Preliminary Covariate Analysis Results for a Fusion of Three FRVT 2006 Algorithms.

Dr. P. Jonathon Phillips
National Institute of Standards and Technology

Dr. J. Ross Beveridge
Dr. Geof H. Givens
Dr. Bruce Draper
Mr. Yui Man Lui
Colorado State University

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Overview

- Scope of the Study
  - FRVT 2006 Uncontrolled to Controlled Imagery.
  - Fusion of three top algorithms.
- Approach
  - Generalized Linear Mixed Effect (GLMM) Model.
- Covariates
  - Properties of subjects, environment and imagery.
- Findings
  - Scientifically significant effects and interactions.

Scope of the Study

- Uncontrolled Imagery matched to Controlled.

- 345 subjects and 110,514 match scores.

Scope of the Study - Covariates

- Performance Variable
  - Verification Outcome, Success of Failure.
- False Accept Rate - FAR
- Properties of Environment
  - Mugshot lighting, indoor uncontrolled, outdoor.
- Attributes of People
  - Gender, Race, Age.
- Measurable Properties of Imagery
  - Distance between Eyes.
  - Face Region In Focus Measure (FRIFM).
    - An edge-density measure by Eric Krotkov*

* “Active Computer Vision by Cooperative Focus and Stereo” by Eric Krotkov.

From Covariate to Quality Metric

- An actionable covariate
  - some degree of control

GLMM and Quality Standards

Factors Affecting Face Image Quality				
	Character **RICHNESS OF IDENTIFYING CHARACTERISTIC – 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

Generalized Linear Mixed Model (GLMM)

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 R.V. with success probability p_{pabj}

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

μ = grand mean

γ_a = effect of setting a of factor A

γ_b = effect of covariate B

γ_j = effect of α_j

γ_{aj} = interaction effect between A and FAR

π_p = subject id. random effect (next page)

Subject Variation

The Mixed in Generalized Linear Mixed effect Model.

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

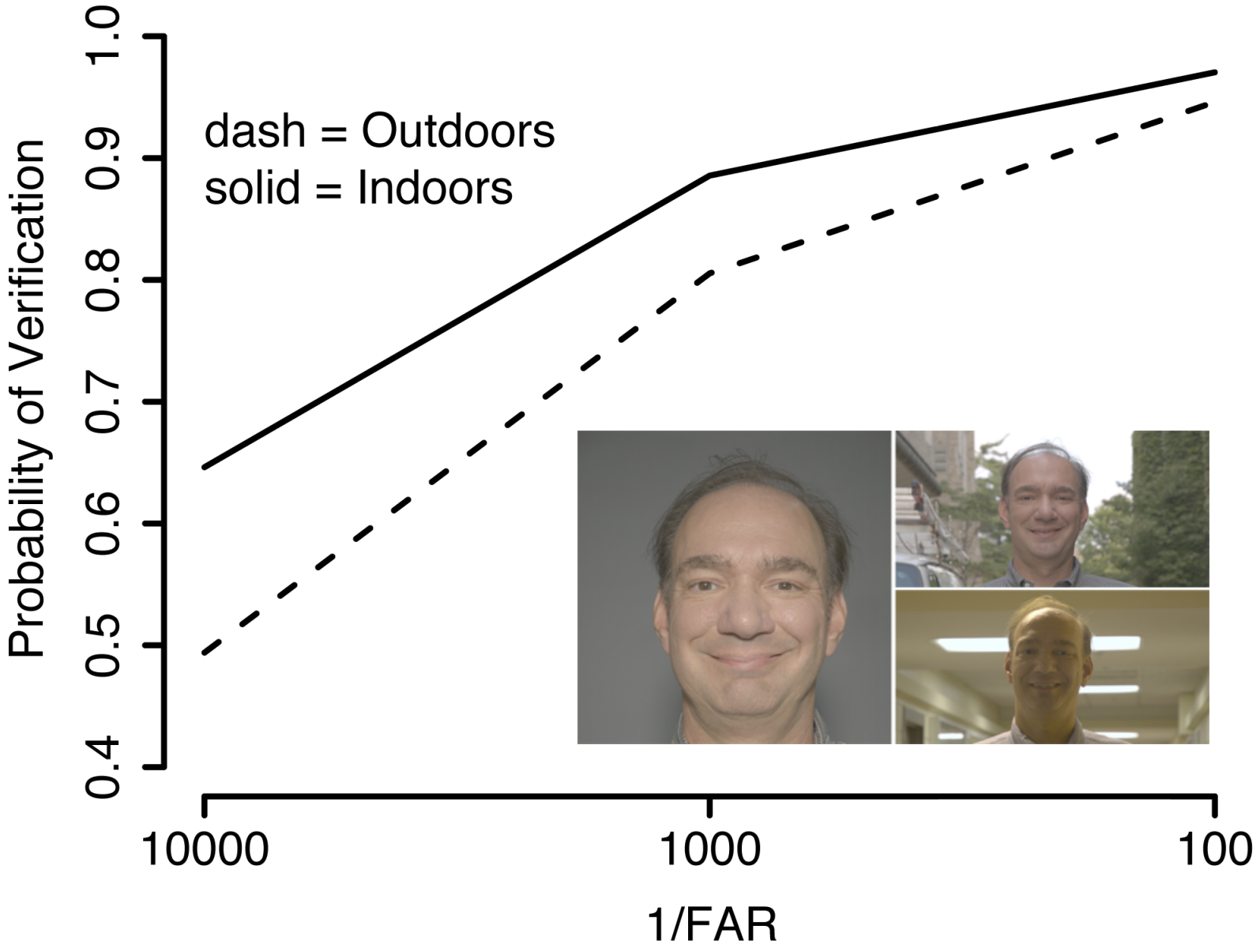
$$\mathrm{E}\left(\pi_p\right) = 0, \ \mathrm{Var}\ \pi_p = \sigma_\pi^2,$$

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

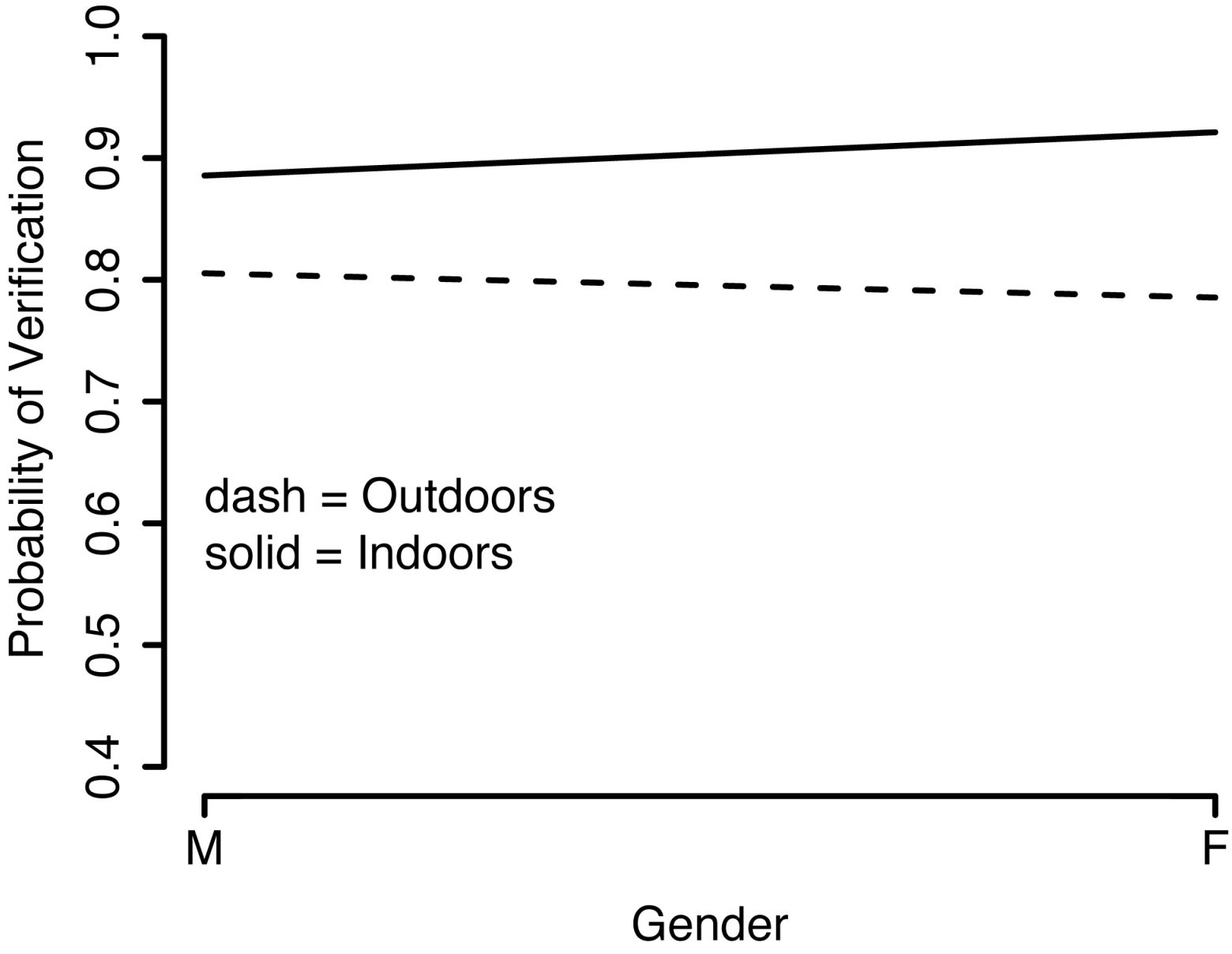
This means:

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

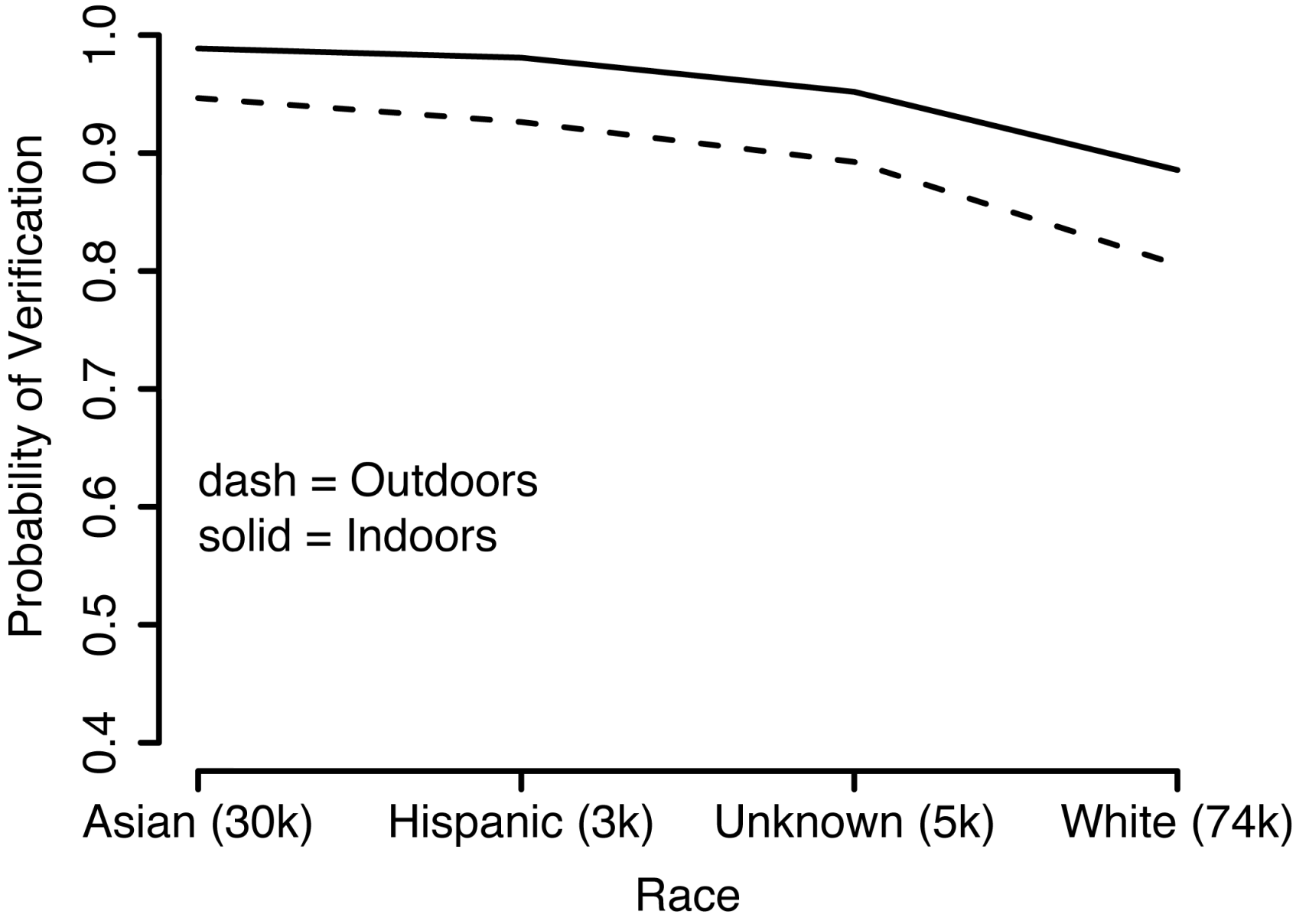
Finding 1: False Accept Rate



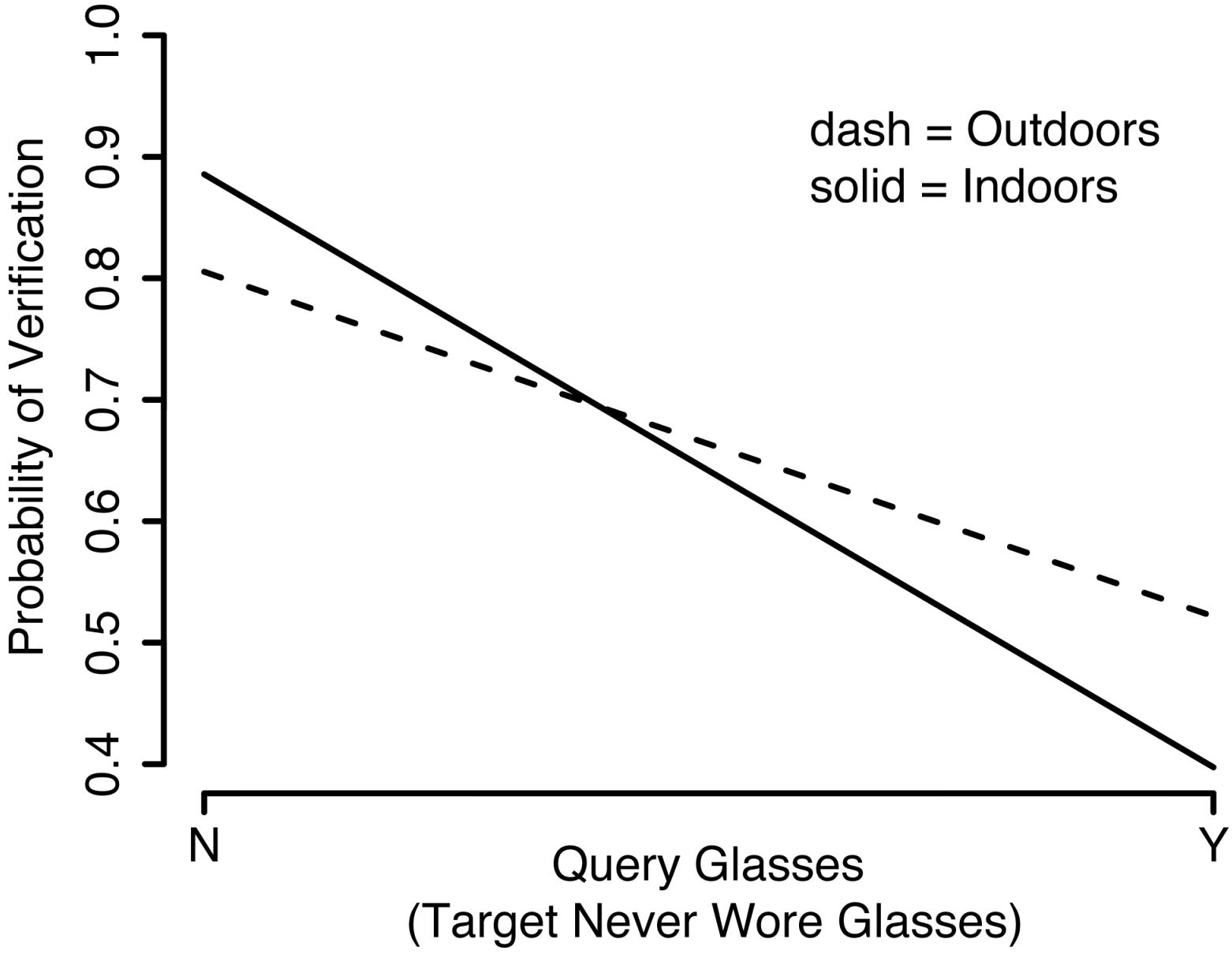
Finding 2: Gender



Finding 3: Race



Finding 4: Glasses



Face Region In Focus Measure

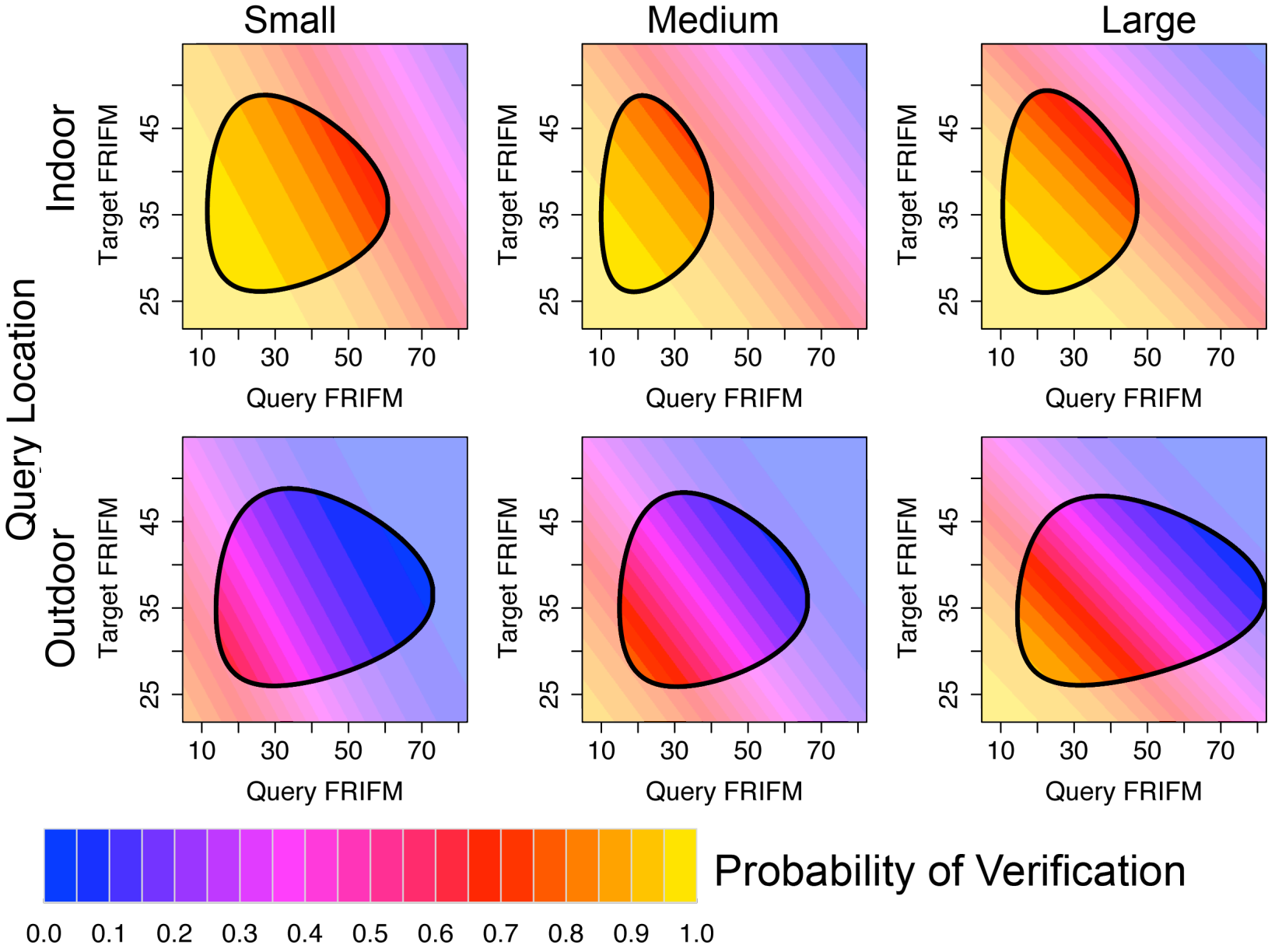
FRIFM: Sum of Sobel edge magnitude inside an ellipse bounding the face.

Face Region In Focus Measure

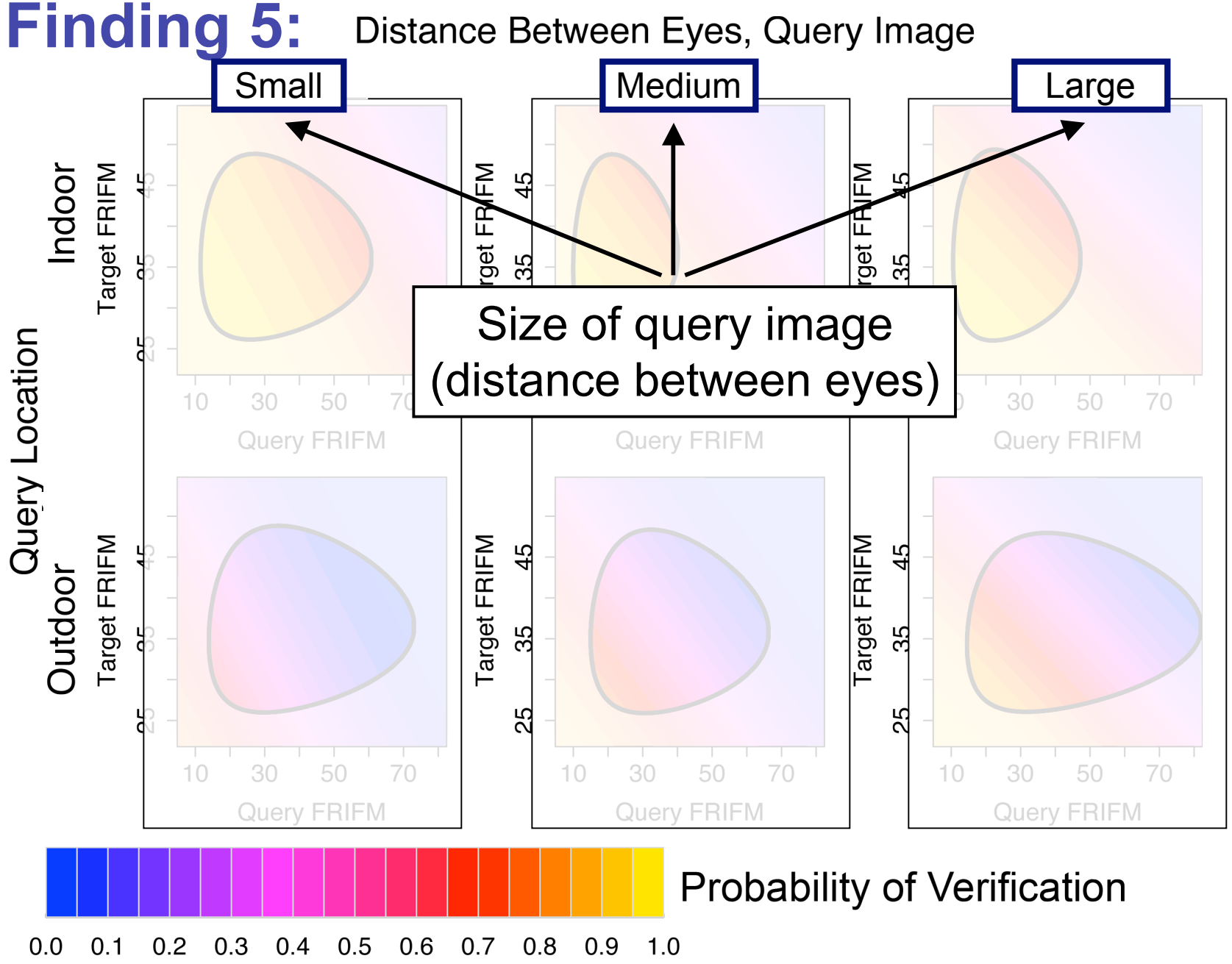
Low FRIFM examples

High FRIFM examples

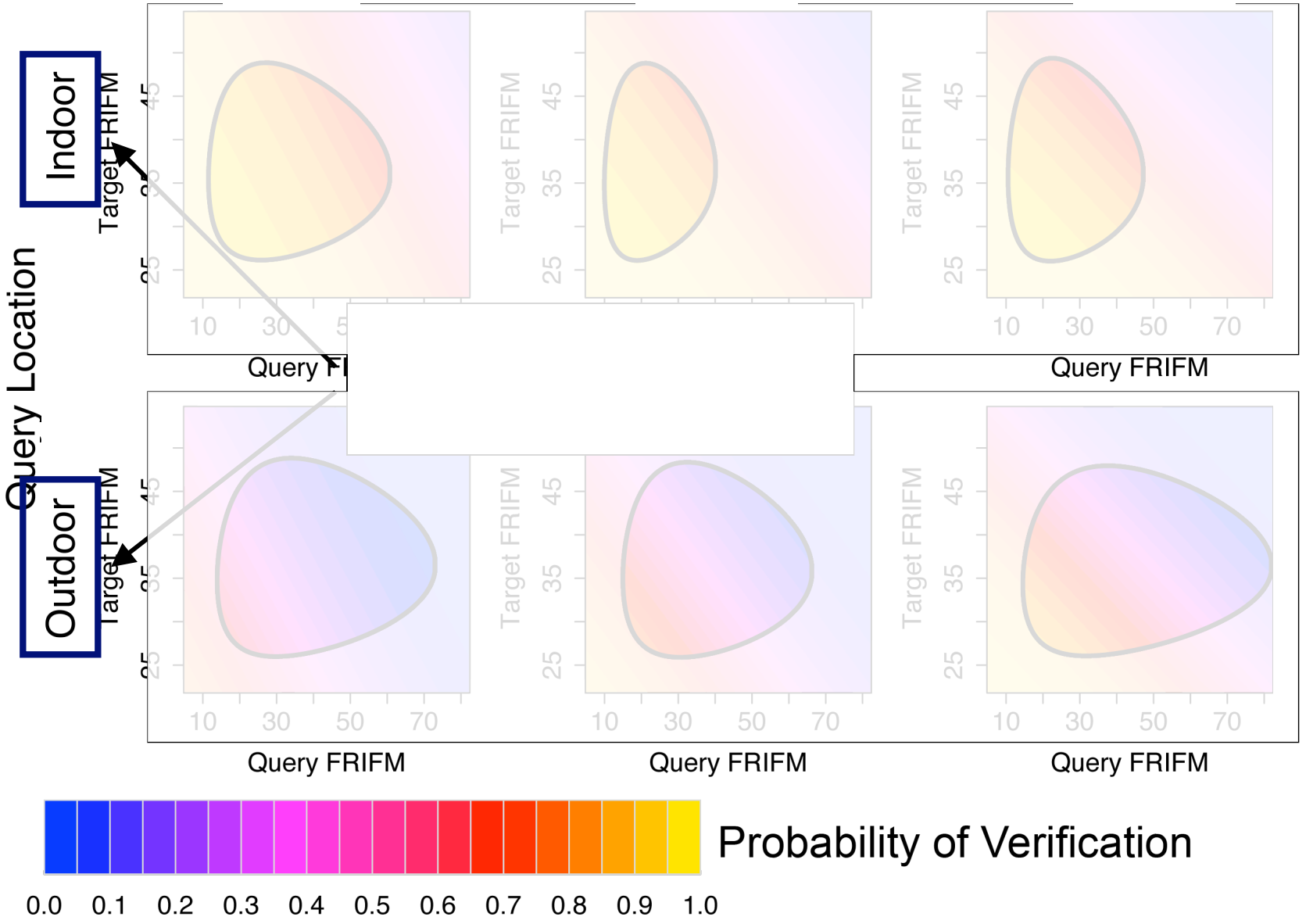
Finding 5: Distance Between Eyes, Query Image



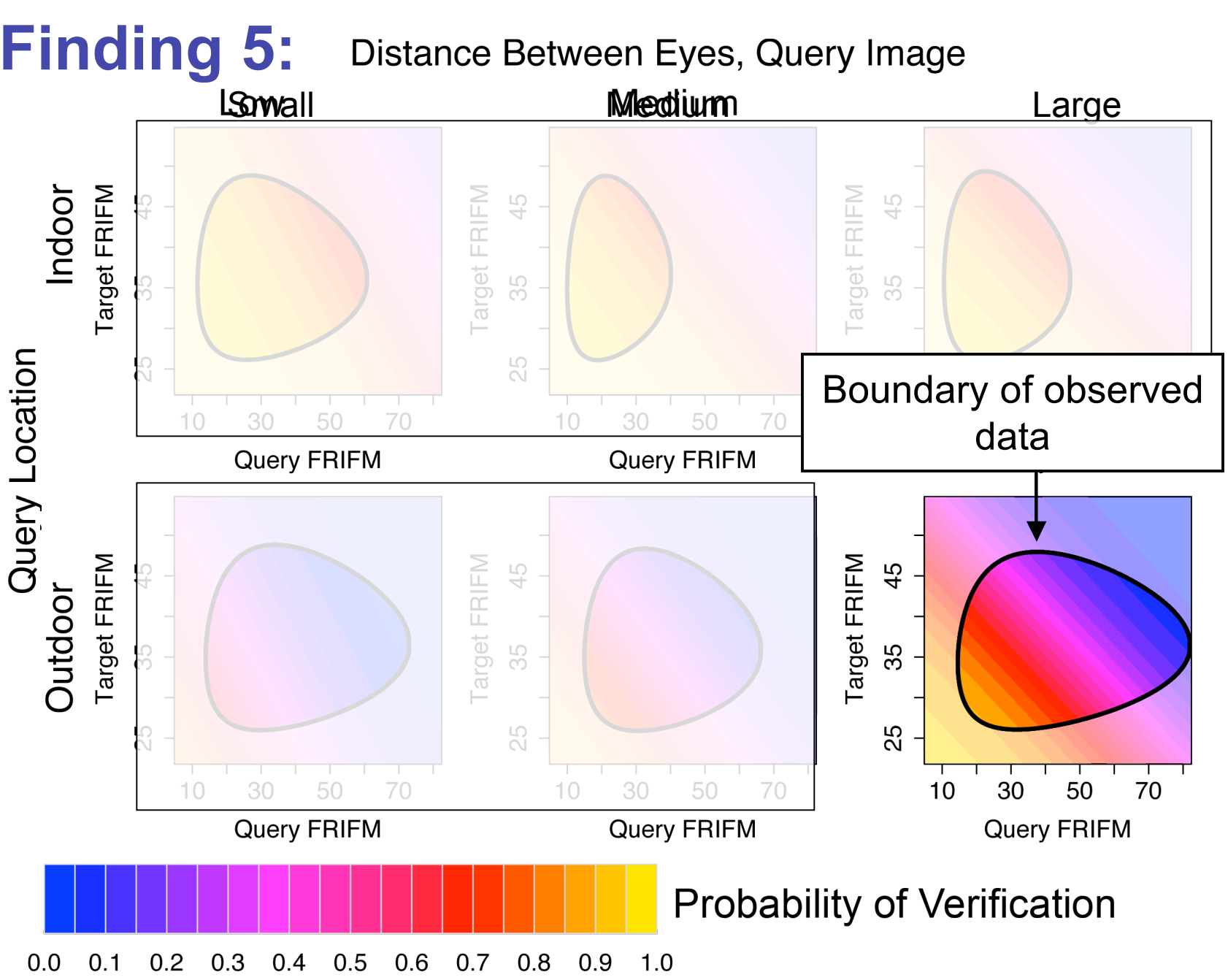
Finding 5:


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

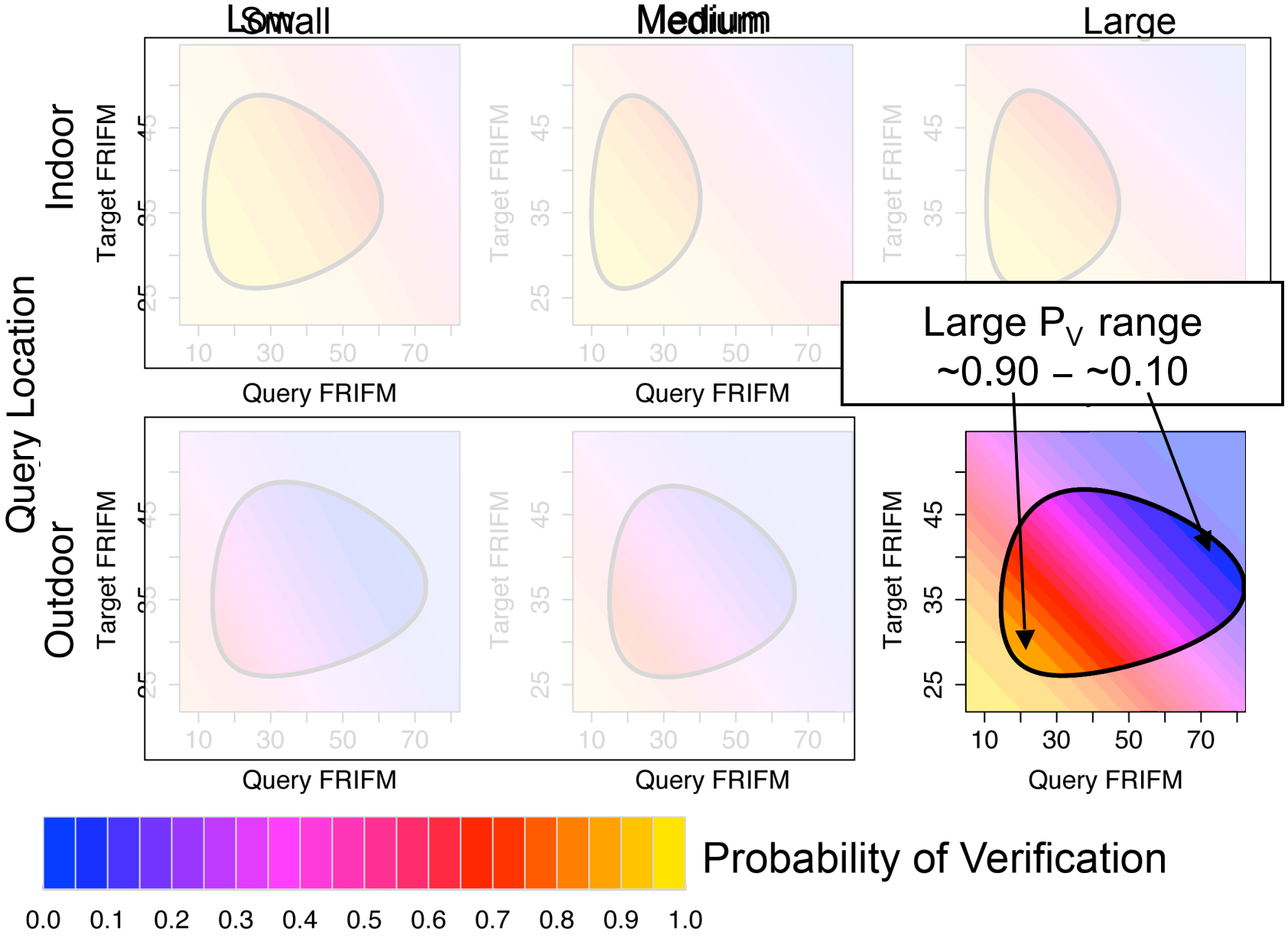
Finding 5: Distance Between Eyes, Query Image



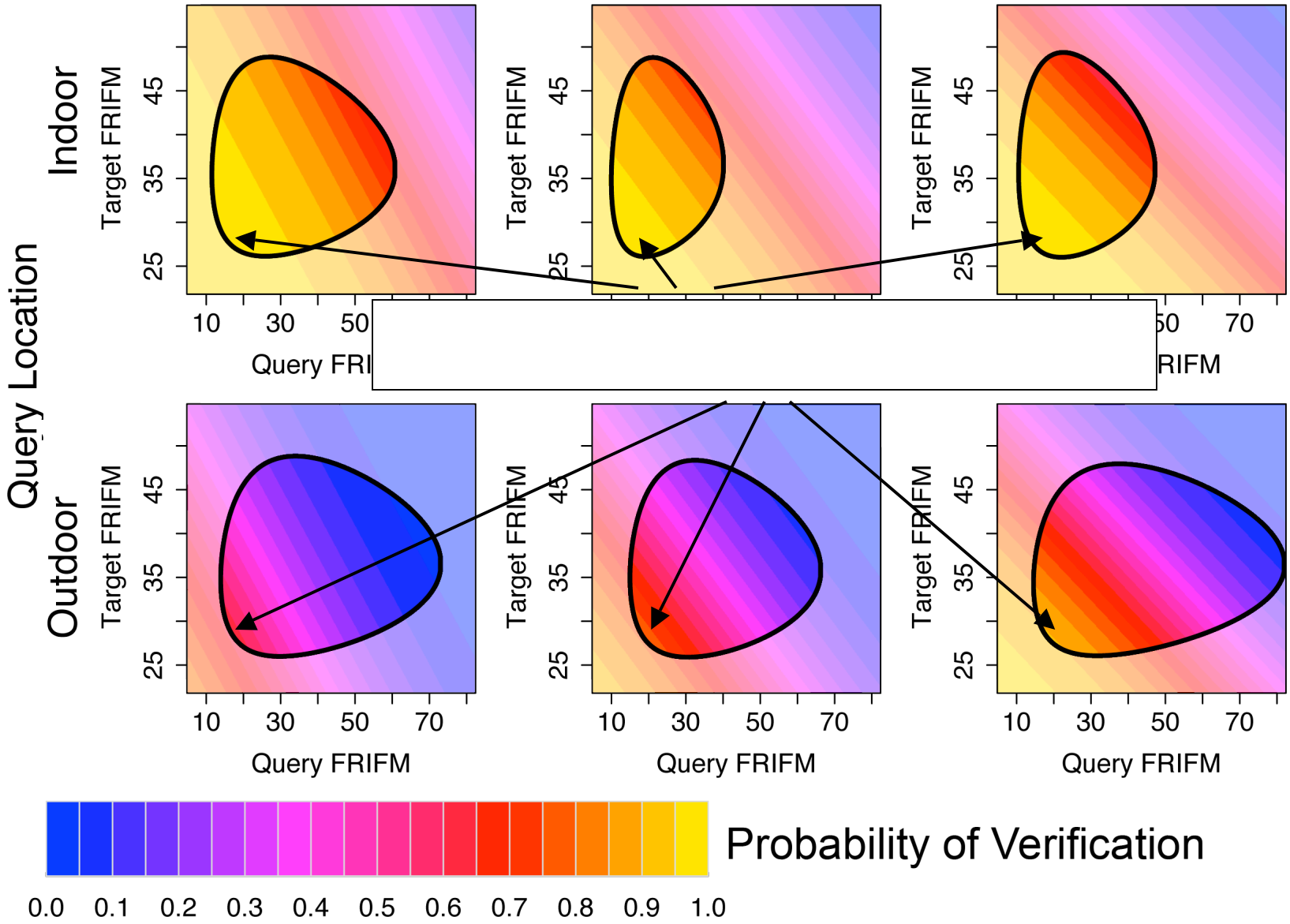
Finding 5:


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
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
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



FRIFM Conclusion

- Large of performance.
  - 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

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.
- Biometrics should use these models.

Thank You