

# – Supplementary Material –

## Rethinking Common Assumptions to Mitigate Racial Bias in Face Recognition Datasets

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### A. Additional Single Race Analysis

In Table 1 we provide the results of our single race experiments in tabular form for completeness.

### B. Additional Race Distribution Analysis

In Figure 1 we provide an extended view of Figure 1 from the main paper, highlighting additional distribution points of interest. This view reinforces that more heavily skewed distributions sometimes do lead to more fairness (less variance) across races.

In Figure 2, we show VGGFace2 [1] race distribution results are comparable to those shown for ArcFace [2] in the main body of the paper. The trends they demonstrate are similar in terms of both accuracy and variance (fairness).

In Table 2, Table 3, Table 4, and Table 5 we provide the results of our race distribution experiments in tabular form for ArcFace and VGGFace2 respectively (2 tables each) again for completeness.

### References

- [1] Qiong Cao, Li Shen, Weidi Xie, Omkar M Parkhi, and Andrew Zisserman. Vggface2: A dataset for recognising faces across pose and age. In *2018 13th IEEE international conference on automatic face & gesture recognition (FG 2018)*, pages 67–74. IEEE, 2018. 1
- [2] Jiankang Deng, Jia Guo, Niannan Xue, and Stefanos Zafeiriou. Arcface: Additive angular margin loss for deep face recognition. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pages 4690–4699, 2019. 1

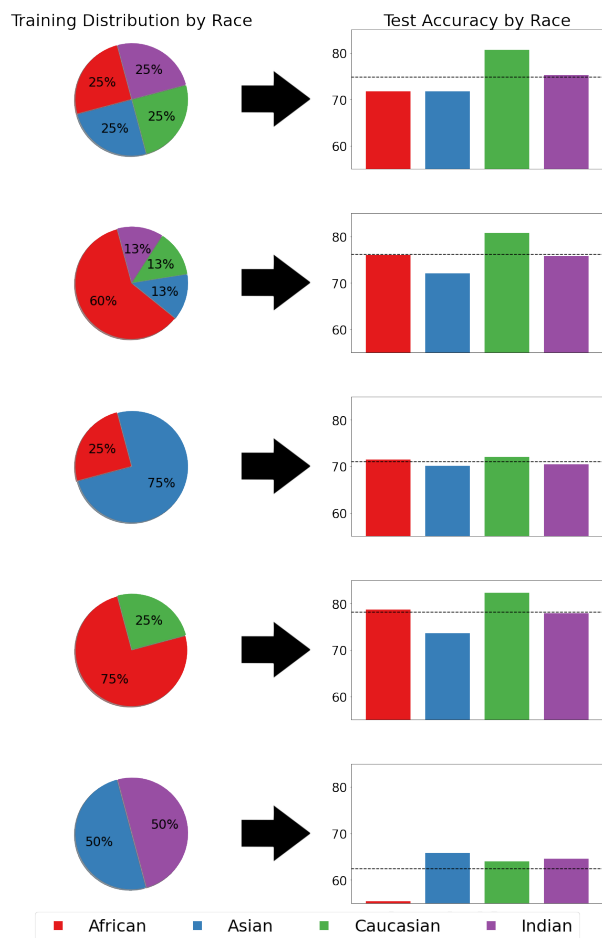


Figure 1: **Balanced vs skewed training datasets.** An extension of our Figure 1 from the main paper, with additional distributions. Data for this figure is described in Section 4.2 of the main paper and provided in Table 2 and Table 3

ArcFace				
Train Race	Test Race			
	African	Asian	Caucasian	Indian
African	85.5 ± 0.3	75.0 ± 0.2	82.4 ± 0.2	80.9 ± 0.7
Asian	58.6 ± 0.5	71.8 ± 0.6	68.7 ± 0.5	66.5 ± 0.4
Caucasian	71.5 ± 0.5	76.4 ± 0.4	89.1 ± 0.2	81.2 ± 0.3
Indian	61.2 ± 0.6	68.5 ± 0.5	73.7 ± 0.4	75.8 ± 0.4

CenterLoss				
Train Race	Test Race			
	African	Asian	Caucasian	Indian
African	73.7 ± 0.8	70.0 ± 0.6	74.8 ± 0.5	73.9 ± 0.4
Asian	56.1 ± 0.4	66.6 ± 0.6	63.7 ± 0.8	63.1 ± 0.9
Caucasian	66.7 ± 0.9	72.3 ± 1.0	81.4 ± 1.1	75.2 ± 0.8
Indian	58.6 ± 1.3	66.5 ± 1.5	71.1 ± 1.2	71.6 ± 0.8

SphereFace				
Train Race	Test Race			
	African	Asian	Caucasian	Indian
African	82.2 ± 0.5	74.3 ± 0.4	80.7 ± 0.4	80.0 ± 0.5
Asian	58.6 ± 0.5	69.2 ± 0.4	67.5 ± 0.4	65.7 ± 0.5
Caucasian	68.4 ± 0.3	75.4 ± 0.2	87.2 ± 0.3	79.0 ± 0.4
Indian	62.5 ± 0.3	70.6 ± 0.3	75.3 ± 0.5	78.3 ± 0.3

VGGFace2				
Train Race	Test Race			
	African	Asian	Caucasian	Indian
African	79.1 ± 0.4	72.3 ± 0.4	78.6 ± 0.3	76.5 ± 0.5
Asian	57.7 ± 0.6	69.5 ± 0.7	67.0 ± 0.7	65.6 ± 0.5
Caucasian	68.4 ± 0.3	73.5 ± 0.5	85.3 ± 0.4	77.1 ± 0.3
Indian	59.9 ± 0.3	68.2 ± 0.5	73.2 ± 0.2	75.1 ± 0.4

Table 1: **Results for single race experiments.** We train on BUPT-Balancedface data corresponding to the race in the Train Race row, and test on RFW data corresponding to the race in the Test Race column. These results correspond to those reported in scatter plot form in the main paper; they are provided as a table here for convenience.

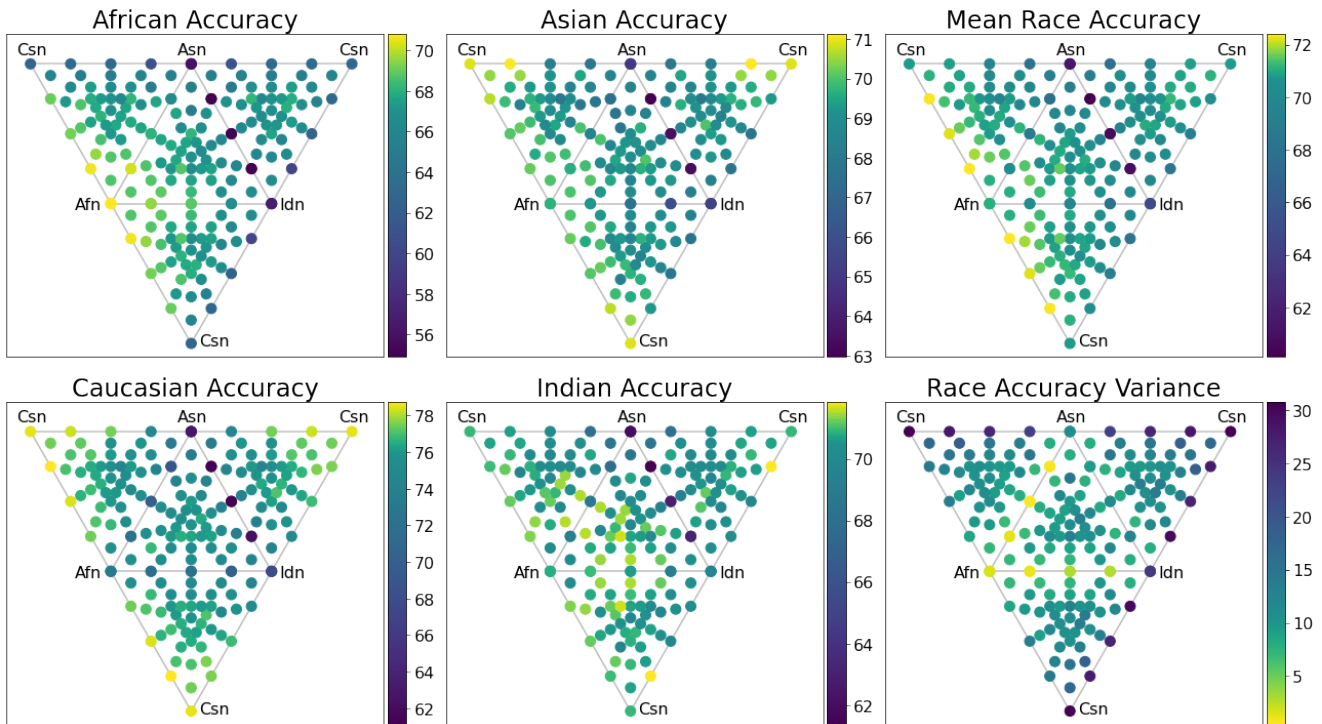


Figure 2: **Race distribution results of VGGFace2** on the 89 distributions identified in the main work. Each plot gives percent accuracy values for a single test race. These plots roughly correspond to flattened versions of the 4 nested 3-simplices; note that each plot consists of 4 connected equilateral triangles, where each triangle contains 4 parallel simplex faces projected into 2 dimensions, one from each simplex, as well as the center point. The corners of the outer simplex, which correspond to training distributions containing only data from a single race, are labeled accordingly, i.e., the point labeled “Afn” is  $(100, 0, 0, 0)$ . For readability, some points are therefore represented multiple times, such as the center  $(25, 25, 25, 25)$ , which appears in the middle of all triangles. Thus, each plot contains 181 points, of which only 89 are unique. In addition to per-race accuracy, overall average accuracy of the races is represented, as well as the accuracy variance between the 4 per-race accuracy results.

# Images per Race				Per-race Accuracy				Overall	
African	Asian	Caucasian	Indian	African	Asian	Caucasian	Indian	Accuracy	Variance
1250	1250	1250	1250	71.68	71.70	80.68	75.25	74.83	13.53
1167	1167	1166	1500	71.83	71.70	79.68	75.08	74.58	10.53
1250	1167	1167	1416	71.87	71.57	80.60	75.40	74.86	13.26
1333	1167	1167	1333	72.87	71.98	80.28	74.52	74.91	10.44
1417	1167	1166	1250	72.60	71.40	80.47	74.38	74.71	12.16
1500	1167	1167	1166	73.00	71.77	79.32	75.15	74.81	8.24
1417	1250	1167	1166	73.83	71.08	80.57	74.82	75.07	11.93
1333	1333	1167	1167	71.98	71.25	79.22	74.57	74.25	9.73
1250	1417	1167	1166	72.18	71.55	79.38	74.55	74.42	9.47
1167	1250	1167	1416	71.62	70.73	79.13	74.75	74.06	10.81
1167	1333	1167	1333	71.83	72.10	80.53	73.53	74.50	12.55
1167	1417	1166	1250	72.45	71.13	79.83	74.72	74.53	11.01
1167	1500	1167	1166	72.08	71.00	79.67	74.65	74.35	11.18
1167	1417	1250	1166	71.48	71.55	79.85	74.02	74.22	11.59
1167	1333	1333	1167	71.25	71.15	79.43	73.97	73.95	11.30
1167	1250	1417	1166	72.02	71.52	81.02	74.65	74.80	14.30
1167	1167	1250	1416	72.05	71.42	79.72	73.70	74.22	10.76
1167	1167	1333	1333	72.43	71.58	80.60	75.40	75.00	12.45
1167	1167	1416	1250	72.67	71.53	80.53	74.83	74.89	12.02
1167	1167	1500	1166	71.88	71.62	80.00	75.00	74.62	11.40
1250	1167	1417	1166	71.93	71.50	80.65	73.68	74.44	13.52
1333	1167	1333	1167	73.62	71.30	80.75	75.23	75.22	12.13
1417	1167	1250	1166	73.00	71.55	79.65	74.70	74.73	9.33

# Images per Race				Per-race Accuracy				Overall	
African	Asian	Caucasian	Indian	African	Asian	Caucasian	Indian	Accuracy	Variance
1250	1250	1250	1250	71.68	71.70	80.68	75.25	74.83	13.53
1000	1000	1000	2000	71.08	71.78	79.65	74.33	74.21	11.32
1250	1000	1000	1750	72.02	72.40	78.62	74.38	74.35	6.86
1500	1000	1000	1500	72.68	71.22	79.90	74.37	74.54	10.81
1750	1000	1000	1250	72.92	72.15	79.53	74.82	74.85	8.24
2000	1000	1000	1000	74.53	71.85	80.33	75.57	75.57	9.40
1750	1250	1000	1000	72.17	72.28	79.30	74.12	74.47	8.39
1500	1500	1000	1000	72.98	71.65	80.33	74.32	74.82	11.02
1250	1750	1000	1000	72.27	71.20	79.72	73.98	74.29	10.80
1000	1250	1000	1750	70.83	71.15	78.83	73.47	73.57	10.26
1000	1500	1000	1500	71.80	71.00	79.42	73.68	73.98	10.82
1000	1750	1000	1250	70.48	70.70	79.20	73.28	73.42	12.36
1000	2000	1000	1000	71.18	71.62	78.80	73.57	73.79	9.17
1000	1750	1250	1000	72.02	71.47	79.42	74.08	74.25	9.86
1000	1500	1500	1000	72.28	72.42	81.07	73.58	74.84	13.19
1000	1250	1750	1000	71.80	72.47	81.73	74.72	75.18	15.49
1000	1000	1250	1750	71.88	70.85	80.00	74.47	74.30	12.57
1000	1000	1500	1500	71.62	71.05	80.67	74.12	74.36	14.58
1000	1000	1750	1250	71.80	71.78	81.40	74.78	74.94	15.40
1000	1000	2000	1000	71.55	71.28	81.37	74.78	74.75	16.51
1250	1000	1750	1000	72.35	71.78	80.52	74.85	74.88	11.94
1500	1000	1500	1000	72.60	71.68	80.63	75.82	75.18	12.26
1750	1000	1250	1000	73.82	71.48	80.35	74.58	75.06	10.64

Table 2: **Results for ArcFace distribution experiments** for the two innermost simplexes. See Table 3 for results for the outermost simplexes.

# Images per Race				Per-race Accuracy				Overall	
African	Asian	Caucasian	Indian	African	Asian	Caucasian	Indian	Accuracy	Variance
1250	1250	1250	1250	71.68	71.70	80.68	75.25	74.83	13.53
667	667	666	3000	70.42	70.68	78.32	73.17	73.15	10.06
1250	667	666	2417	72.03	71.22	79.13	75.17	74.39	9.68
1833	667	667	1833	73.52	71.60	79.68	75.27	75.02	8.94
2417	667	666	1250	75.15	71.53	79.87	75.38	75.48	8.73
3000	667	667	666	75.97	72.05	80.73	75.82	76.14	9.49
2417	1250	667	666	75.88	71.70	79.42	75.50	75.62	7.47
1833	1833	667	667	72.72	71.63	79.57	75.25	74.79	9.32
1250	2417	667	666	72.05	71.30	77.97	72.98	73.58	6.78
667	1250	666	2417	70.82	71.70	78.17	73.53	73.55	8.05
667	1833	667	1833	69.80	71.10	77.90	73.17	72.99	9.47
667	2417	666	1250	68.77	70.08	77.15	72.20	72.05	10.17
667	3000	667	666	68.78	69.87	76.97	72.32	71.98	9.92
667	2417	1250	666	70.12	71.07	79.55	73.02	73.44	13.55
667	1833	1833	667	69.68	71.32	80.33	74.08	73.85	16.47
667	1250	2417	666	69.93	71.93	81.73	74.95	74.64	19.97
667	666	1250	2417	70.62	70.27	79.93	73.88	73.67	15.05
667	667	1833	1833	70.17	71.67	80.93	75.00	74.44	17.11
667	666	2417	1250	71.80	71.88	81.63	73.68	74.75	16.36
667	667	3000	666	70.78	72.17	82.45	75.57	75.24	20.35
1250	667	2417	666	72.60	72.83	81.78	76.10	75.83	13.73
1833	667	1833	667	74.52	72.47	81.58	76.12	76.17	11.44
2417	667	1250	666	75.75	71.92	81.05	75.58	76.07	10.60

# Images per Race				Per-race Accuracy				Overall	
African	Asian	Caucasian	Indian	African	Asian	Caucasian	Indian	Accuracy	Variance
1250	1250	1250	1250	71.68	71.70	80.68	75.25	74.83	13.53
0	0	0	5000	58.38	66.17	70.57	74.32	67.36	35.17
1250	0	0	3750	71.33	67.37	73.18	73.60	71.37	6.07
2500	0	0	2500	74.85	69.60	74.32	74.50	73.32	4.64
3750	0	0	1250	78.03	69.87	77.10	76.58	75.40	10.46
5000	0	0	0	78.92	71.05	77.28	76.65	75.97	8.77
3750	1250	0	0	76.78	70.40	76.40	76.00	74.90	6.81
2500	2500	0	0	72.80	68.87	74.02	72.75	72.11	3.76
1250	3750	0	0	71.52	70.15	72.05	70.43	71.04	0.60
0	1250	0	3750	56.57	64.72	63.62	65.02	62.48	11.92
0	2500	0	2500	55.47	65.80	63.97	64.58	62.45	16.71
0	3750	0	1250	56.12	65.03	61.52	63.20	61.47	11.09
0	5000	0	0	55.73	66.03	62.98	62.60	61.84	14.19
0	3750	1250	0	62.55	71.00	78.43	72.10	71.02	31.97
0	2500	2500	0	63.67	72.03	81.35	73.30	72.59	39.29
0	1250	3750	0	64.23	71.50	82.80	74.70	73.31	44.41
0	0	1250	3750	63.23	69.72	79.02	74.00	71.49	33.57
0	0	2500	2500	64.83	70.78	81.98	74.82	73.10	38.89
0	0	3750	1250	64.13	72.58	83.27	75.25	73.81	46.66
0	0	5000	0	66.48	73.05	84.15	76.92	75.15	40.91
1250	0	3750	0	74.78	72.50	83.67	76.65	76.90	17.42
2500	0	2500	0	76.38	72.90	83.68	77.10	77.52	15.20
3750	0	1250	0	78.68	73.58	82.30	77.83	78.10	9.61

Table 3: **Results for ArcFace distribution experiments** for the two outermost simplexes. See Table 2 for results for the innermost simplexes.

# Images per Race				Per-race Accuracy				Overall	
African	Asian	Caucasian	Indian	African	Asian	Caucasian	Indian	Accuracy	Variance
1250	1250	1250	1250	66.95	68.97	75.82	69.73	70.37	10.93
1167	1167	1166	1500	67.60	69.32	76.25	70.00	70.79	10.70
1250	1167	1167	1416	67.33	69.67	76.03	70.62	70.91	10.17
1333	1167	1167	1333	66.70	68.63	76.35	70.72	70.60	13.04
1417	1167	1166	1250	68.72	69.23	76.58	71.65	71.55	9.68
1500	1167	1167	1166	67.25	68.73	75.98	71.22	70.80	10.98
1417	1250	1167	1166	67.73	69.50	76.00	70.93	71.04	9.48
1333	1333	1167	1167	67.55	69.28	75.73	71.45	71.00	9.36
1250	1417	1167	1166	67.62	69.22	75.57	71.43	70.96	8.92
1167	1250	1167	1416	66.98	70.00	76.08	71.20	71.07	10.75
1167	1333	1167	1333	66.47	68.98	76.42	70.53	70.60	13.38
1167	1417	1166	1250	67.18	69.12	75.88	70.45	70.66	10.45
1167	1500	1167	1166	68.15	68.90	76.03	70.13	70.80	9.62
1167	1417	1250	1166	66.18	67.95	74.50	70.00	69.66	9.64
1167	1333	1333	1167	67.02	68.73	75.45	70.27	70.37	9.94
1167	1250	1417	1166	67.30	69.28	76.08	70.13	70.70	10.72
1167	1167	1250	1416	67.18	69.00	77.12	70.48	70.95	14.06
1167	1167	1333	1333	66.85	68.40	76.67	70.20	70.53	13.96
1167	1167	1416	1250	68.02	68.82	76.25	70.92	71.00	10.31
1167	1167	1500	1166	67.90	69.68	76.50	70.87	71.24	10.35
1250	1167	1417	1166	67.78	69.82	76.43	70.82	71.21	10.28
1333	1167	1333	1167	68.08	69.28	76.58	70.43	71.10	10.73
1417	1167	1250	1166	67.37	68.92	76.08	71.13	70.88	10.83
# Images per Race				Per-race Accuracy				Overall	
African	Asian	Caucasian	Indian	African	Asian	Caucasian	Indian	Accuracy	Variance
1250	1250	1250	1250	66.95	68.97	75.82	69.73	70.37	10.93
1000	1000	1000	2000	66.32	69.25	75.75	70.33	70.41	11.66
1250	1000	1000	1750	67.52	69.25	75.47	70.68	70.73	8.74
1500	1000	1000	1500	67.58	68.45	75.20	70.98	70.55	8.76
1750	1000	1000	1250	67.75	69.52	75.52	70.70	70.87	8.30
2000	1000	1000	1000	68.73	70.03	76.82	70.78	71.59	9.64
1750	1250	1000	1000	67.33	68.88	75.65	69.92	70.45	9.87
1500	1500	1000	1000	67.80	68.52	75.30	70.33	70.49	8.57
1250	1750	1000	1000	66.67	67.80	75.60	69.75	69.95	11.84
1000	1250	1000	1750	66.52	68.98	75.32	71.12	70.48	10.44
1000	1500	1000	1500	66.33	69.05	75.78	70.08	70.31	11.85
1000	1750	1000	1250	66.88	69.65	75.10	70.30	70.48	8.75
1000	2000	1000	1000	65.00	68.50	75.60	70.75	69.96	14.79
1000	1750	1250	1000	66.82	68.52	75.68	70.07	70.27	11.09
1000	1500	1500	1000	66.45	69.15	76.08	69.97	70.41	12.41
1000	1250	1750	1000	67.38	69.25	77.18	70.15	70.99	13.77
1000	1000	1250	1750	65.88	69.27	74.83	69.72	69.93	10.23
1000	1000	1500	1500	67.33	69.20	75.98	70.68	70.80	10.36
1000	1000	1750	1250	66.67	69.63	76.72	70.63	70.91	13.36
1000	1000	2000	1000	66.50	69.58	77.07	70.93	71.02	14.77
1250	1000	1750	1000	68.67	68.32	76.55	69.65	70.80	11.28
1500	1000	1500	1000	67.57	69.87	76.90	70.57	71.23	11.97
1750	1000	1250	1000	68.55	69.93	76.87	70.43	71.45	10.27

Table 4: **Results for VGGFace2 distribution experiments** for the two innermost simplexes. See Table 5 for results for the outermost simplexes.

# Images per Race				Per-race Accuracy				Overall	
African	Asian	Caucasian	Indian	African	Asian	Caucasian	Indian	Accuracy	Variance
1250	1250	1250	1250	66.95	68.97	75.82	69.73	70.37	10.93
667	667	666	3000	66.77	68.33	74.28	70.43	69.95	7.94
1250	667	666	2417	66.65	68.88	75.15	71.20	70.47	9.89
1833	667	667	1833	68.32	68.92	75.22	71.52	70.99	7.40
2417	667	666	1250	68.90	69.23	75.55	71.43	71.28	7.03
3000	667	667	666	68.68	69.98	75.63	70.07	71.09	7.18
2417	1250	667	666	68.70	69.88	75.63	71.55	71.44	6.88
1833	1833	667	667	67.68	69.97	75.45	71.52	71.15	8.01
1250	2417	667	666	67.65	67.75	74.27	70.07	69.93	7.19
667	1250	666	2417	66.22	68.93	73.73	70.67	69.89	7.45
667	1833	667	1833	66.28	68.62	74.20	69.30	69.60	8.30
667	2417	666	1250	66.98	68.43	74.37	70.48	70.07	7.71
667	3000	667	666	65.35	68.53	73.28	68.48	68.91	8.03
667	2417	1250	666	65.70	69.47	75.95	70.35	70.37	13.44
667	1833	1833	667	64.92	69.12	75.75	70.27	70.01	14.94
667	1250	2417	666	65.13	70.48	77.32	70.73	70.92	18.66
667	666	1250	2417	66.70	68.73	75.87	70.47	70.44	11.59
667	667	1833	1833	66.43	68.60	76.33	70.42	70.45	13.54
667	666	2417	1250	65.58	69.78	77.60	70.63	70.90	18.62
667	667	3000	666	65.88	70.45	77.45	70.70	71.12	17.03
1250	667	2417	666	67.25	69.85	77.05	71.20	71.34	12.89
1833	667	1833	667	68.77	70.15	76.67	70.75	71.58	9.13
2417	667	1250	666	69.55	69.57	77.13	71.40	71.91	9.65

# Images per Race				Per-race Accuracy				Overall	
African	Asian	Caucasian	Indian	African	Asian	Caucasian	Indian	Accuracy	Variance
1250	1250	1250	1250	66.95	68.97	75.82	69.73	70.37	10.93
0	0	0	5000	56.75	65.33	67.72	69.63	64.86	24.24
1250	0	0	3750	66.83	65.90	70.07	69.08	67.97	2.80
2500	0	0	2500	68.82	67.72	72.15	70.62	69.83	2.87
3750	0	0	1250	69.53	69.20	71.73	70.98	70.36	1.08
5000	0	0	0	70.80	69.68	73.13	70.82	71.11	1.58
3750	1250	0	0	70.28	69.60	72.20	69.35	70.36	1.25
2500	2500	0	0	68.10	68.40	69.85	68.80	68.79	0.44
1250	3750	0	0	66.60	67.45	68.97	68.00	67.75	0.74
0	1250	0	3750	54.90	63.37	62.20	63.20	60.92	12.27
0	2500	0	2500	54.98	63.48	61.10	62.87	60.61	11.31
0	3750	0	1250	54.92	62.97	61.18	61.37	60.11	9.47
0	5000	0	0	56.02	64.97	62.75	61.88	61.40	10.94
0	3750	1250	0	60.98	67.83	74.58	68.12	67.88	23.14
0	2500	2500	0	63.07	68.23	77.50	70.08	69.72	26.78
0	1250	3750	0	63.25	71.12	78.28	70.65	70.82	28.28
0	0	1250	3750	59.98	67.72	75.08	70.32	68.27	29.90
0	0	2500	2500	62.42	67.78	76.88	69.83	69.23	26.86
0	0	3750	1250	62.87	69.23	77.57	71.85	70.38	27.89
0	0	5000	0	62.83	70.90	78.52	70.93	70.80	30.76
1250	0	3750	0	69.05	70.70	78.75	70.98	72.37	14.11
2500	0	2500	0	69.17	70.05	78.42	71.20	72.21	13.37
3750	0	1250	0	70.65	70.18	77.45	71.32	72.40	8.66

Table 5: Results for VGGFace2 distribution experiments for the two outermost simplexes. See Table 4 for results for the innermost simplexes.