Face Recognition Vendor Test 2006 Experiment 4 Covariate Study

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Motivation

Factors that influence face recognition

Motivation - Attributes of People

What makes recognition harder/easier?

Young

…

Motivation - Attributes of People

Gender?

Age

Motivation - Attributes of People

Race?

Age

Gender

Motivation - Smile?

Expression?

Age

Gender

Race

Motivation - Environment

Control: Mugshot vs. posed indoor or outdoor

Age

Gender

Race

Expression

Motivation - Glasses

Glasses in uncontrolled imagery.

Age

Gender

Race

Expression

Uncontrolled

Motivation - Recap

Age

Gender

Race

Expression

Uncontrolled

Glasses

...

But Wait, There's More, Quality

- You cannot do much about
  - Gender, Age, Race, …
- Some control over
  - Setting, Glasses, Expression, …
- What about measurable image properties?
  - Resolution, Focus, …

ISO SC 37 "Biometrics" - **Factors Affecting Face Image Quality Imaging**
ACQUISITION PROCESS AND CAPTURE DEVICE PROPERTIES
…
2. physical properties (e.g. resolution and contrast)

Covariate Analysis

For Analysis We Need …

- Lots of Performance Data
  - FRVT 2006

FACE RECOGNITION VENDOR TEST 2006

- Specific Problem
  - Uncontrolled frontal still against mugshot gallery

- Methodology
  - Generalized Linear Mixed Effect Model

$$\log\left(\frac{p_{padj}}{1-p_{padj}}\right) = \mu + \gamma_a + \gamma_b B + \gamma_j + \gamma_{aj} + \pi_p$$

Introduction - More on FRVT

FACE RECOGNITION VENDOR TEST 2006

22 participants, 10 countries

China	Denmark	Germany	Israel	Japan
Romania	Spain	South Korea	United Kingdom	United States

10 US, 7 foreign, 5 with offices in and outside the US

Executing Agency

National Institute of Standards and Technology — NIST
...working with industry to foster innovation, trade, security and jobs

Sponsoring Agencies

Director of National Intelligence
Intelligence Technology Innovation Center — ITIC

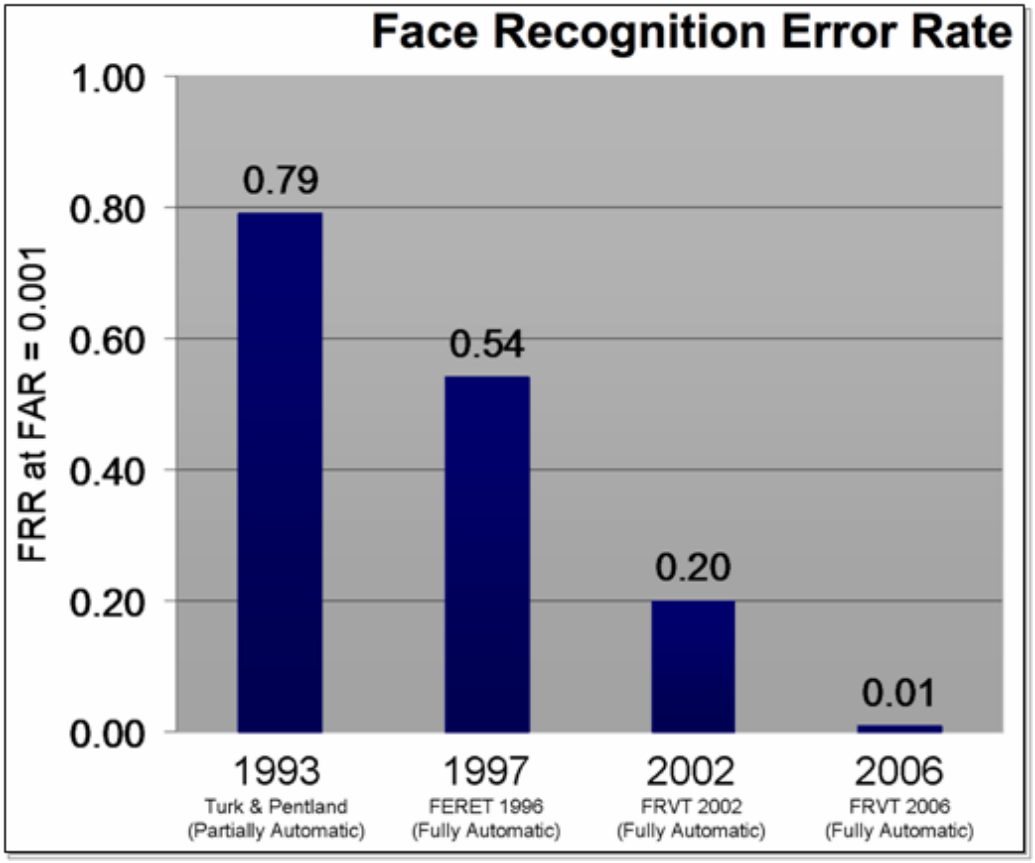
Homeland Security
- Science & Technology Directorate
- Transportation Security Administration

Federal Bureau of Investigation
www.fbi.gov

National Institute of Justice
The Research, Development, and Evaluation Agency of the U.S. Department of Justice

COMBATING TERRORISM
TSWG
TECHNICAL SUPPORT WORKING GROUP

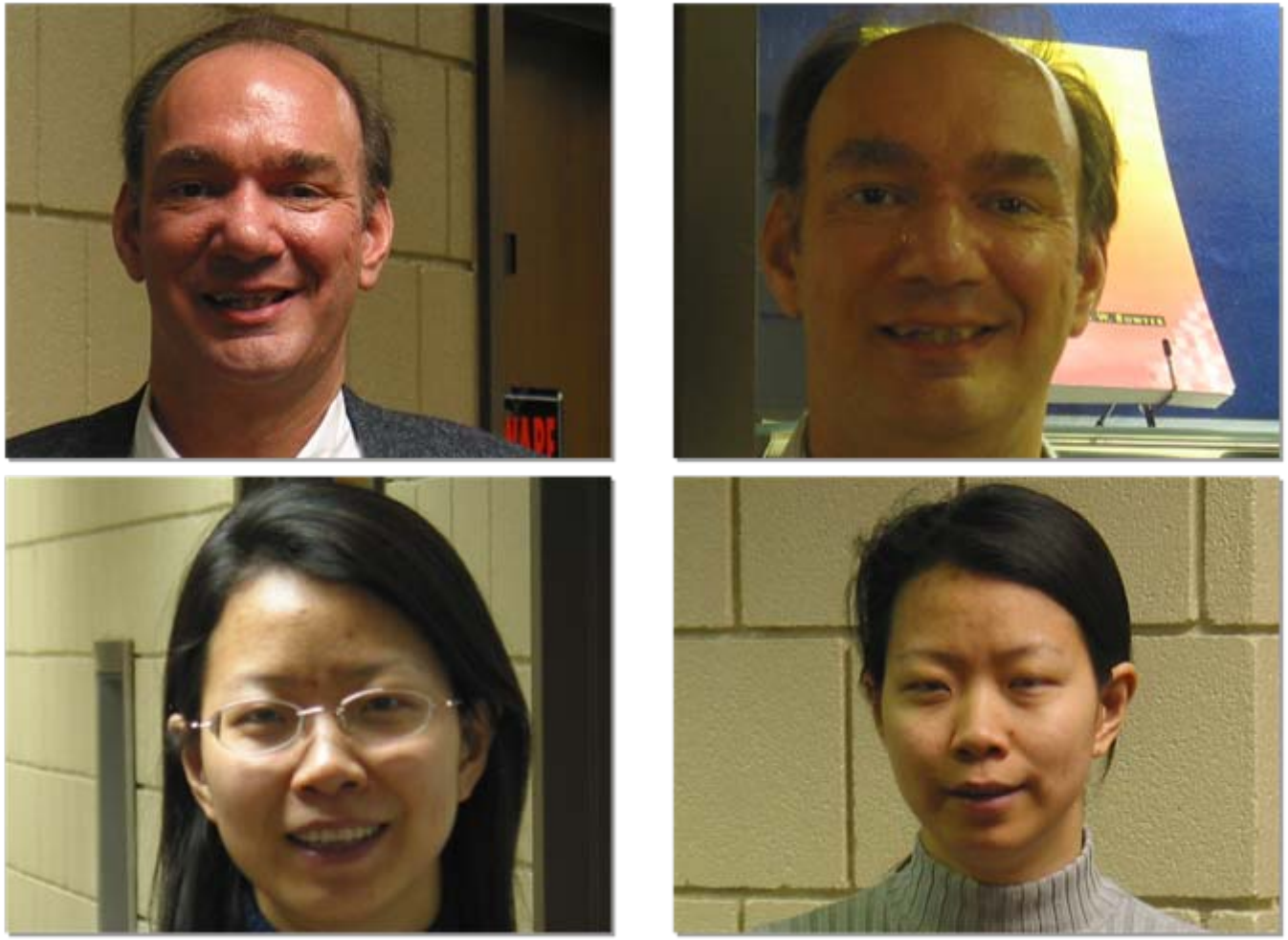
Introduction - Progress



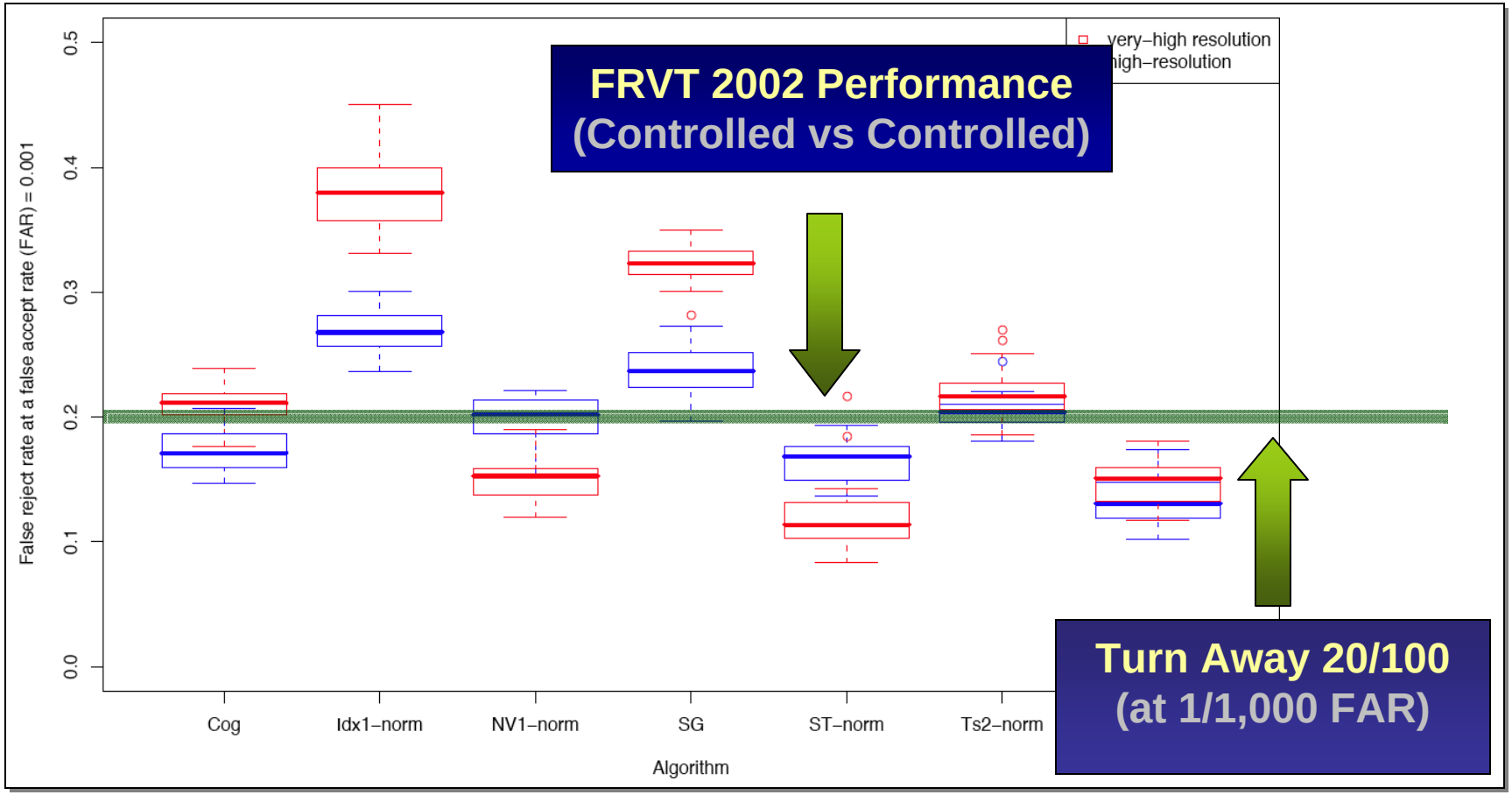
2006 - Falsely turn away 1/100 people, when only admitting 1/1000 imposters.

For controlled frontal still images

Our Focus - Uncontrolled Stills



Uncontrolled to Controlled Still



2006 - Falsely turn away 10/100 to 40/100 people, when only admitting 1/1000 impostors.

FRVT Covariate Analysis

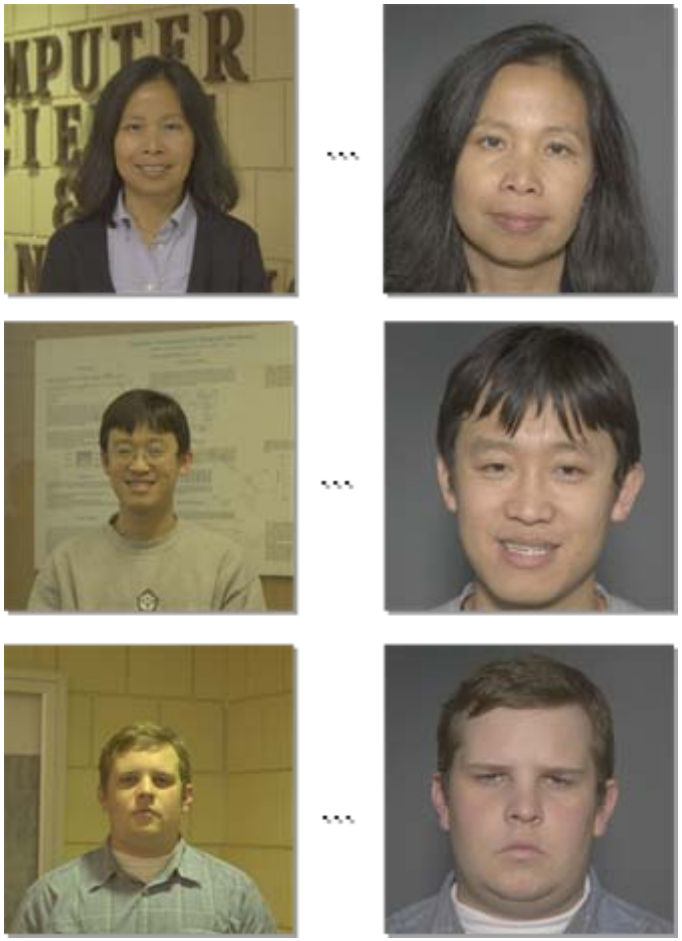
- Algorithm - score fusion of 3 top performers.

- Imagery - Uncontrolled match to Controlled.

- Subset of FRVT 2006 Experiment 4
- 345 subjects and <u>110,514</u> match scores.

Performance Variable

- Verification Outcome: Success / Failure



Verified	FAR	Gender	Race	…
Yes	1/100	Female	Asian	…

FAR is a factor

Verified	FAR	Gender	Race	…
No	1/1,000	Male	Asian	…

Levels 1/100 1/1,000 & 1/10,000

Verified	FAR	Gender	Race	…
Yes	1/10,000	Male	White	…

Distributed across pairs.

There are 110,514 pairs like this!

* Outcomes for illustration purposes only.

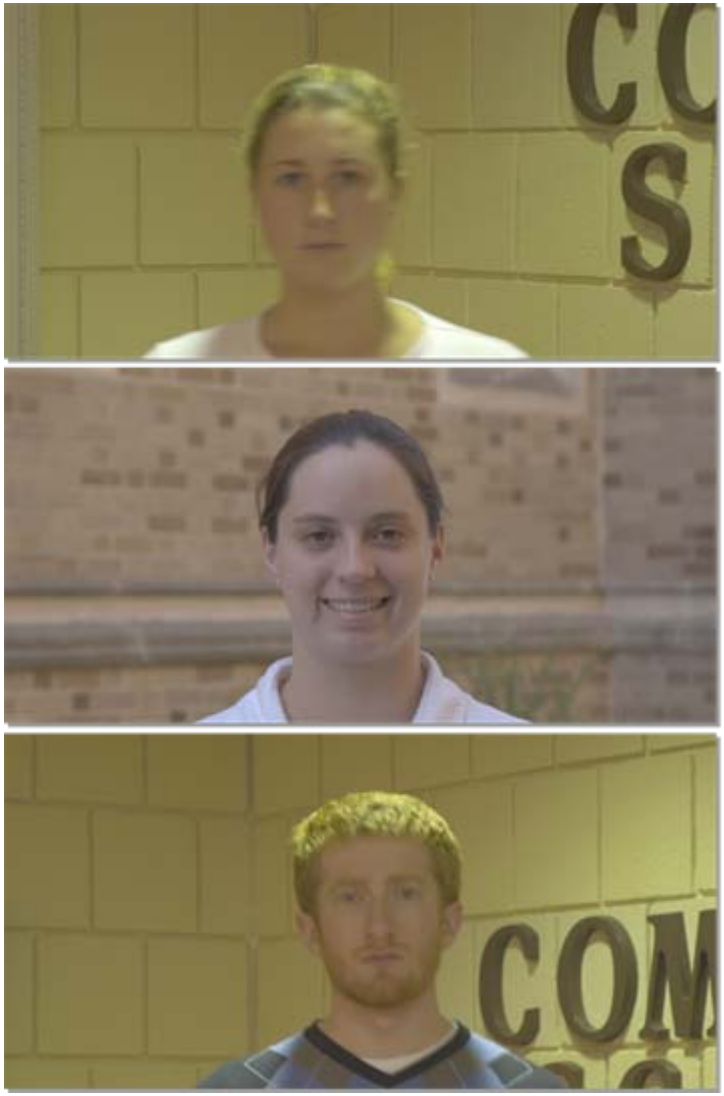
Face Region In Focus Measure

FRIFM: Sum of Sobel edge magnitude inside an ellipse bounding the face.

"Active Computer Vision by Cooperative Focus and Stereo" by Eric Krotkov.

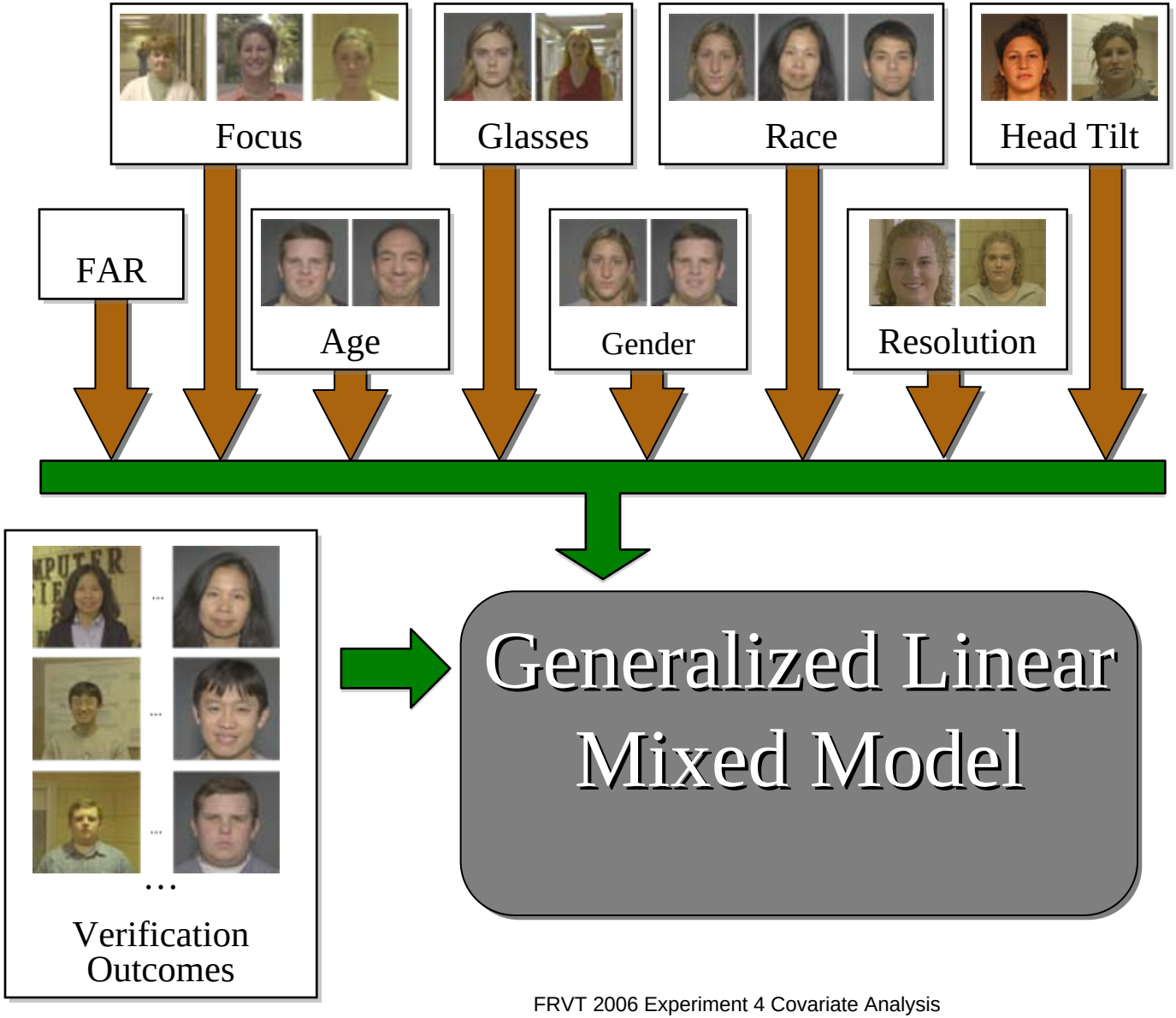
Face Region In Focus Measure

Low FRIFM examples

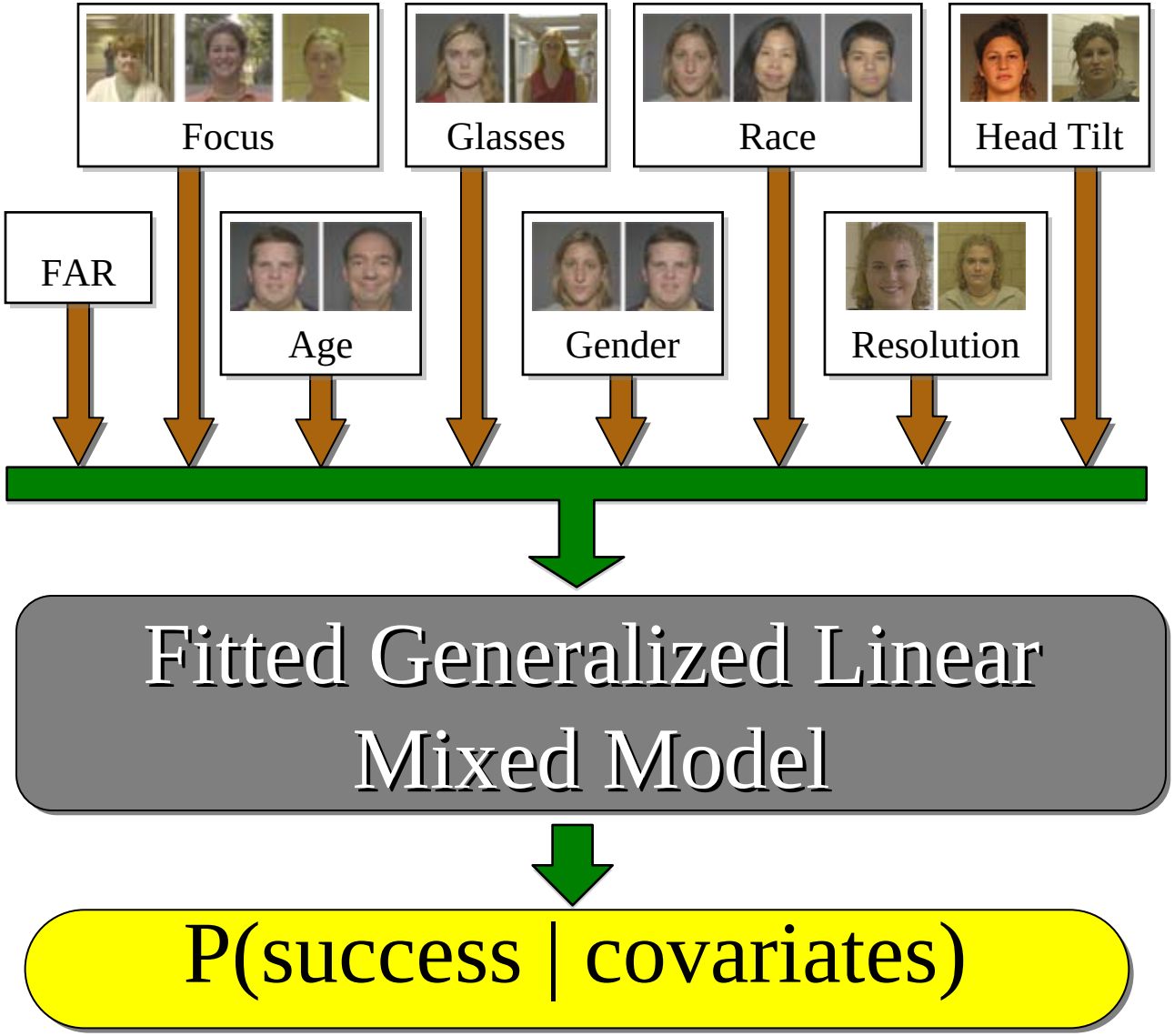


High FRIFM examples

Fitting a Statistical Model



Using the Statistical Model



Generalized Linear Mixed Model

Analysis is: ***Mixed Effects Logistic Regression with Repeated Measures on People.***

- Let A and B be 2 covariates that might influence algorithm performance. For example, A=gender (categorical) and B=Query-Eye-Distance (continuous).
  - Let a index levels of A.
- Let j index the FAR setting, α_j
- Y_{pabj} is
  - 1 if Person p is verified correctly, 0 otherwise.
- Y_{pabj} depends on:
  - person p, covariates A and B, and
  - false alarm rate α_j.

GLMM Model Continued …

Y_{pabj} is Bernoulli Random Variable with success probability p_{pabj}.

$$\log\left(\frac{p_{padj}}{1-p_{padj}}\right) = \mu + \gamma_a + \gamma_b B + \gamma_j + \gamma_{aj} + \pi_p$$

$$\begin{aligned}
\mu &= \text{grand mean} \\
\gamma_a &= \text{effect of setting } a \text{ of factor } A \\
\gamma_b &= \text{effect of covariate } B \\
\gamma_j &= \text{effect of } \alpha_j\text{, i.e. a FAR setting} \\
\gamma_{aj} &= \text{interaction effect between } A \text{ and FAR} \\
\pi_p &= \text{subject id. random effect (next page)}
\end{aligned}$$

Subject Variation

The Mixed in Generalized Linear Mixed effect Model.

$$[\pi_1, \ldots, \pi_n]^T \quad \text{Multivariate Normal where}$$

$$E(\pi_p) = 0, \text{ Variance } \pi_p = \sigma_\pi^2,$$

$$\text{Cor}\left(y_{pabj}, y_{p'a'b'j'}\right) = \begin{cases} \phi & \text{if} \quad p = p' \\ 0 & \text{if} \quad p \neq p' \end{cases}$$

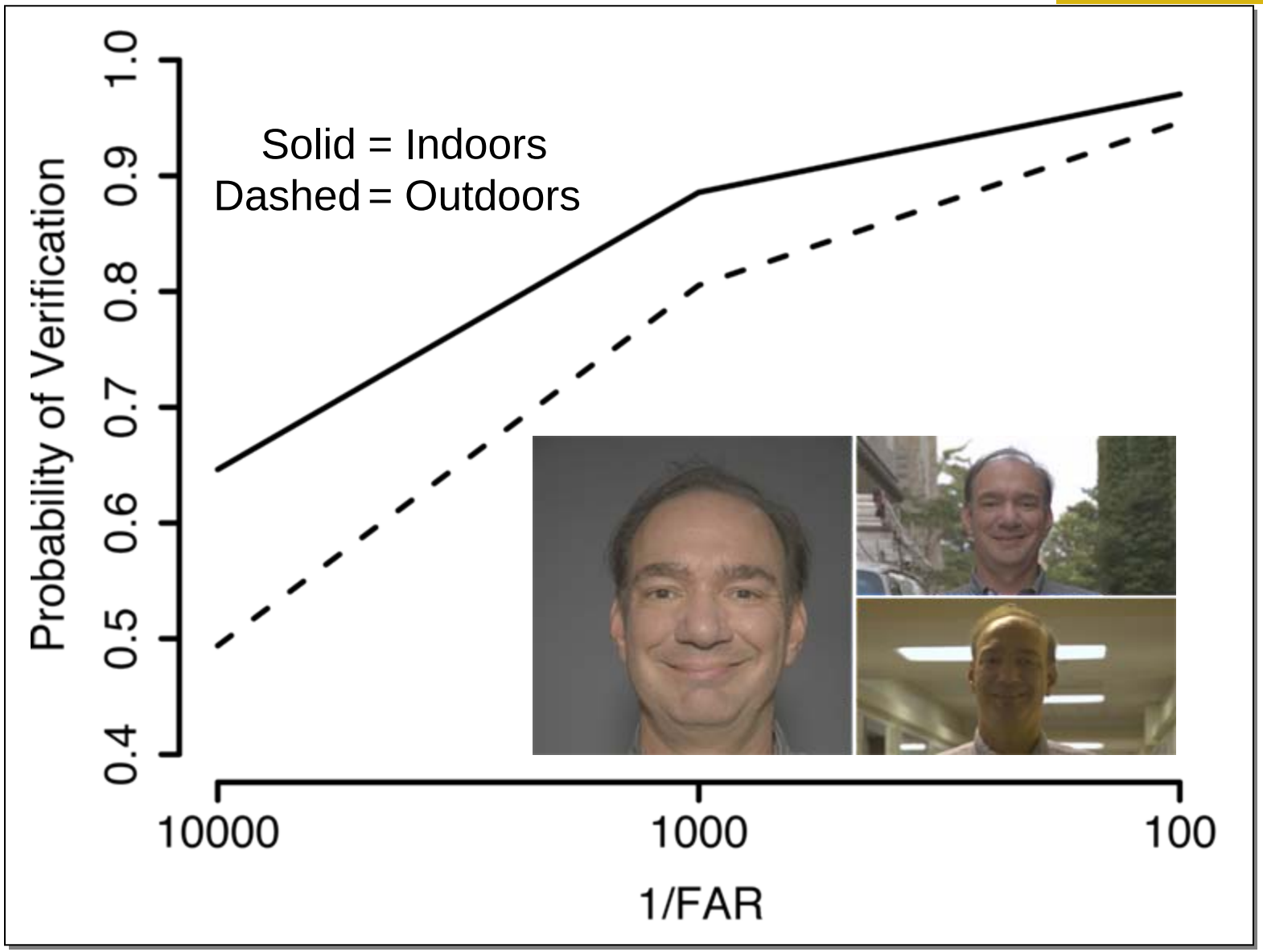
This means:

The outcomes, i. e. verification success/failure, are uncorrelated when testing different people but correlated when testing the same person under different configurations.

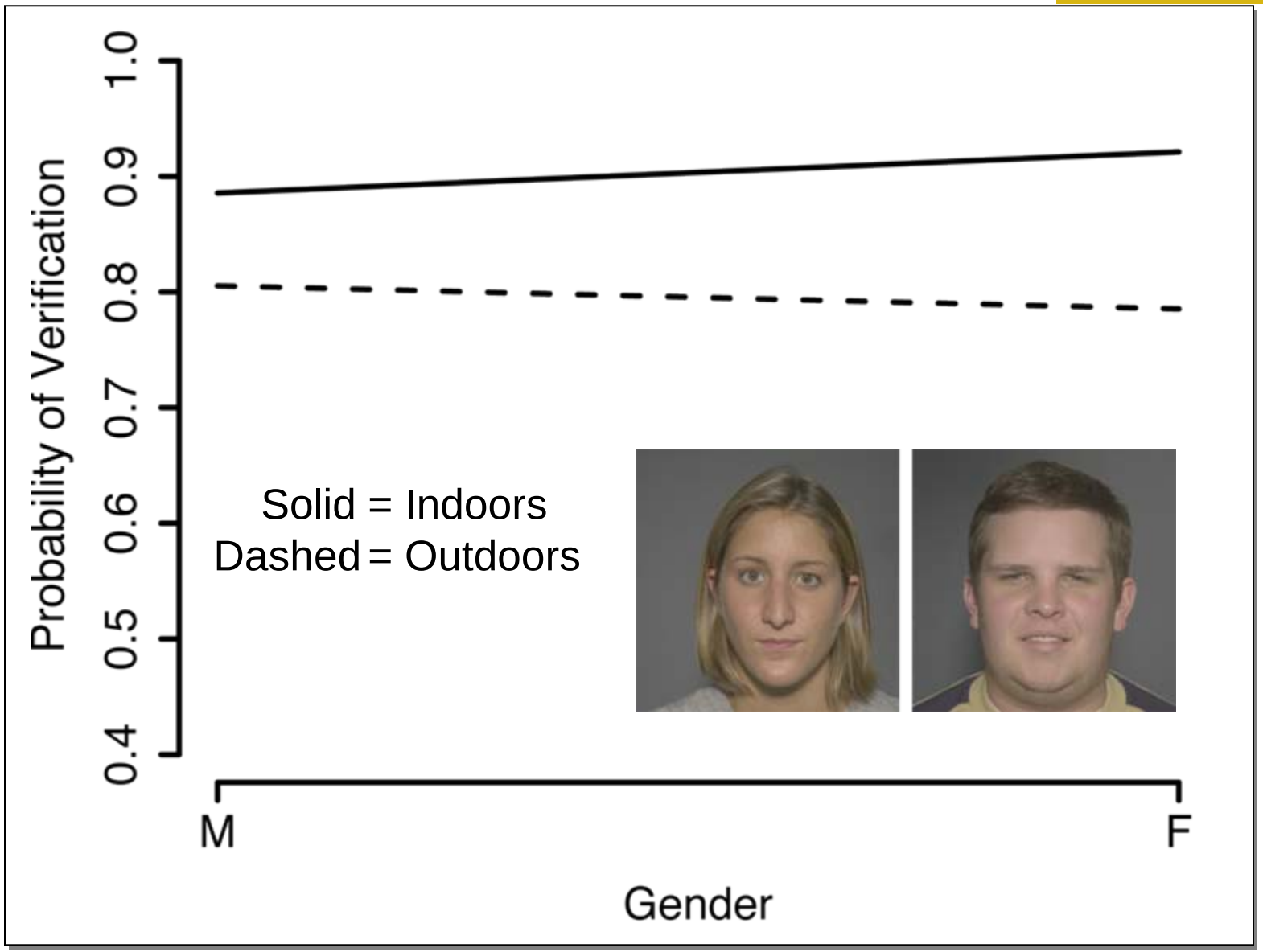
Vendor Test Covariate Analysis Findings

From the highly expected …
… to the unexpected.

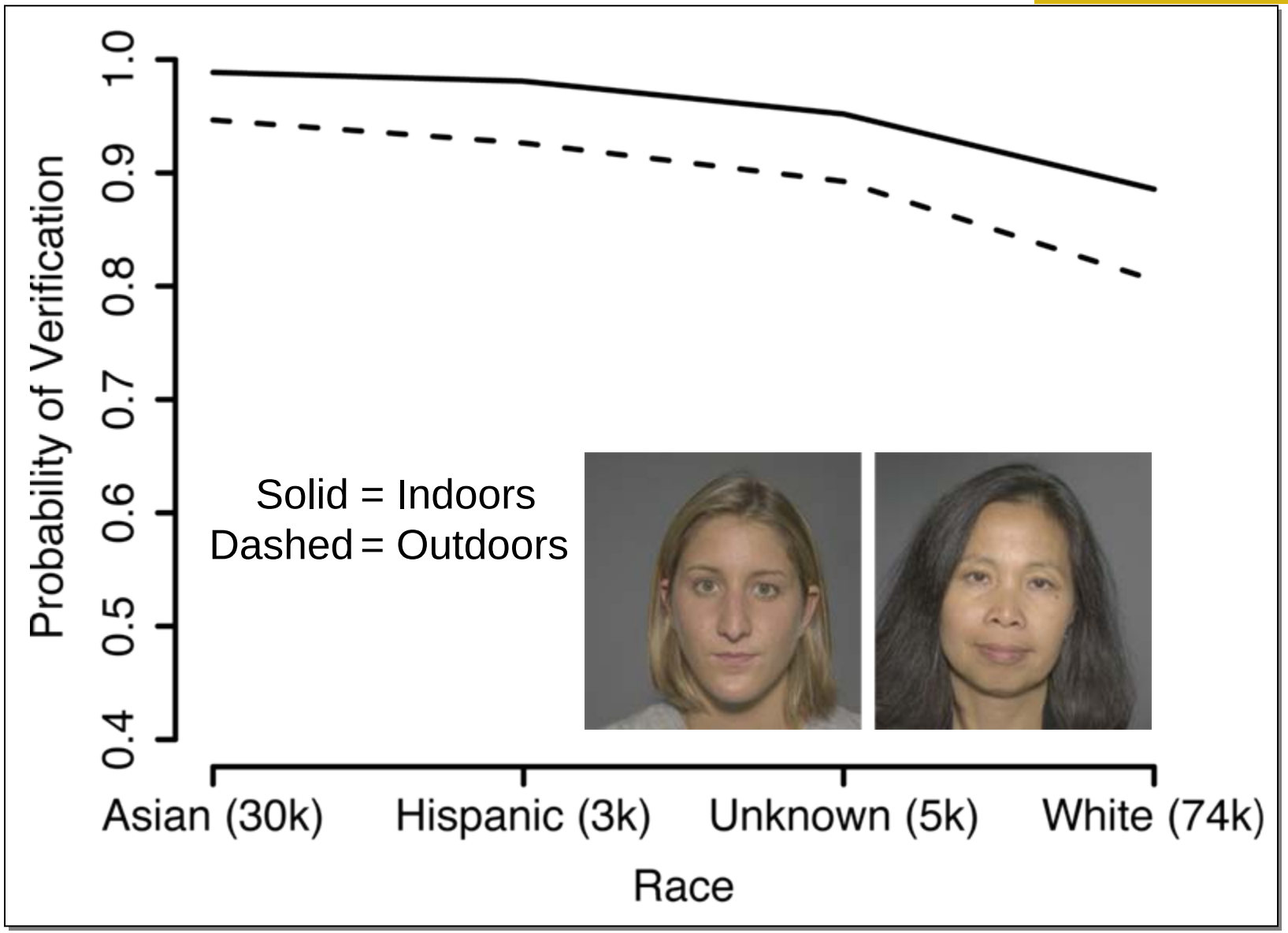
Finding 1: False Accept Rate



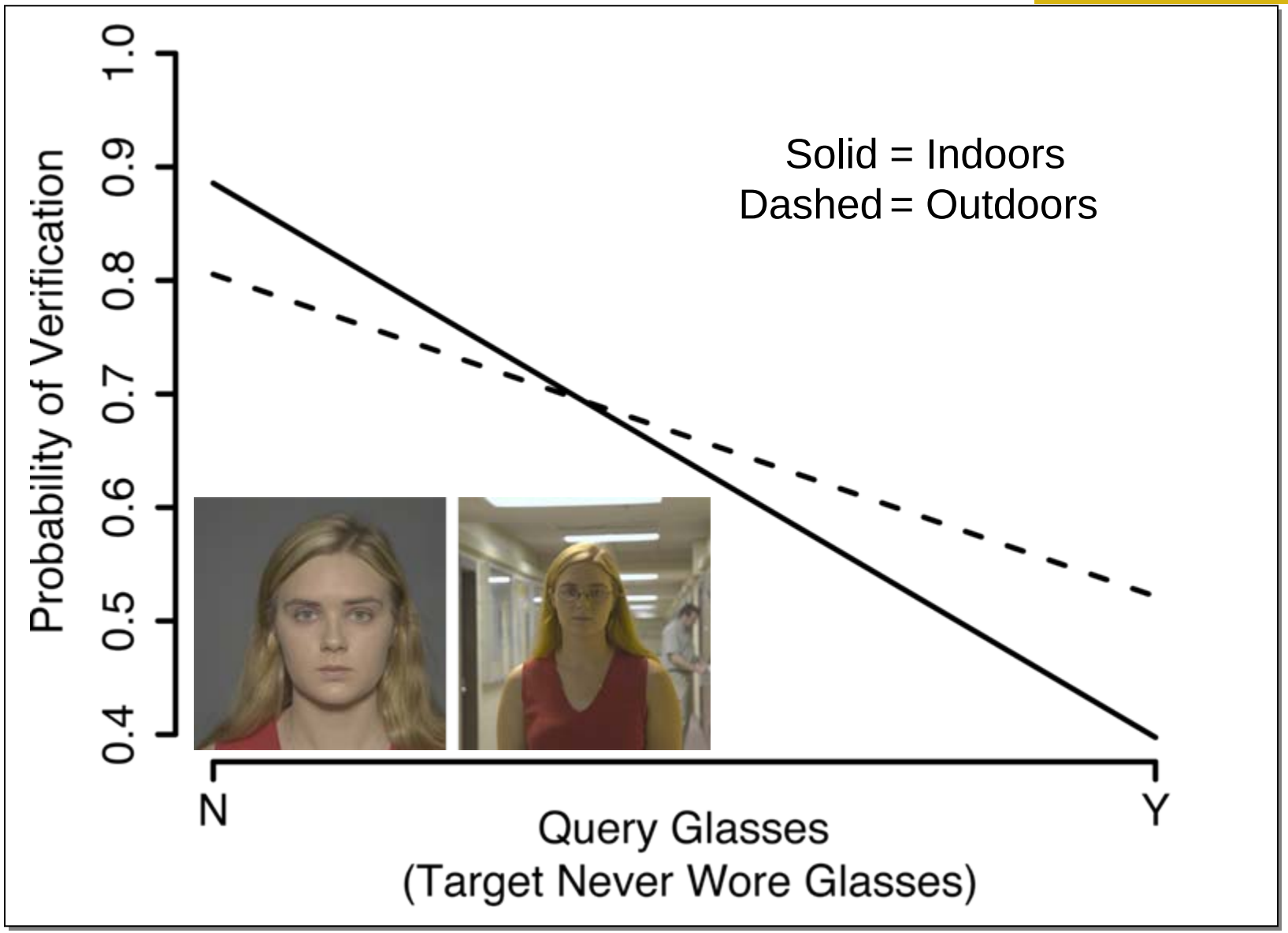
Finding 2: Gender



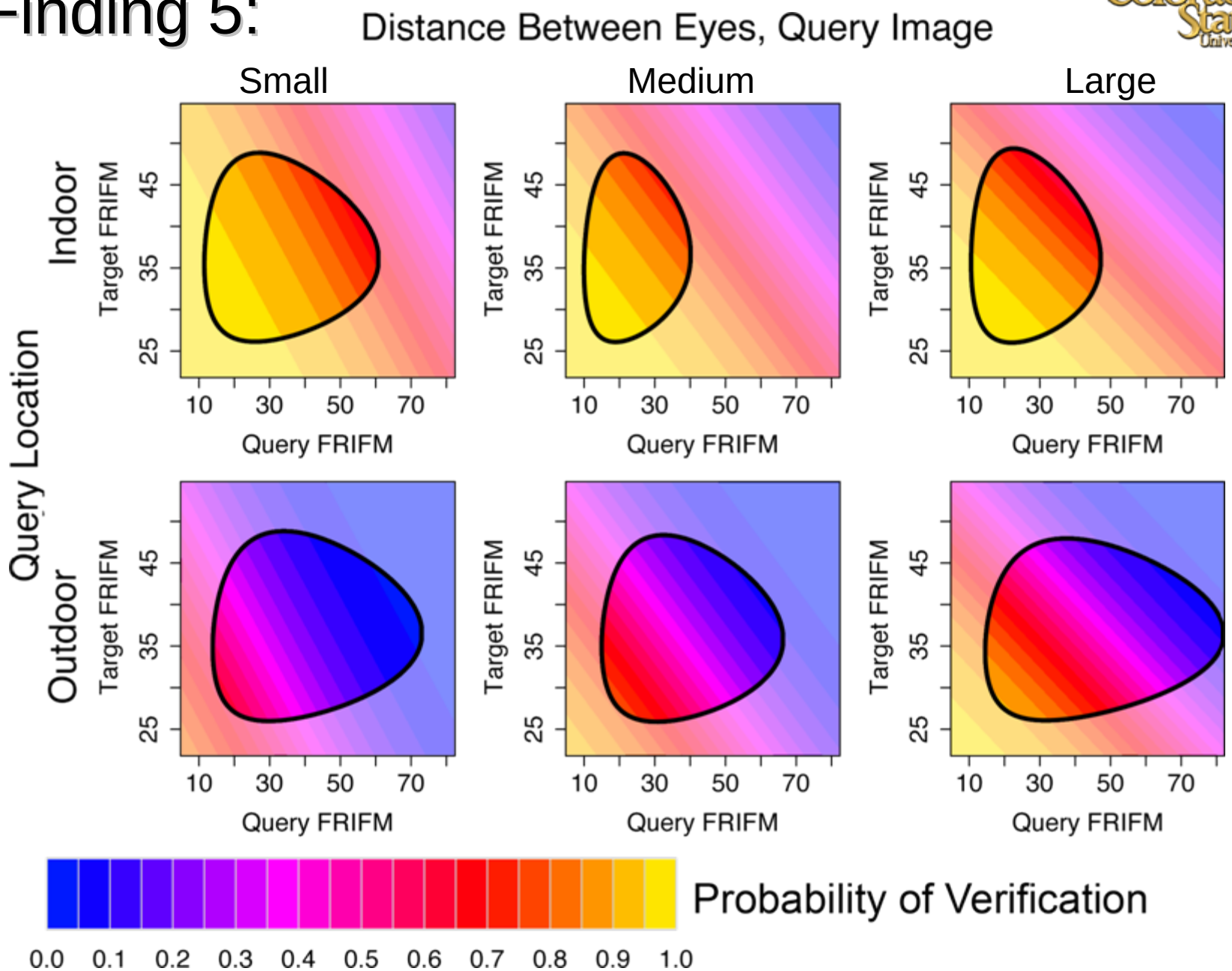
Finding 3: Race



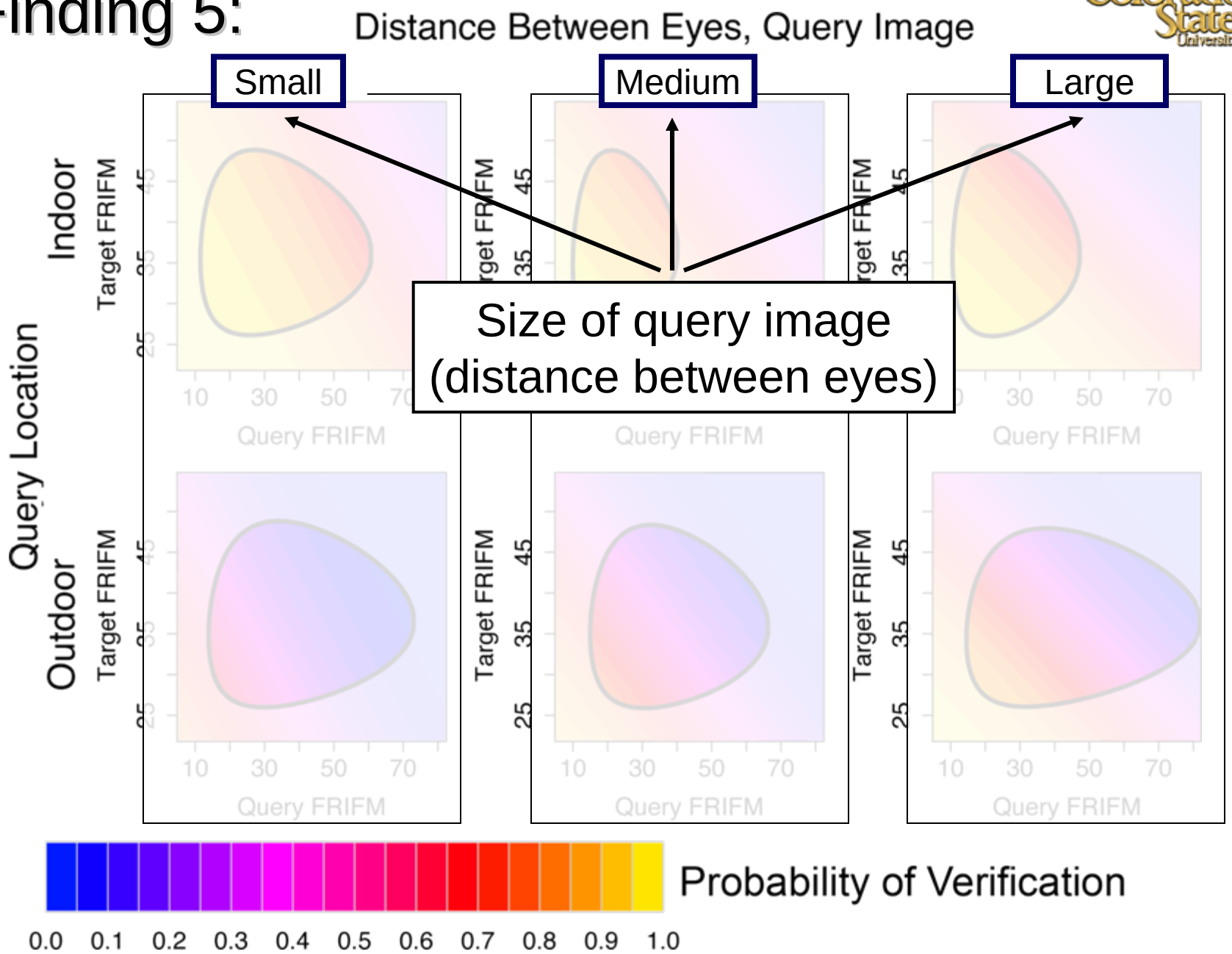
Finding 4: Glasses



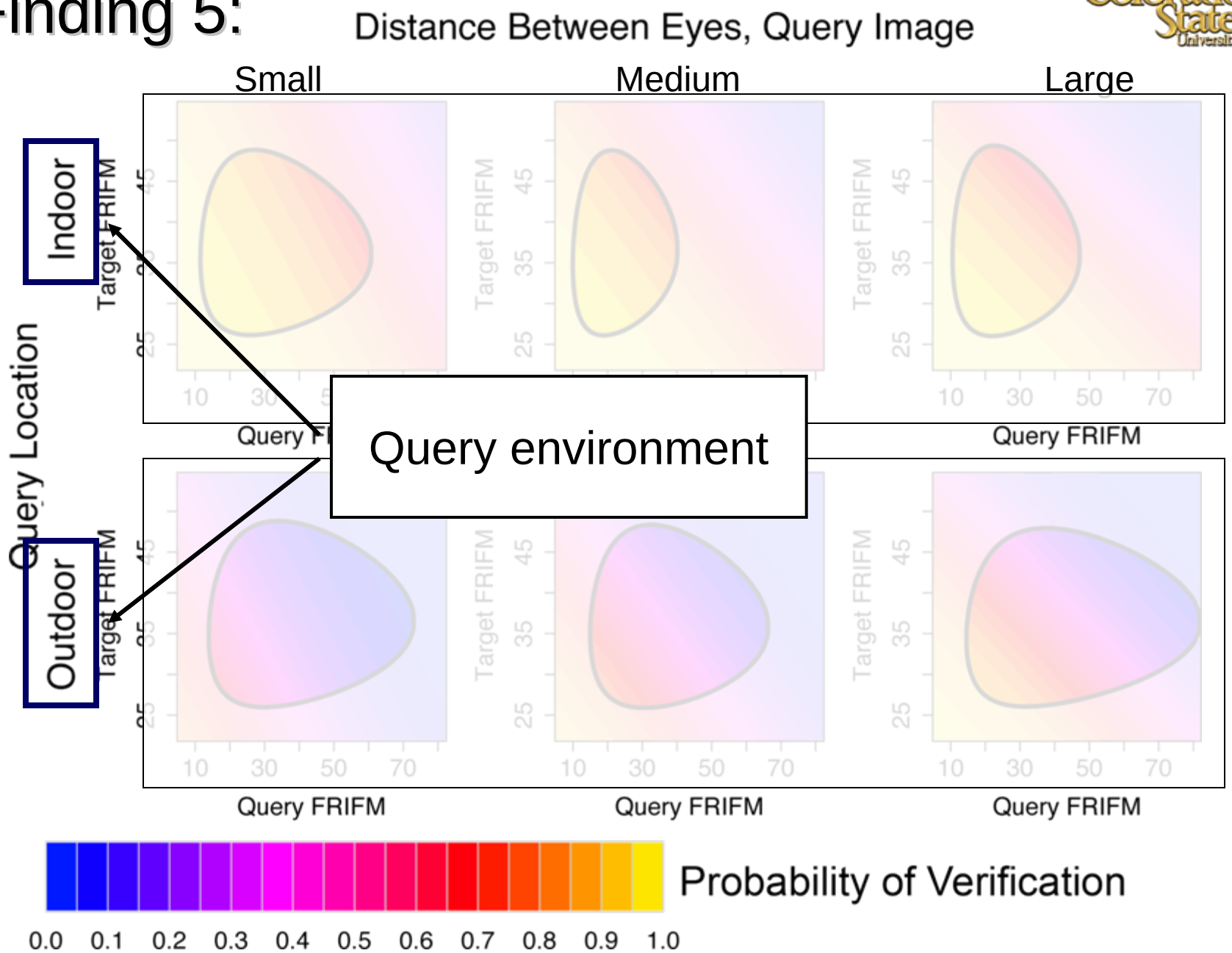
Finding 5:


Distance Between Eyes, Query Image
Small
Medium
Large
Query Location
Indoor
Outdoor
Target FRIFM
Query FRIFM
25
35
45
10
30
50
70
Probability of Verification
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

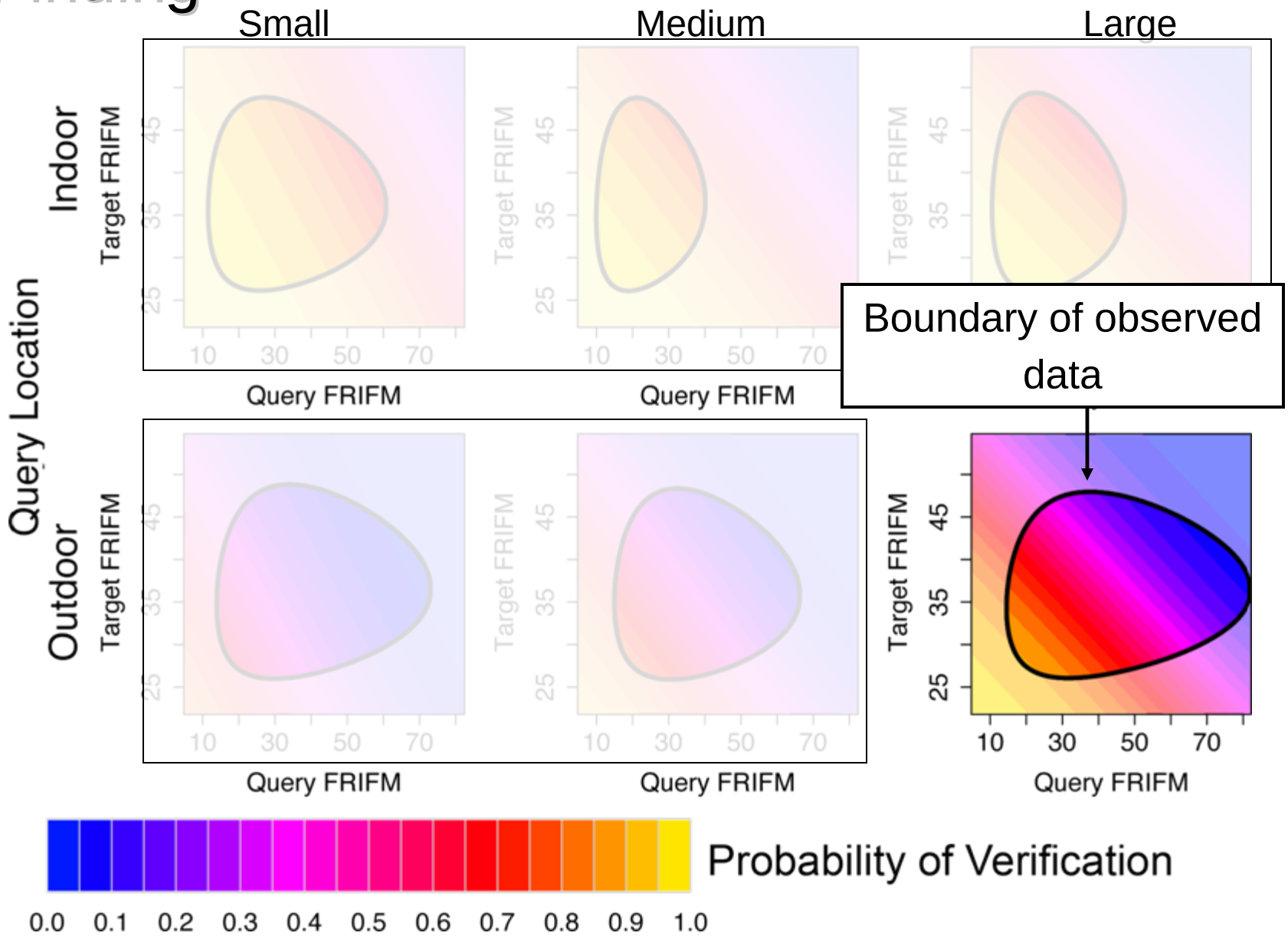
Finding 5:


Distance Between Eyes, Query Image
Small
Medium
Large
Size of query image
(distance between eyes)
Query Location
Indoor
Outdoor
Target FRIFM
Query FRIFM
10
30
50
70
25
35
45
Probability of Verification
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

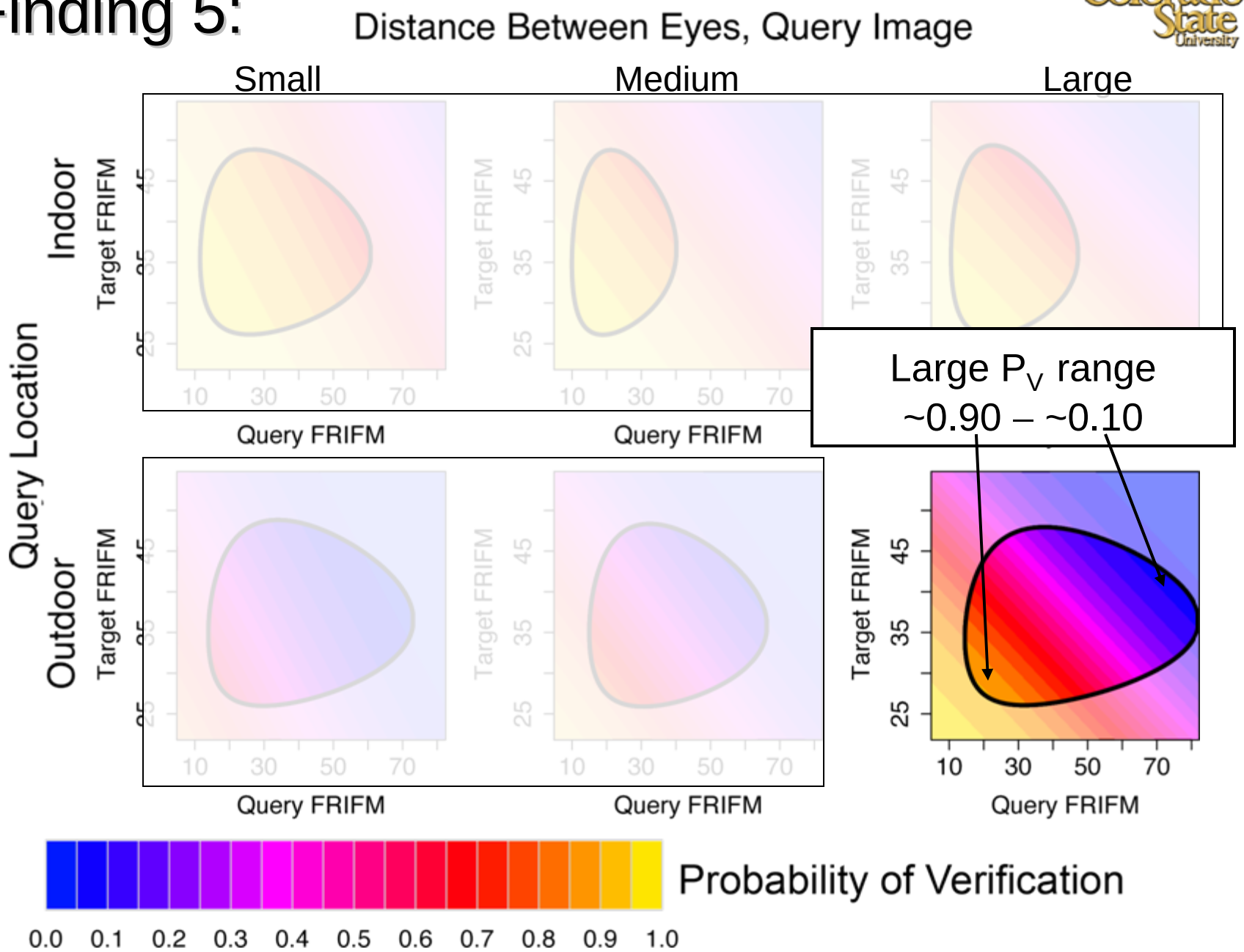
Finding 5:


Distance Between Eyes, Query Image
Small
Medium
Large
Indoor
Outdoor
Query Location
Query environment
Target FRIFM
Query FRIFM
10
30
50
70
25
35
45
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Probability of Verification

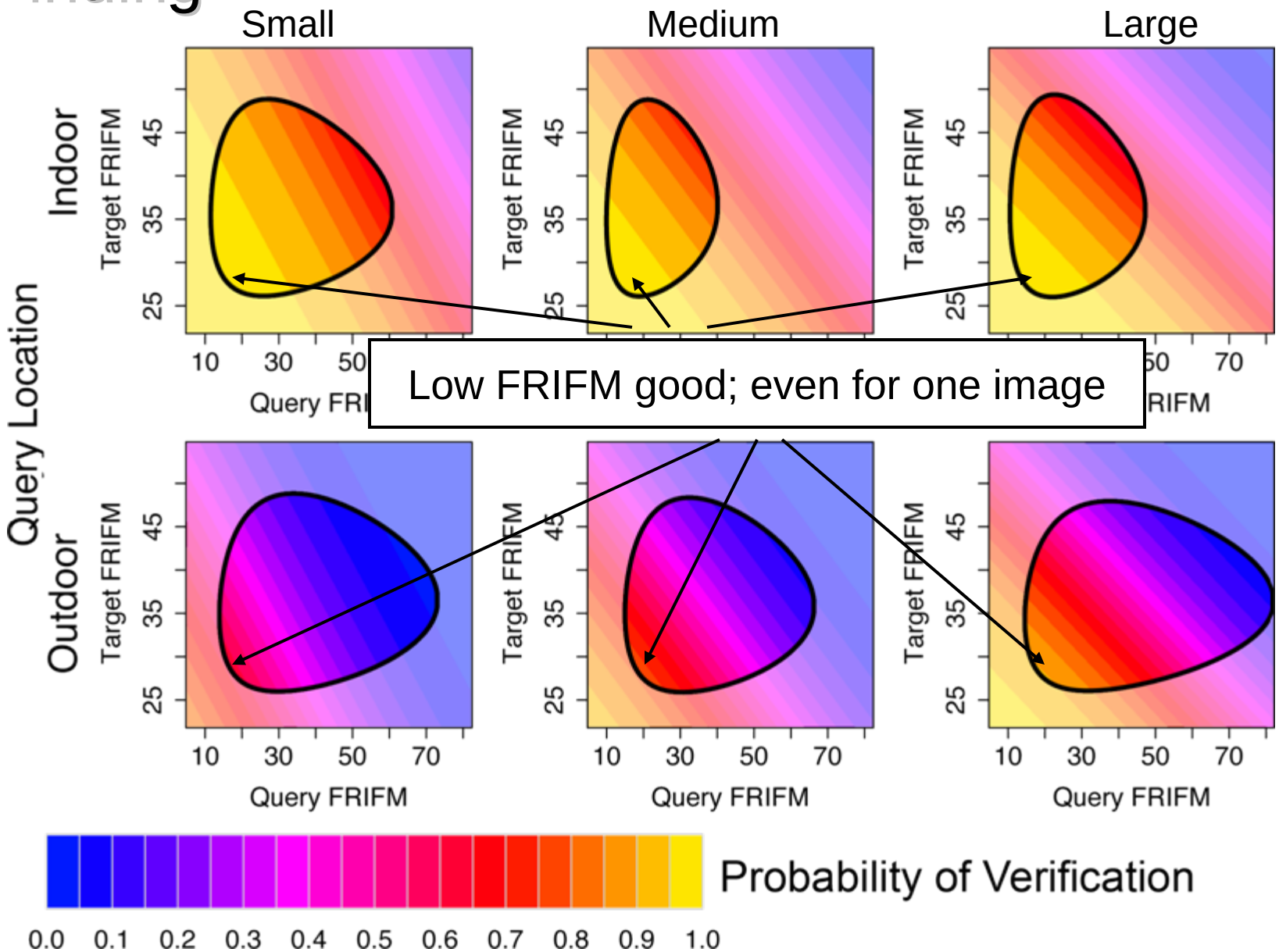
Finding 5:


Distance Between Eyes, Query Image
Small
Medium
Large
Query Location
Indoor
Outdoor
Target FRIFM
Query FRIFM
10
30
50
70
25
35
45
Boundary of observed data
Probability of Verification
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Finding 5:


Distance Between Eyes, Query Image
Small
Medium
Large
Query Location
Indoor
Outdoor
Target FRIFM
Query FRIFM
10
30
50
70
25
35
45
Large P_V range
~0.90 – ~0.10
Probability of Verification
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Finding 5:


Distance Between Eyes, Query Image
Small
Medium
Large
Query Location
Indoor
Outdoor
Target FRIFM
Query FRIFM
Low FRIFM good; even for one image
Probability of Verification
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

FRIFM Conclusion

- Large performance variation.
  - Indoors [>0.95, ~.0.70]
  - Outdoors [~0.90, ~0.10].
- Interaction between covariates
  - Environments (indoors, outdoors)
  - Query image size
  - Target and query FRIFM
- Low FRIFM good
  - Effect if control for only one image
- Outdoors: query size very important

FRIFM Conclusion

- According to this analysis
- Out of focus is higher quality
- Remember, edge density surrogate for focus
  - Is this really quality, …
  - Or other environmental factors, …
  - Or algorithm aberration?

GLMM and Quality Standards

From Covariates to Quality Measures ….

Factors Affecting Face Image Quality				
	Character **RICHNESS OF IDENTIFYING CHARACTERISTIC Š BIOLOGICAL CHARACTERS**	**Behavior** **SPOOFING**	**Imaging** **ACQUISITION PROCESS AND CAPTURE DEVICE PROPERTIES**	**Environment** **AMBIENT CONDITION**
FACE	1. anatomical characteristic (e.g. head dimensions, eye position) 2. injuries and scars 3. ethnic group 4. impairment 5. Heavy facial wears, such as thick or dark glasses	1. closed eyes 2. (exaggerated) expression 3. hair across the eye 4. head pose 5. makeup 6. subject posing (frontal / non-frontal to camera)	1. image enhancement and data reduction process 2. physical properties (e.g. resolution and contrast) 3. optical distortions 4. static properties of the background (e.g. wallpaper) 5. camera characteristics • sensor resolution 6. scene characteristics • geometric distortion	1. dynamic characteristics of the background like moving objects 2. variation in lighting and relate potential defects as • deviation from the symmetric lighting • uneven lighting on the face area • extreme strong or weak illumination 3. subject posing, e.g.: • too far (face too small), or too near (face too big) • out of focus (low sharpness) • partial occlusion of the face

Conclusion

- Quality is NOT in the eyes of the beholder
- It is in the performance numbers

- Model quantifies performance change.
  - Turn the knob.
  - Read off the change in performance.
  - Interaction between covariates.
- Tells us where to put our efforts
  - Indoors it is FRIFM.
  - Outdoors it is Query Image Size.
- These models are used in other fields.
  - e.g., Biomedical.
- Studies of Biometrics should use them.

Thank You