.0026	0.0021

4.2 Index Fingers

Figure 25 and Table 27 show the DET of index fingers over the three datasets evaluated in PFT II. Combined finger positions were generated by sum fusion.

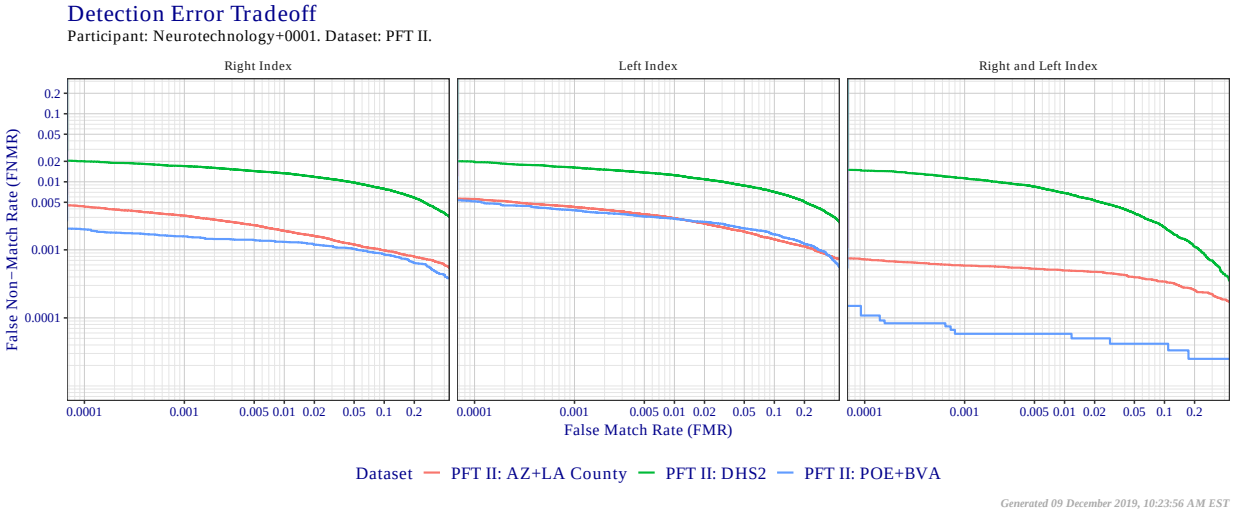

Figure 25: Detection error tradeoff of index fingers compared in PFT II. Combined finger positions were generated by sum fusion.

Table 27: False non-match rate values at specific false match rates for the PFT II datasets.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
PFT II: AZ+LA County			
R Index	0.0044	0.0032	0.0019
L Index	0.0056	0.0043	0.0029
R & L Index	0.0007	0.0006	0.0005
PFT II: DHS2			
R Index	0.0201	0.0170	0.0133
L Index	0.0198	0.0162	0.0125
R & L Index	0.0146	0.0113	0.0068
PFT II: POE+BVA			
R Index	0.0020	0.0016	0.0013
L Index	0.0052	0.0038	0.0029
R & L Index	0.0001	0.0001	0.0001

4.3 Arizona/Los Angeles County

Figure 26 and Table 28 show the DET of all finger combinations compared in PFT II's evaluation of the combined datasets from the Arizona Department of Public Safety and the Los Angeles County Sheriff's Department. Curves in each dataset are separated by the impression types compared. Combined finger positions were generated by sum fusion.

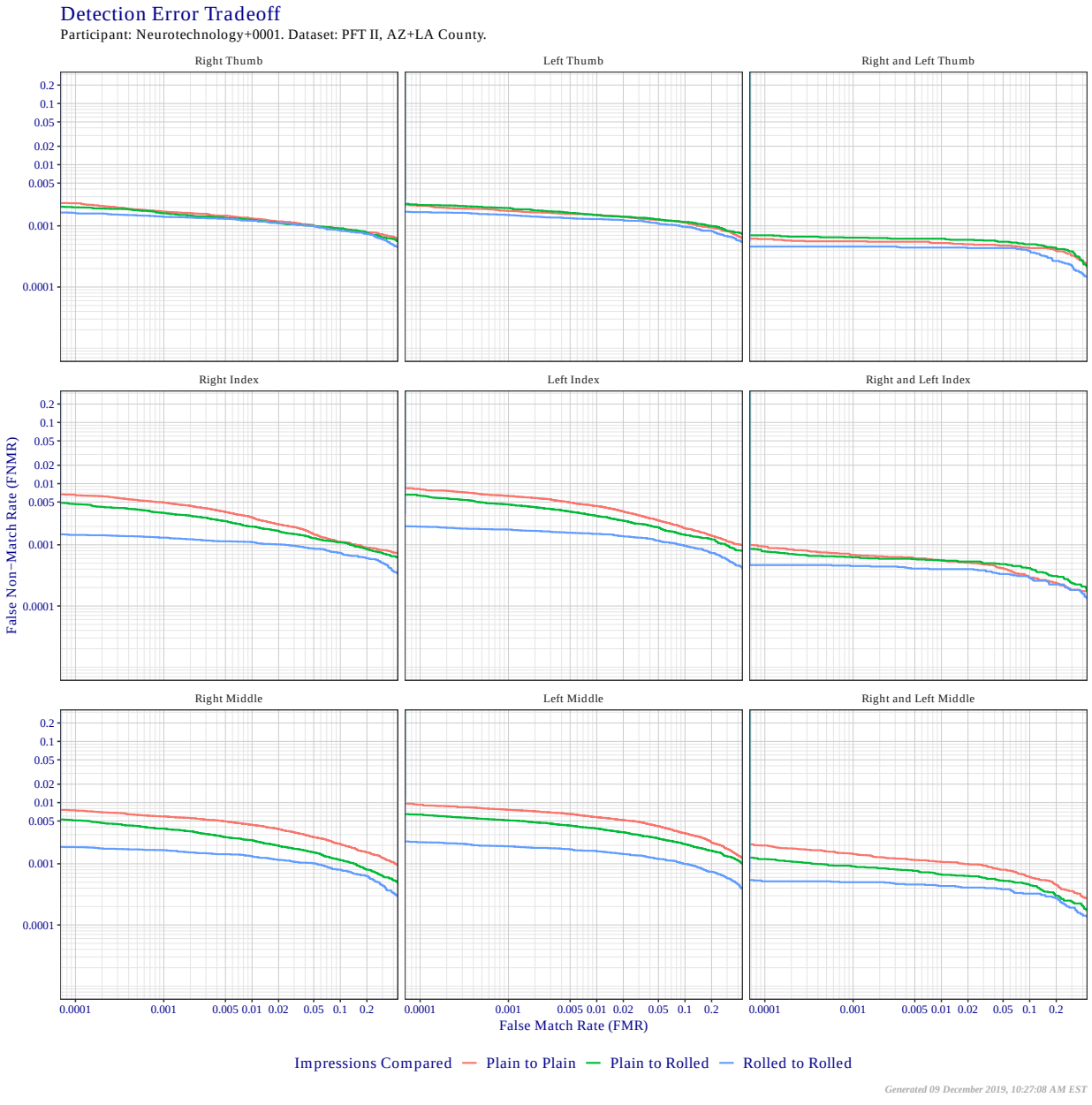

Figure 26: Detection error tradeoff of comparisons from the PFT II AZ/LA dataset, separated by impression type. Combined finger positions were generated by sum fusion.

Table 28: False non-match rate values at specific false match rates for the PFT II AZ+LA County dataset.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
Plain to Plain			
R Thumb	0.0023	0.0017	0.0013
R Index	0.0066	0.0049	0.0028
R Middle	0.0075	0.0060	0.0043
L Thumb	0.0021	0.0018	0.0015
L Index	0.0082	0.0063	0.0043
L Middle	0.0092	0.0076	0.0058
R & L Thumb	0.0006	0.0006	0.0005
R & L Index	0.0009	0.0007	0.0006
R & L Middle	0.0020	0.0015	0.0011
Plain to Rolled			
R Thumb	0.0020	0.0016	0.0013
R Index	0.0047	0.0033	0.0020
R Middle	0.0051	0.0038	0.0024
L Thumb	0.0022	0.0020	0.0015
L Index	0.0064	0.0046	0.0030
L Middle	0.0064	0.0051	0.0038
R & L Thumb	0.0007	0.0006	0.0006
R & L Index	0.0008	0.0006	0.0006
R & L Middle	0.0012	0.0009	0.0007
Rolled to Rolled			
R Thumb	0.0016	0.0014	0.0012
R Index	0.0015	0.0013	0.0011
R Middle	0.0019	0.0017	0.0013
L Thumb	0.0017	0.0015	0.0013
L Index	0.0020	0.0018	0.0015
L Middle	0.0023	0.0019	0.0016
R & L Thumb	0.0005	0.0005	0.0004
R & L Index	0.0005	0.0005	0.0004
R & L Middle	0.0005	0.0005	0.0004

5 Comparison to Original PFT

The Original PFT evaluation ran at NIST from 2003 until February 2010. The plots and tables in this section use identical datasets and comparison pairs as the Original PFT evaluation and are directly comparable to results posted for the Original PFT and the "Original PFT Dataset" section in PFT II reports on the NIST website:

https://nist.gov/itl/iad/image-group/nist-proprietary-fingerprint-template-pft-evaluation-2003-2010

5.1 Index Fingers

Figure 27 and Table 29 show the DET of index fingers over the three datasets evaluated in the Original PFT evaluation. Combined finger positions were generated by sum fusion.

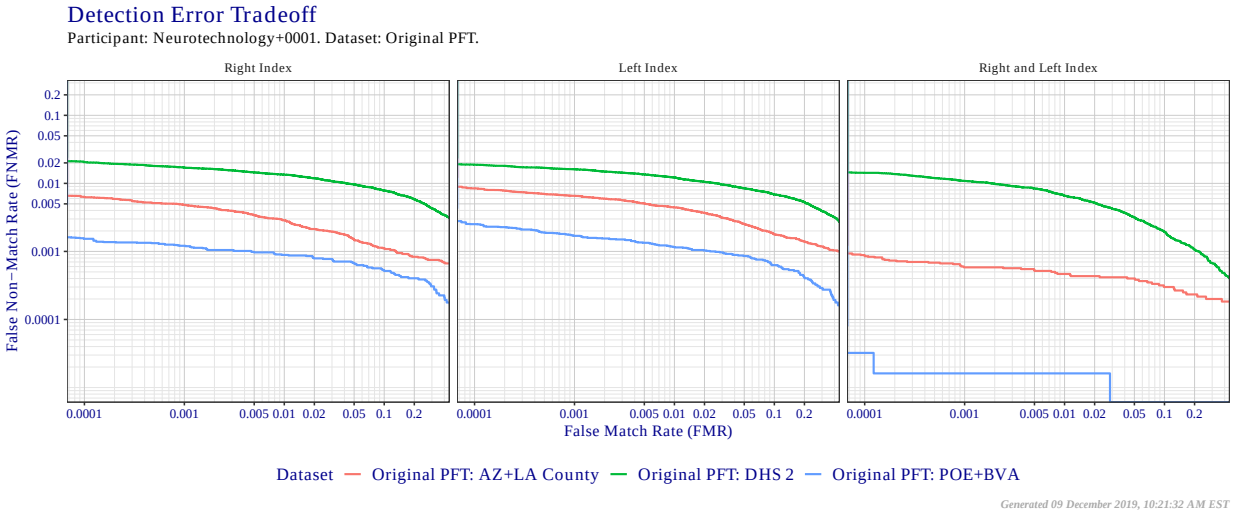

Figure 27: Detection error tradeoff of index fingers compared in the Original PFT evaluation. Combined finger positions were generated by sum fusion.

Table 29: False non-match rate values at specific false match rates for the Original PFT dataset. Combined finger positions were generated by sum fusion.

FRGP	FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
Original PFT: AZ+LA County			
R Index	0.0064	0.0048	0.0029
L Index	0.0084	0.0066	0.0044
R & L Index	0.0009	0.0006	0.0005
Original PFT: DHS 2			
R Index	0.0209	0.0170	0.0134
L Index	0.0189	0.0161	0.0122
R & L Index	0.0143	0.0109	0.0066
Original PFT: POE+BVA			
R Index	0.0016	0.0012	0.0009
L Index	0.0025	0.0017	0.0012
R & L Index	0.0000	0.0000	0.0000

6 Comparison to MINEX III

Minutia Exchange (MINEX) III is NIST's ongoing test of interoperable fingerprint template generation and matching. The only data permitted to be stored in a MINEX-compliant template are minutia type (ridge ending, bifurcation, or unknown), angle, location, and quality, as well as finger position and image quality. PFT III templates have no restrictions on the contents of the template. The results shown in this section are computed based on the exact MINEX III dataset, but using the proprietary template generator and matcher from Neurotechnology+0001.

Note that while *Neurotechnology* may be a participant in both PFT III and MINEX III (perhaps even with the same identifier of Neurotechnology+0001), it **does not** indicate that the same underlying implementation was used. Information about equivalence of implementations should be addressed to the participant.

6.1 Single Finger

Figure Figure 28 and Table 30 show single finger results, which corresponds to Figure 2 and Table 4 from any MINEX III report card.

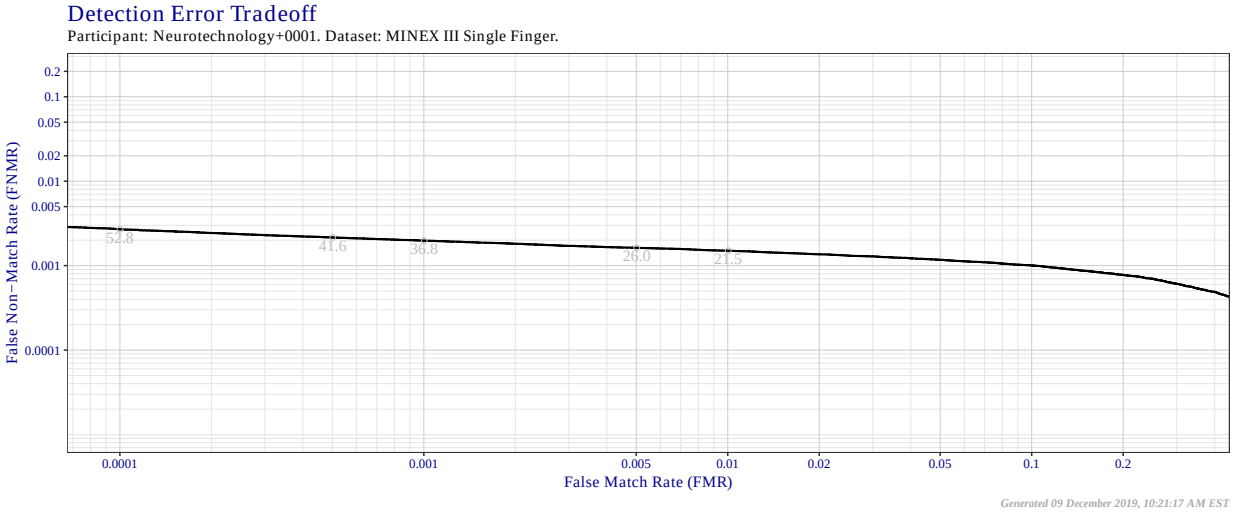

Figure 28: Detection error tradeoff of individual index fingers compared in the MINEX III evaluation.

Table 30: False non-match rate values at specific false match rates for the MINEX III single finger dataset.

FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
0.0027	0.002	0.0015

6.2 Two Finger

Figure 29 and Table 31 show combined two finger results (i.e., sum fusion of the single finger results), which correspond to Figure 7 and Table 7 from any MINEX III report card.

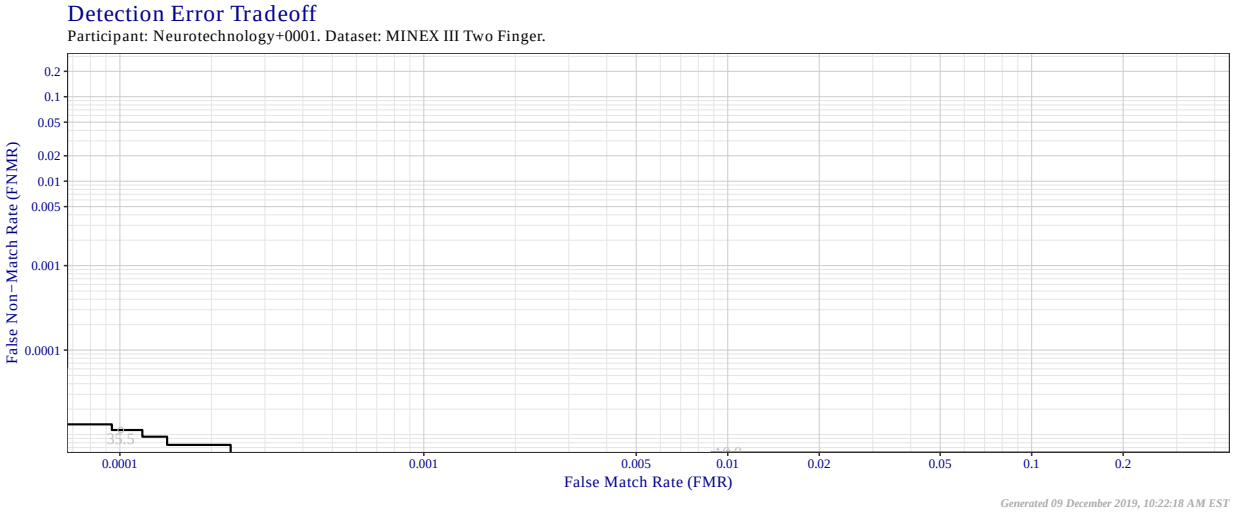

Figure 29: Detection error tradeoff of combined index fingers compared in the MINEX III evaluation.

Table 31: False non-match rate values at specific false match rates for the MINEX III two finger dataset.

FNMR @ FMR = 0.0001	FNMR @ FMR = 0.001	FNMR @ FMR = 0.01
0.000011	0.000002	0