Iris Recognition I

CSE 40537/60537 Biometrics

Daniel Moreira

Spring 2022

UNIVERSITY OF NOTRE DAME

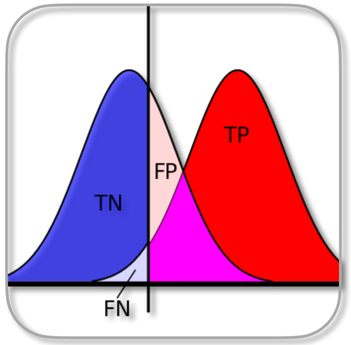
Today you will…

Get to know
Reasons to use irises for recognition.
How irises compare to fingerprints.

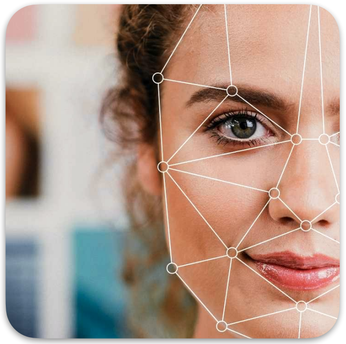
UNIVERSITY OF NOTRE DAME

Course Overview

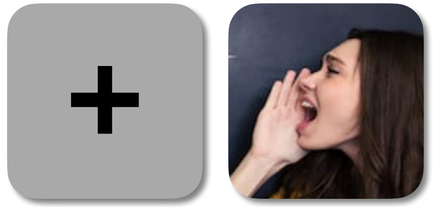
Content



Basics
Concepts
Metrics
Metric implementation



Core Traits (3)
Concepts
Baseline implementation
Data collection
Evaluation
Attacks
Assignments



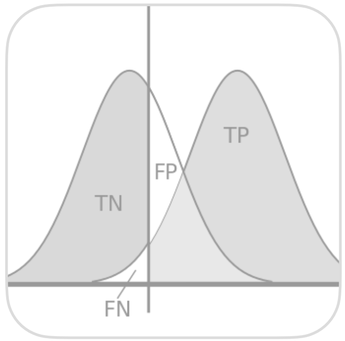
Alternative Traits and Fusion
Concepts

Invited Talks (2)
State of the art
Future work

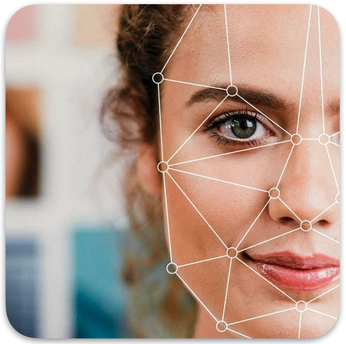
UNIVERSITY OF NOTRE DAME

Course Overview

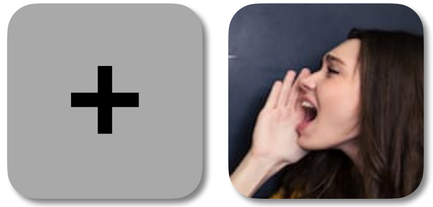
Content



Basics
Concepts
Metrics
Metric implementation



Core Traits (3)
Concepts
Baseline implementation
Data collection
Evaluation
Attacks
Assignments

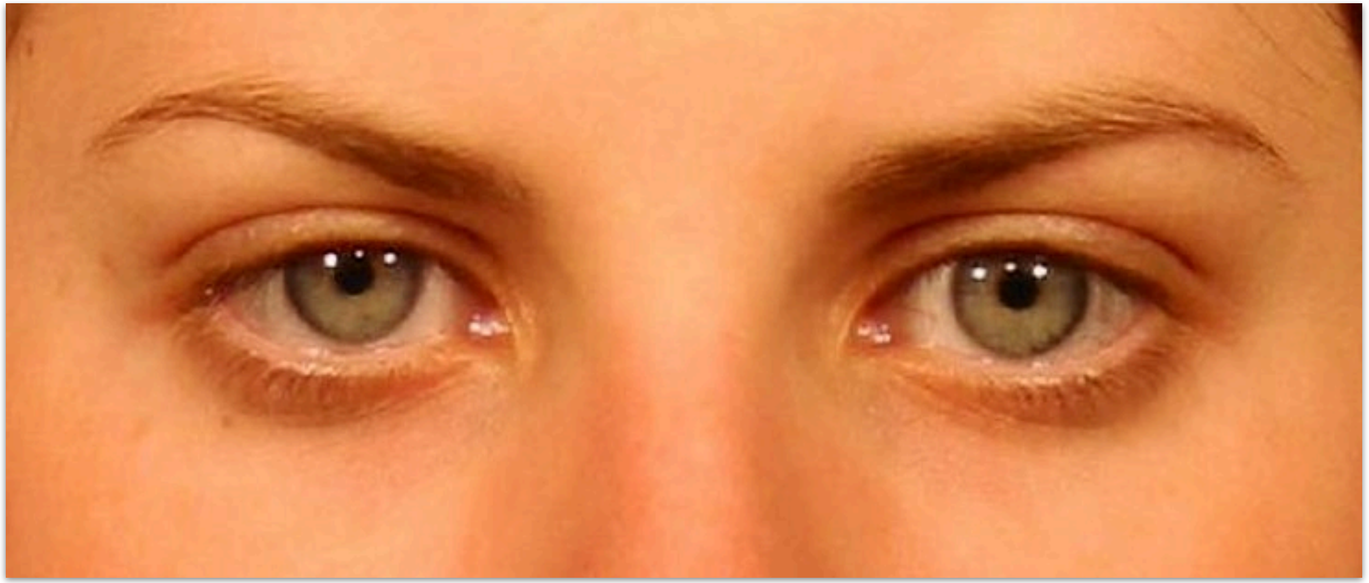


Alternative Traits and Fusion
Concepts

Invited Talks (2)
State of the art
Future work

UNIVERSITY OF NOTRE DAME

Irises

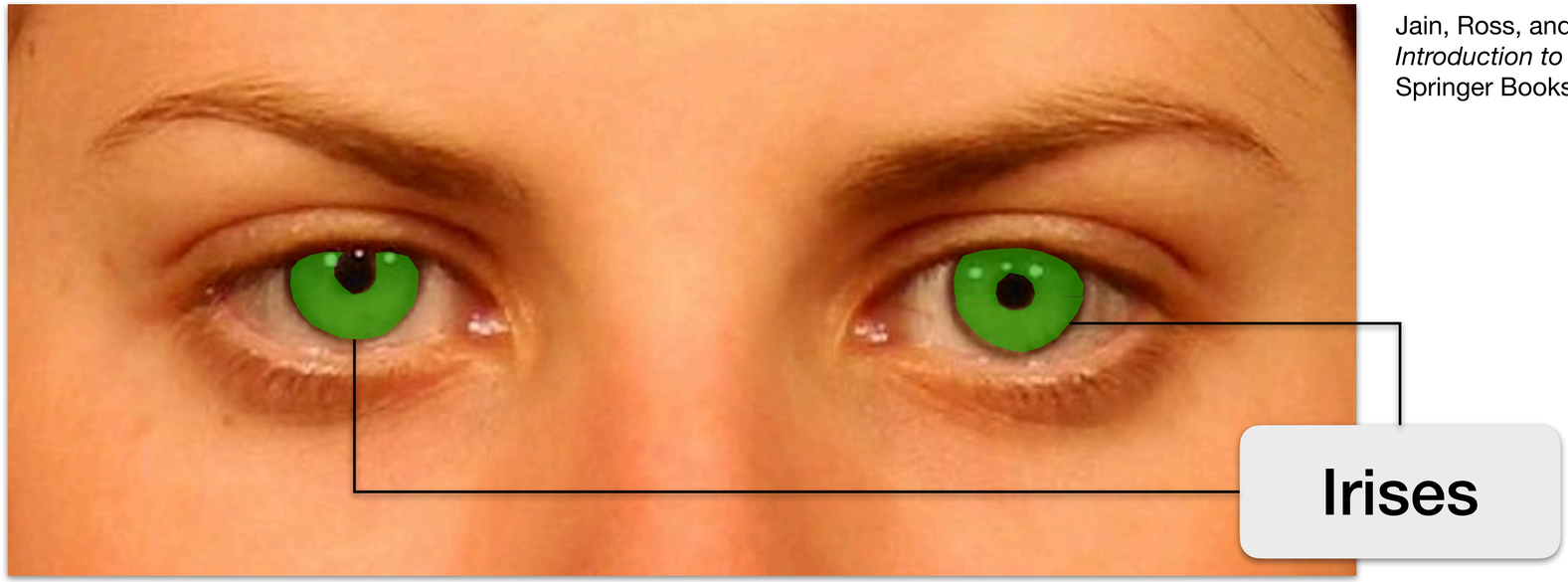


Jain, Ross, and Nadakumar
Introduction to Biometrics
Springer Books, 2011

Ocular Region

UNIVERSITY OF NOTRE DAME

Irises



Jain, Ross, and Nadakumar
Introduction to Biometrics
Springer Books, 2011

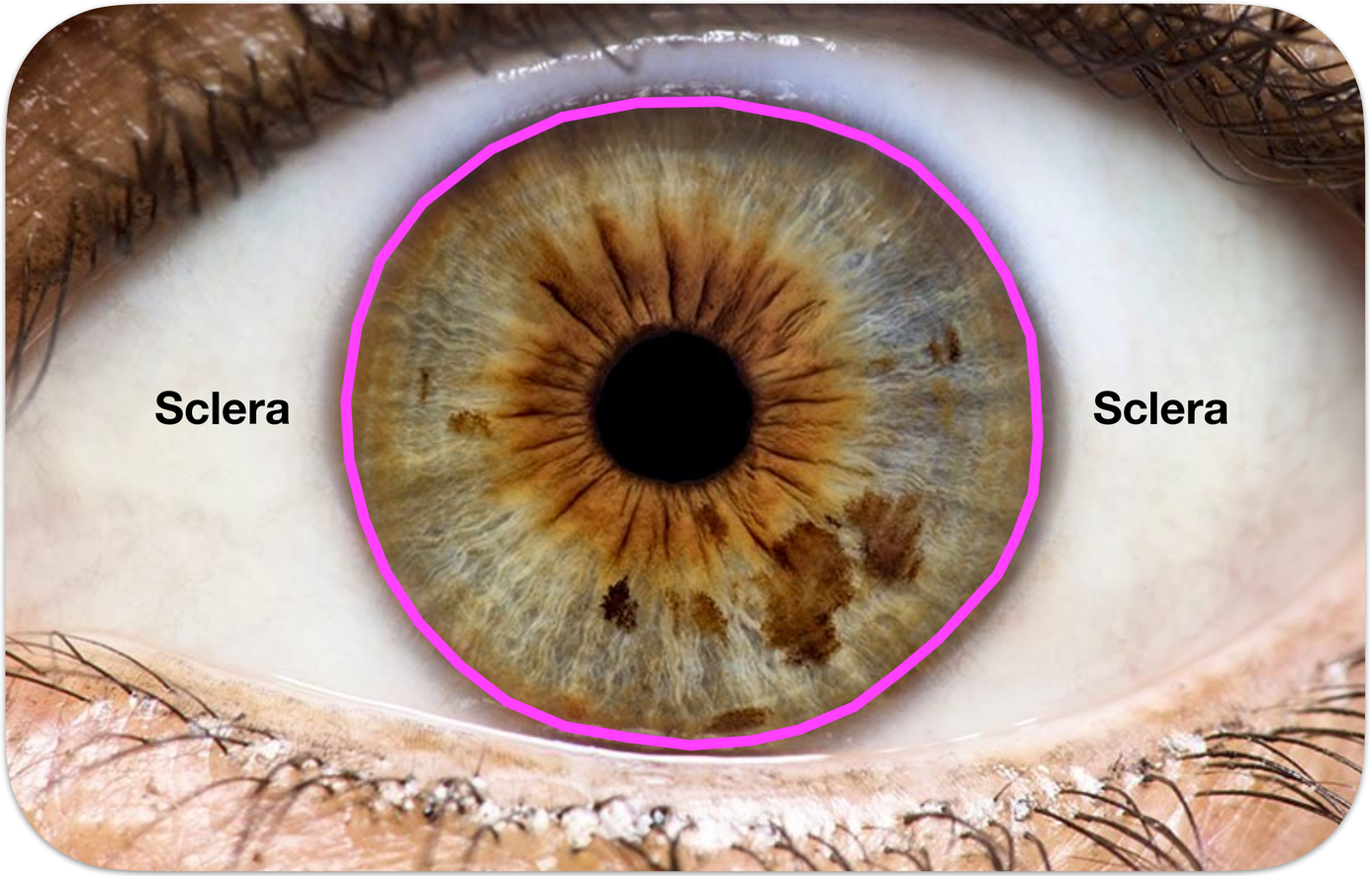
Ocular Region

UNIVERSITY OF NOTRE DAME

Anatomy

UNIVERSITY OF NOTRE DAME

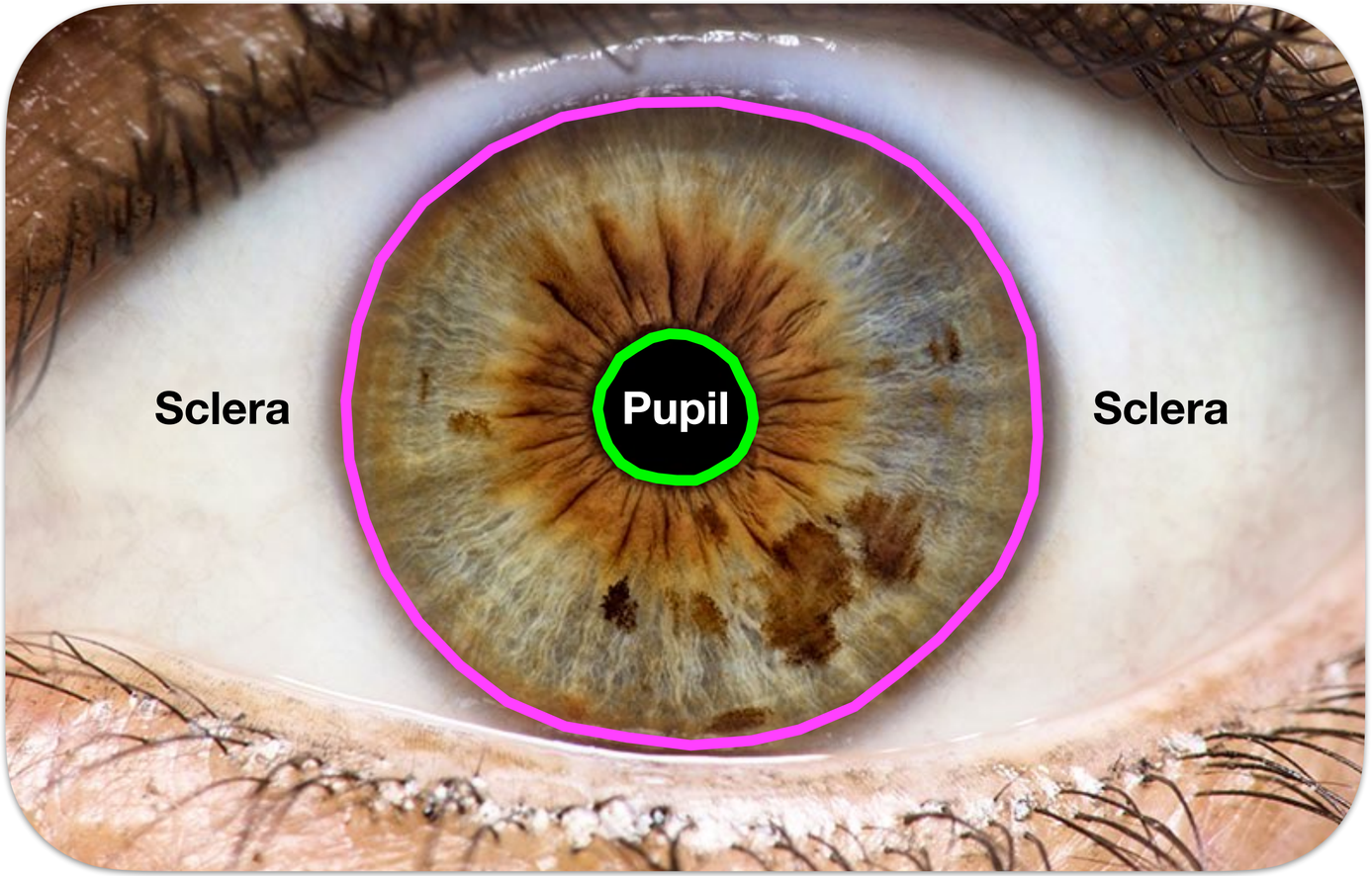
Anatomy



Limbus boundary

UNIVERSITY OF NOTRE DAME

Anatomy

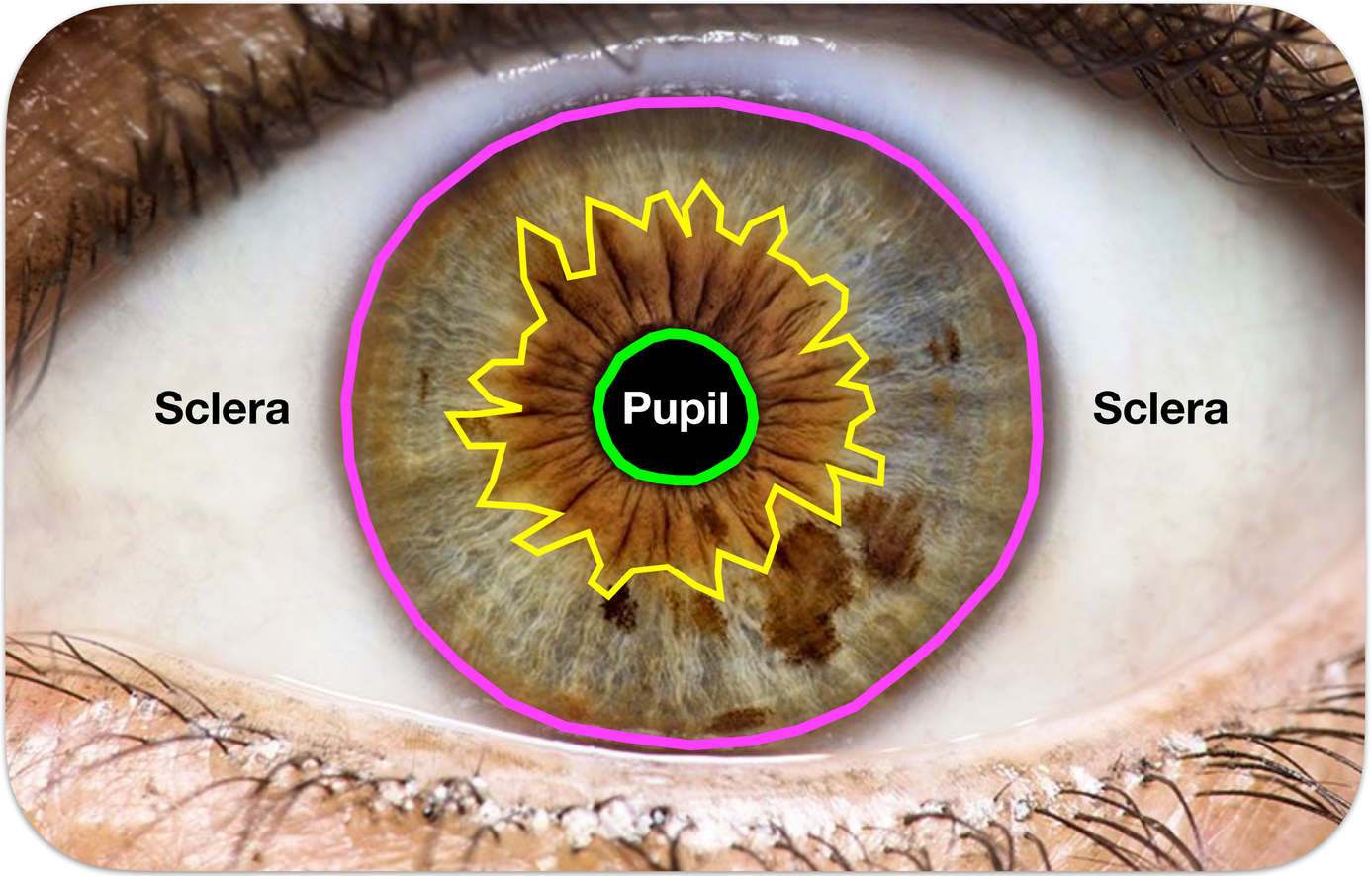


Limbus boundary

Pupillary boundary

UNIVERSITY OF NOTRE DAME

Anatomy



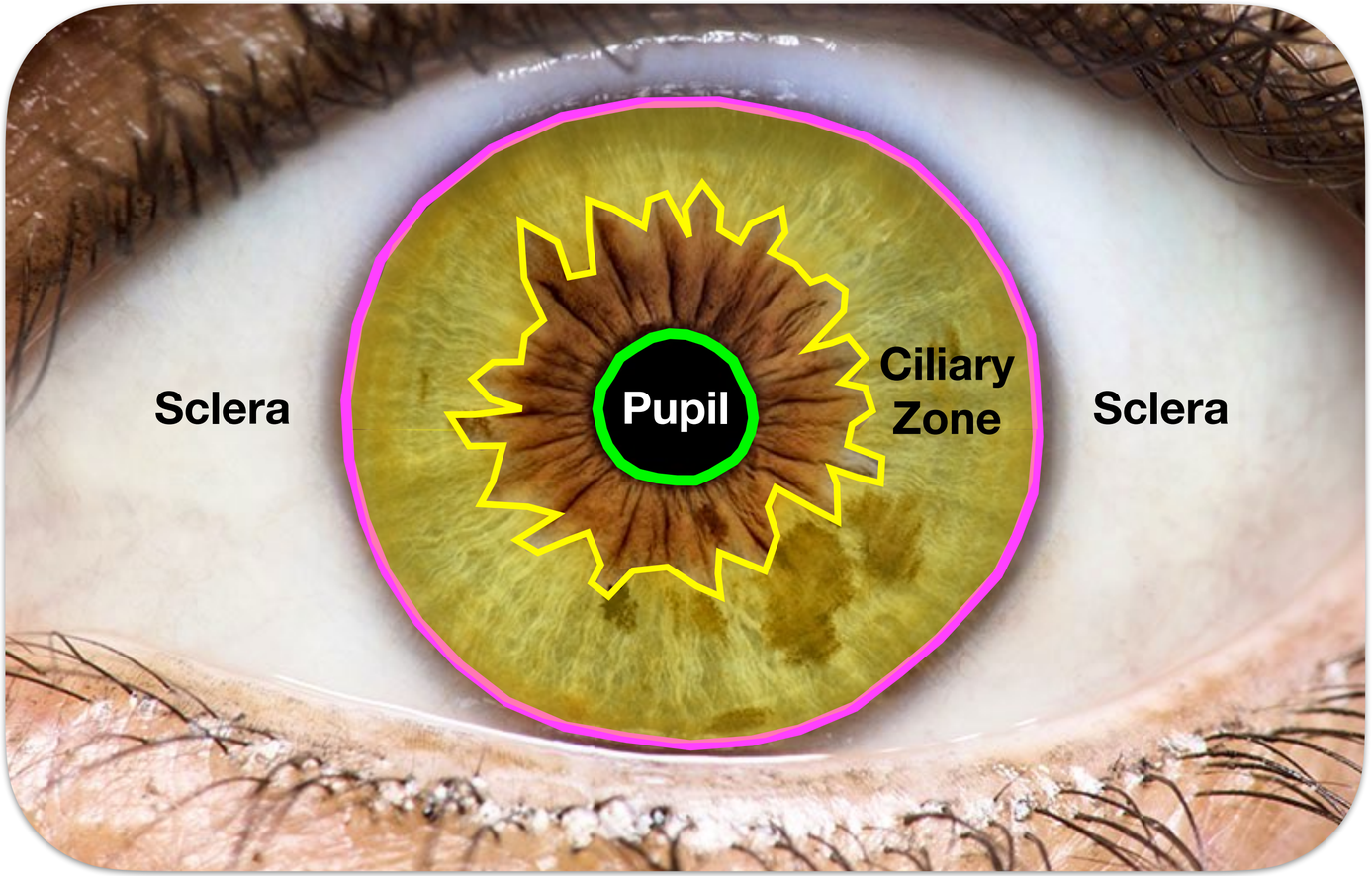
Limbus boundary

Pupillary boundary

Collarette

UNIVERSITY OF NOTRE DAME

Anatomy



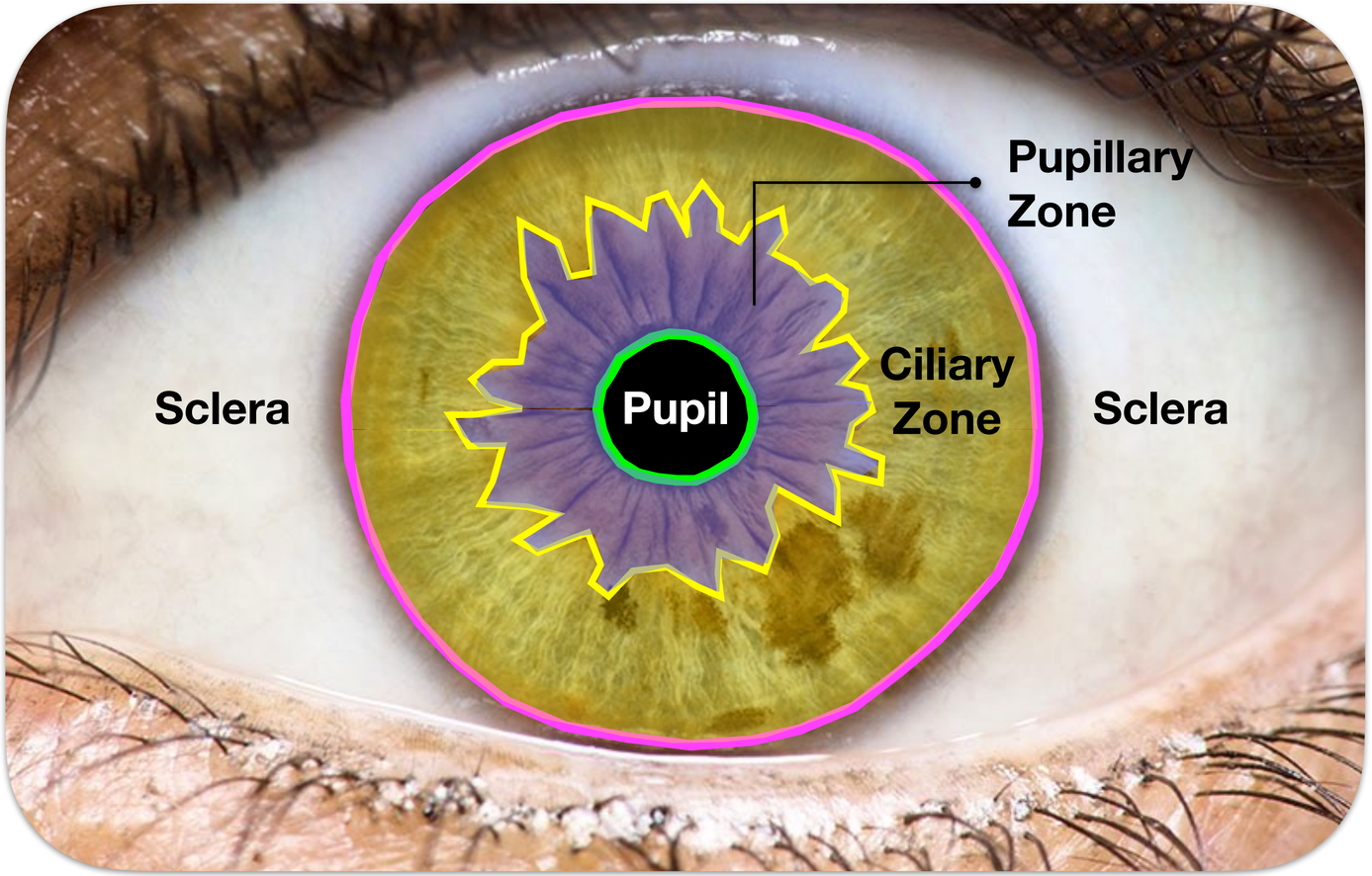
Limbus boundary

Pupillary boundary

Collarette

UNIVERSITY OF NOTRE DAME

Anatomy



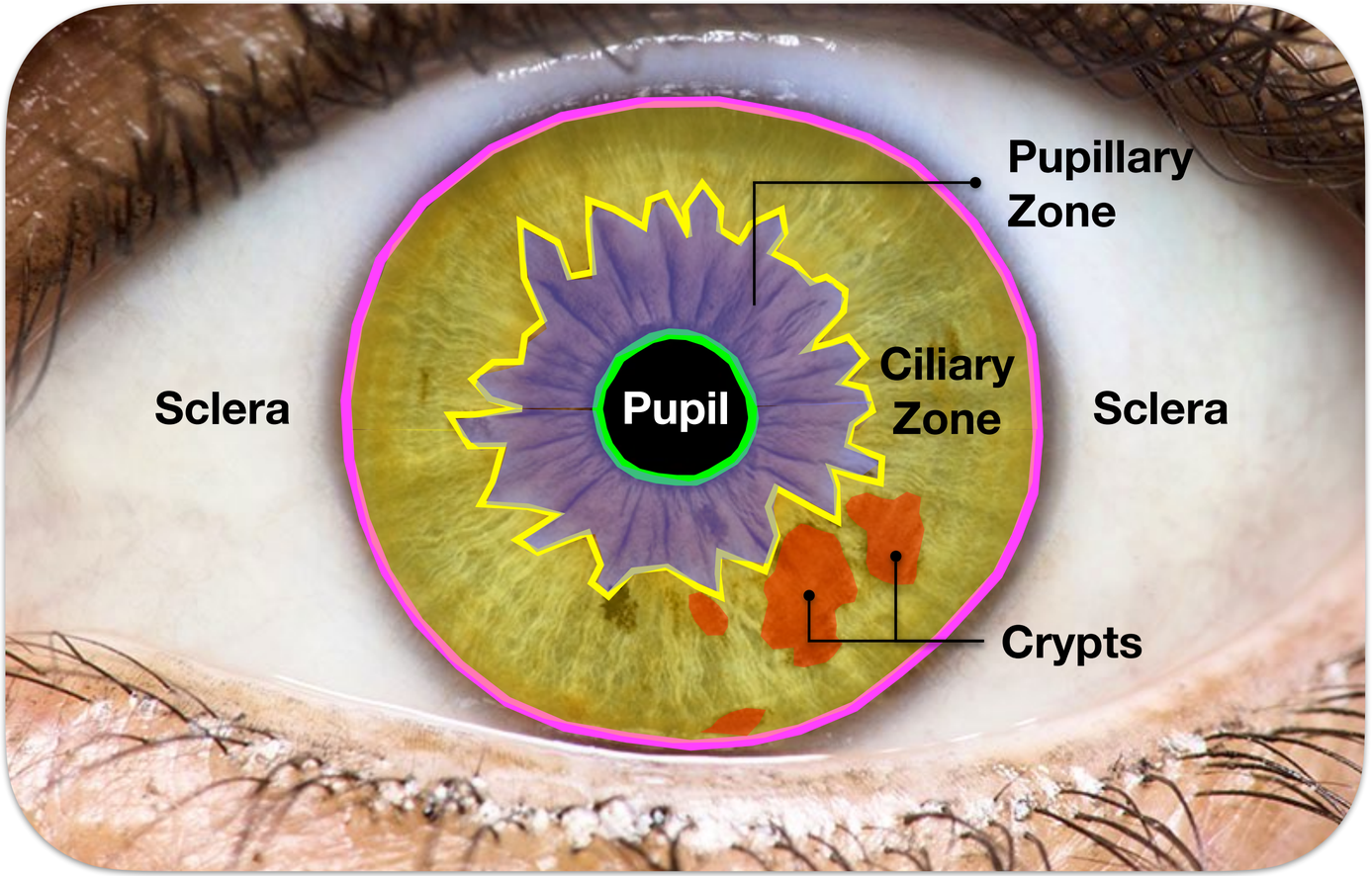
Limbus boundary

Pupillary boundary

Collarette

UNIVERSITY OF NOTRE DAME

Anatomy



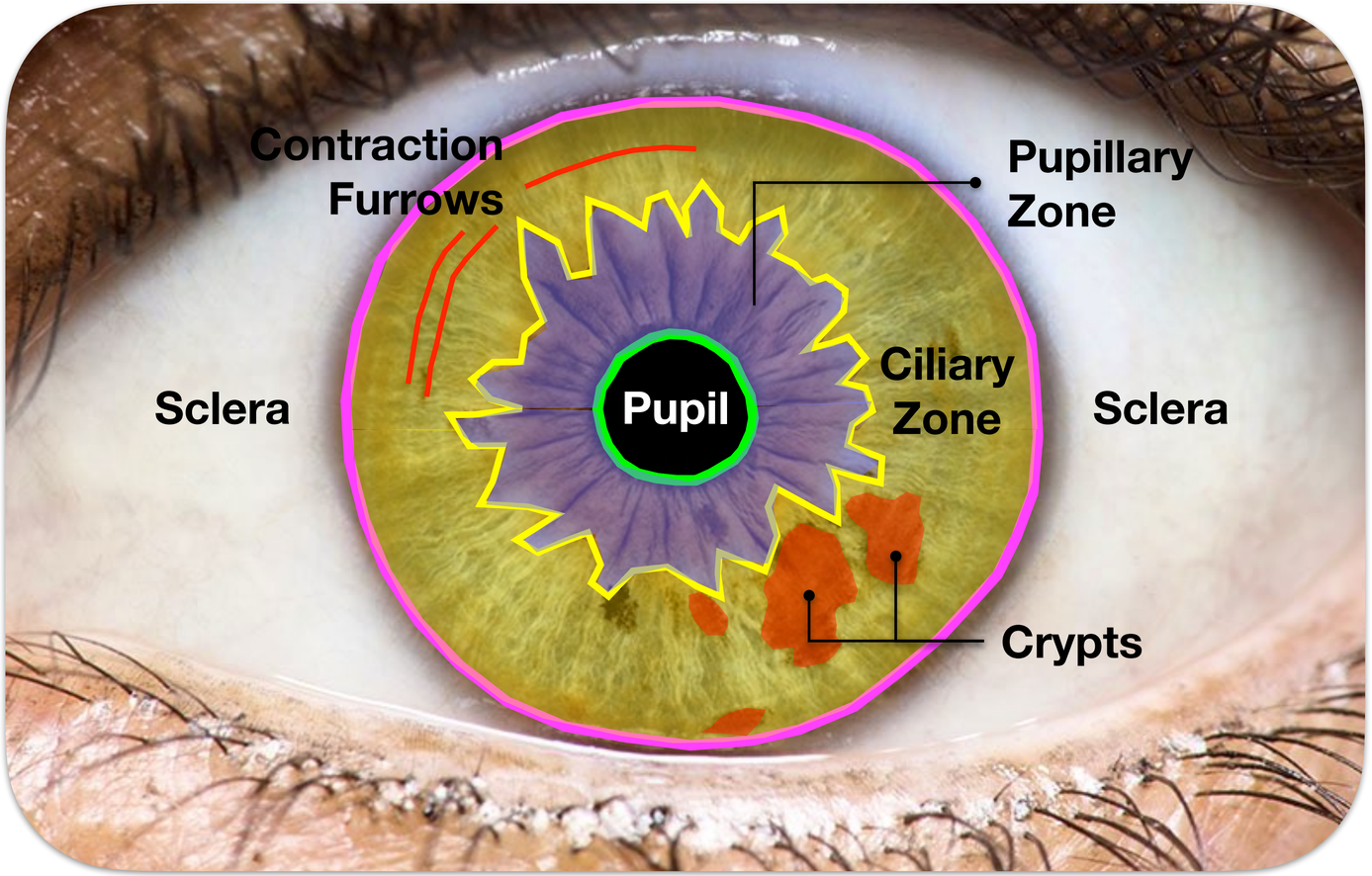
Limbus boundary

Pupillary boundary

Collarette

UNIVERSITY OF NOTRE DAME

Anatomy



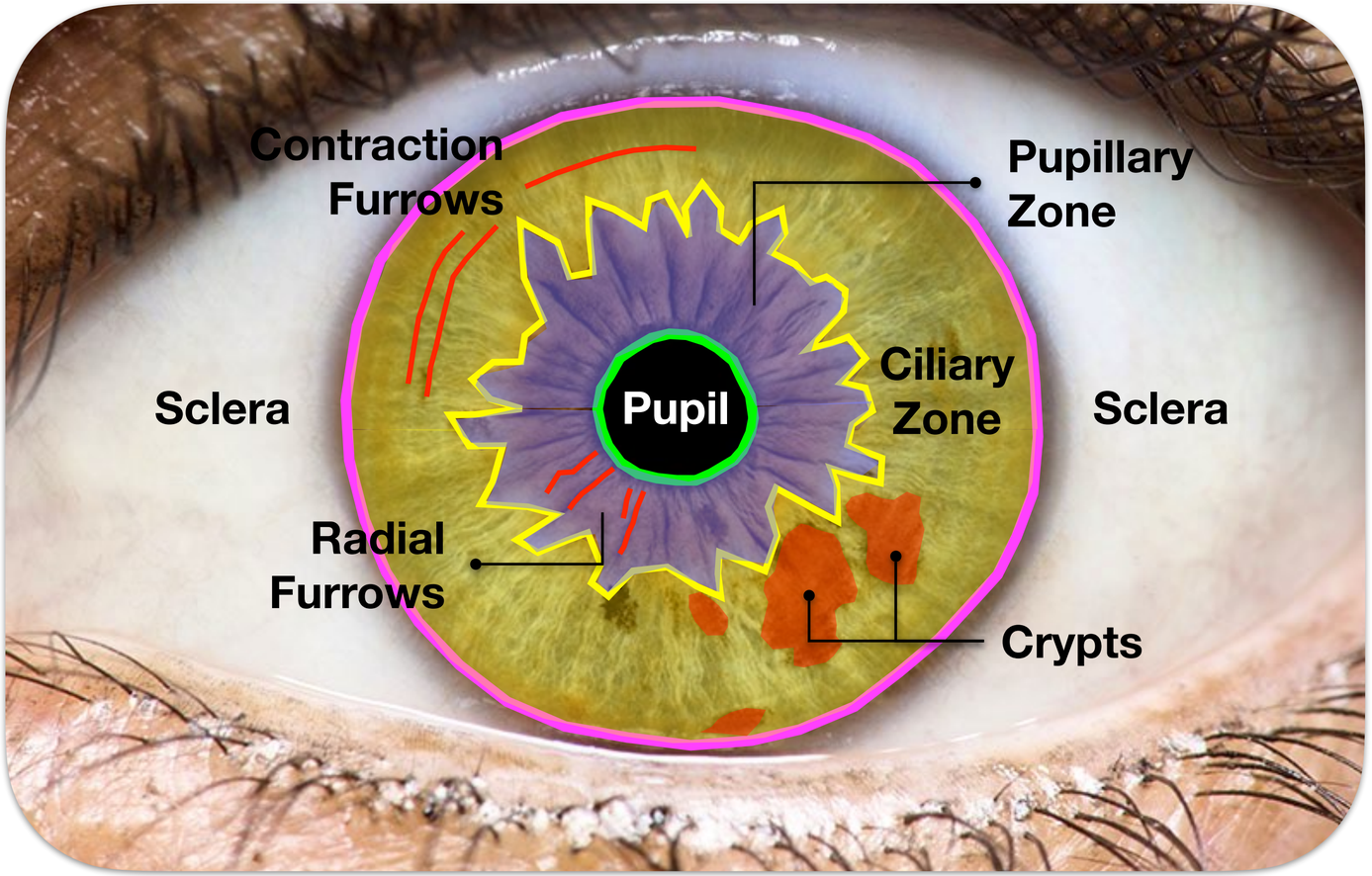
Limbus boundary

Pupillary boundary

Collarette

UNIVERSITY OF NOTRE DAME

Anatomy



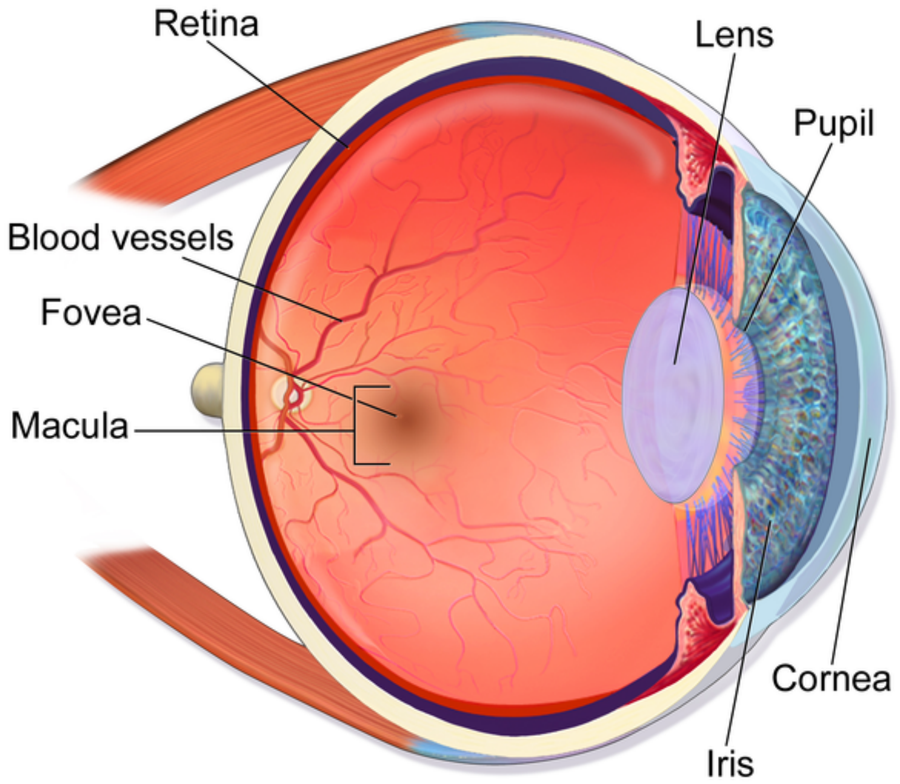
Limbus boundary

Pupillary boundary

Collarette

UNIVERSITY OF NOTRE DAME

Anatomy

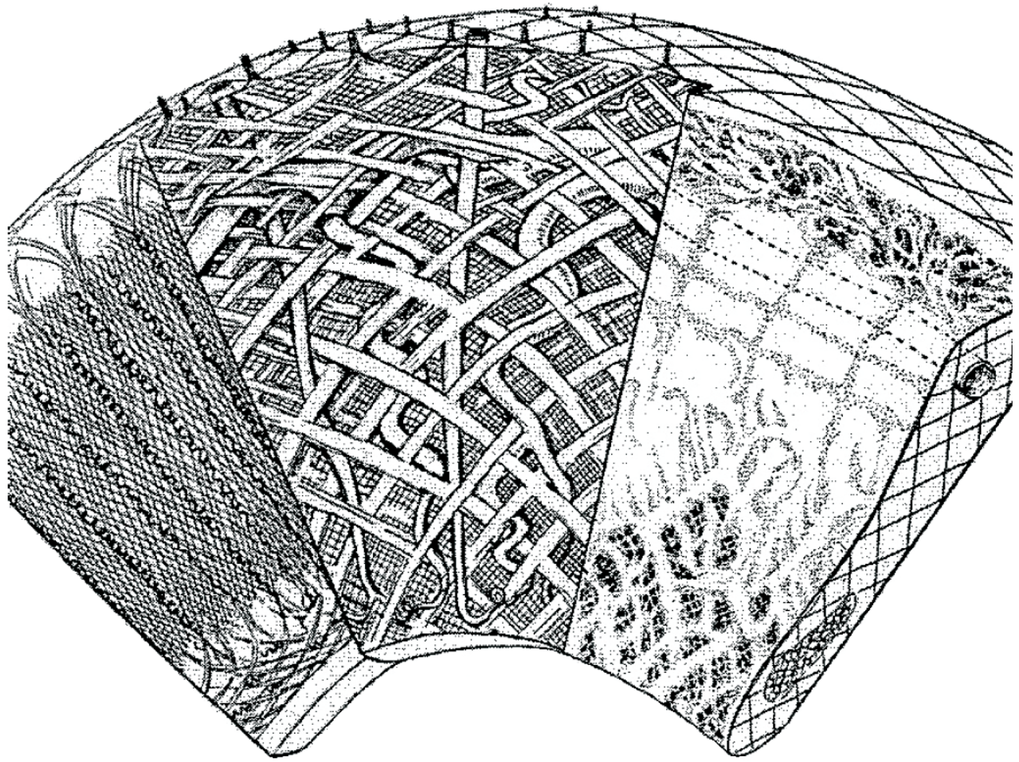


commons.wikimedia.org

Iris
Located behind the cornea and in front of the lens.

UNIVERSITY OF NOTRE DAME

Anatomy



Hans Rohen
Der bau der regenbogenhault beim menschen und einigen Saugern
Gegenbaur Morphology Journal, 1951

Iris
Located behind the cornea and in front of the lens.

Complex mesh of muscle beams, blood vessels, nerves, and pigmented skin.

UNIVERSITY OF NOTRE DAME

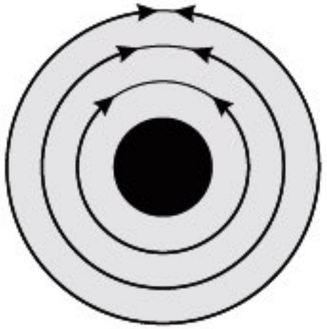
Anatomy

Suren Manvelyan

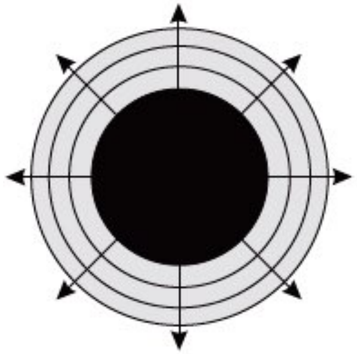
UNIVERSITY OF NOTRE DAME

Anatomy

Adam Czajka



Sphincter Muscles



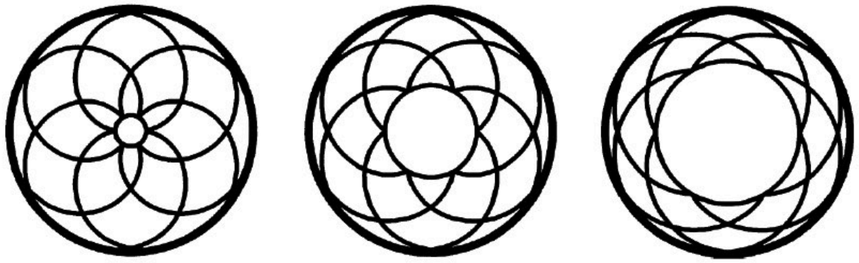
Dilator Muscles

Iris
Located behind the cornea and in front of the lens.

Complex mesh of muscle beams, blood vessels, nerves, and pigmented skin.

Function: regulate the amount of light entering the eye by dilating or contracting the pupil.

H. J. Wyatt
A minimum wear-and-tear meshwork for the iris.
Vision Research, 2000



Non-linear constrictions and dilations.

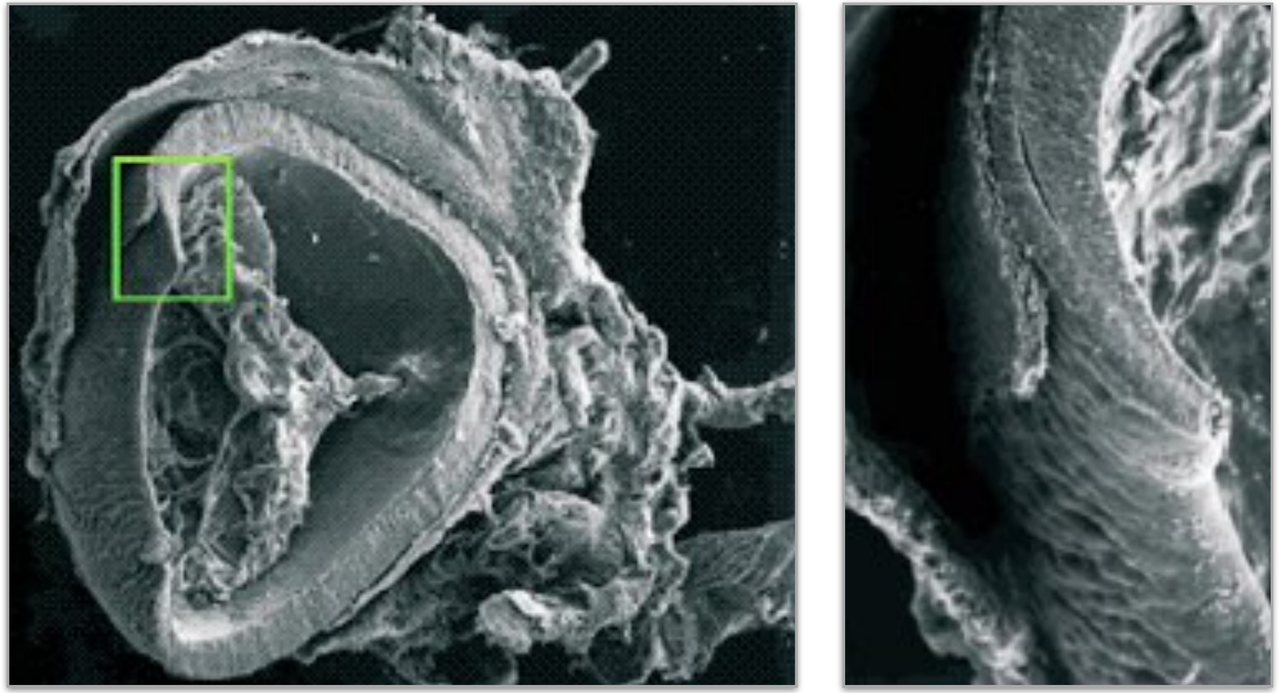
UNIVERSITY OF NOTRE DAME

Genesis

Epigenetic Trait

Development starts in the end of the 2nd month of gestation.

Fully developed by the 8th month of gestation.



Adam Czajka

UNIVERSITY OF NOTRE DAME

Genesis

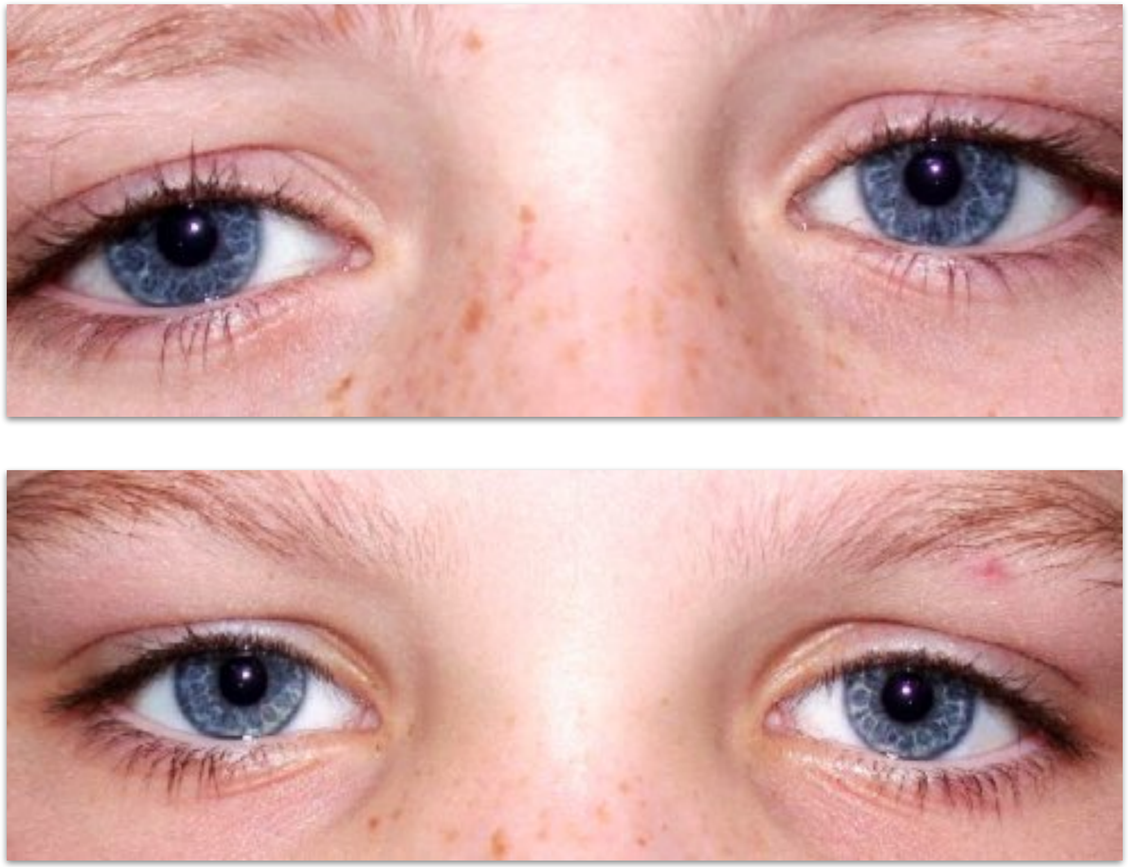
J. Daugman
Evolving Methods in Iris Recognition
BTAS, 2012

Epigenetic Trait

Different gestations will lead to different irises (except for color), even if DNA is the same.

Right and left irises are different.

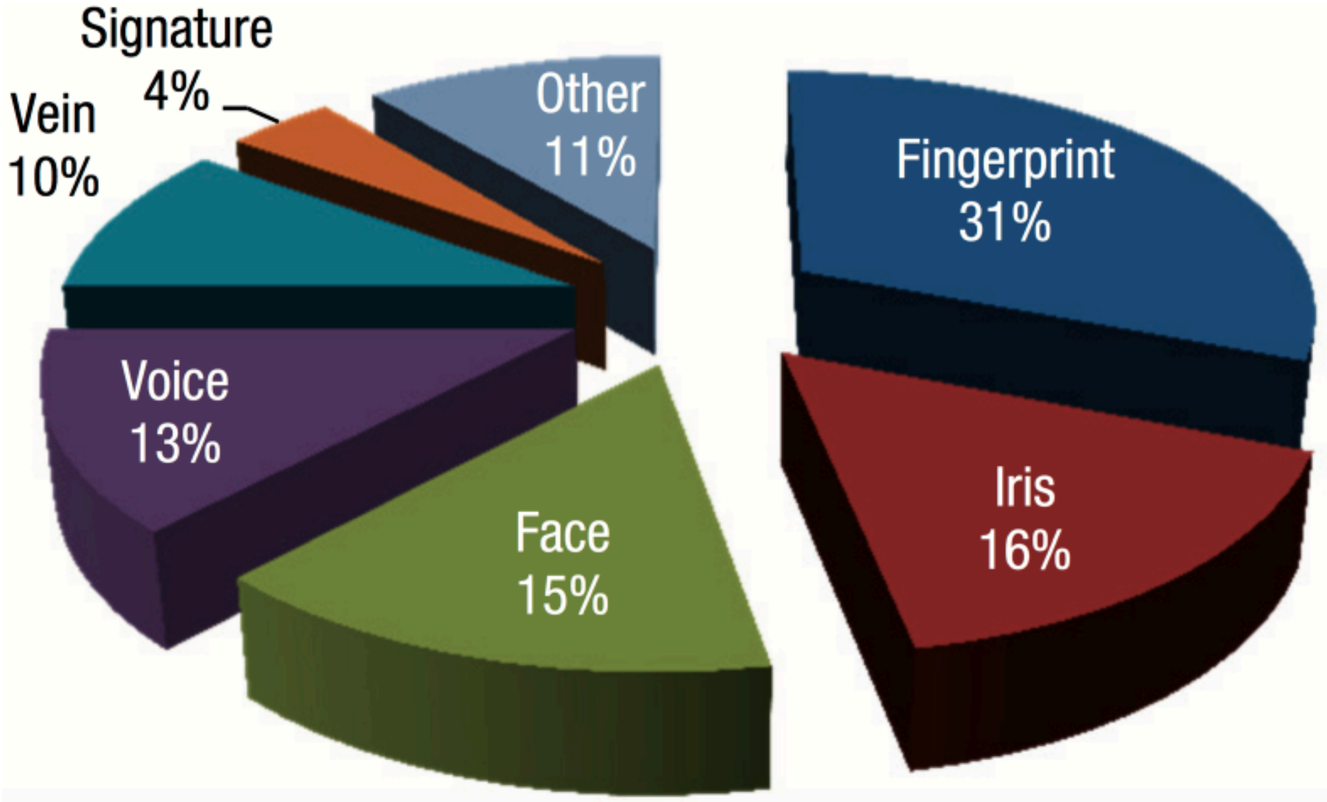
Identical twins have different irises.



UNIVERSITY OF NOTRE DAME

Why Irises?

Market



Source: Mani and Nadeski, *Processing solutions for biometric systems,* Texas Instruments, 2015

UNIVERSITY OF NOTRE DAME

Why Irises?

Universality (1/8)
Does everybody have the trait?

Probably

better than

>

UNIVERSITY OF NOTRE DAME

Why Irises?

Uniqueness (2/8)
How likely two or more individuals will present the same trait?

Probably

>

UNIVERSITY OF NOTRE DAME

Why Irises?

Uniqueness (2/8)
How likely two or more individuals will present the same trait?

E.g., identical twins
Same faces.
Four different irises.

Source: John Daugman
Lecture Notes, 2018

UNIVERSITY OF NOTRE DAME

Why Irises?

Permanence (3/8)
How easily does the trait change?

Probably

>

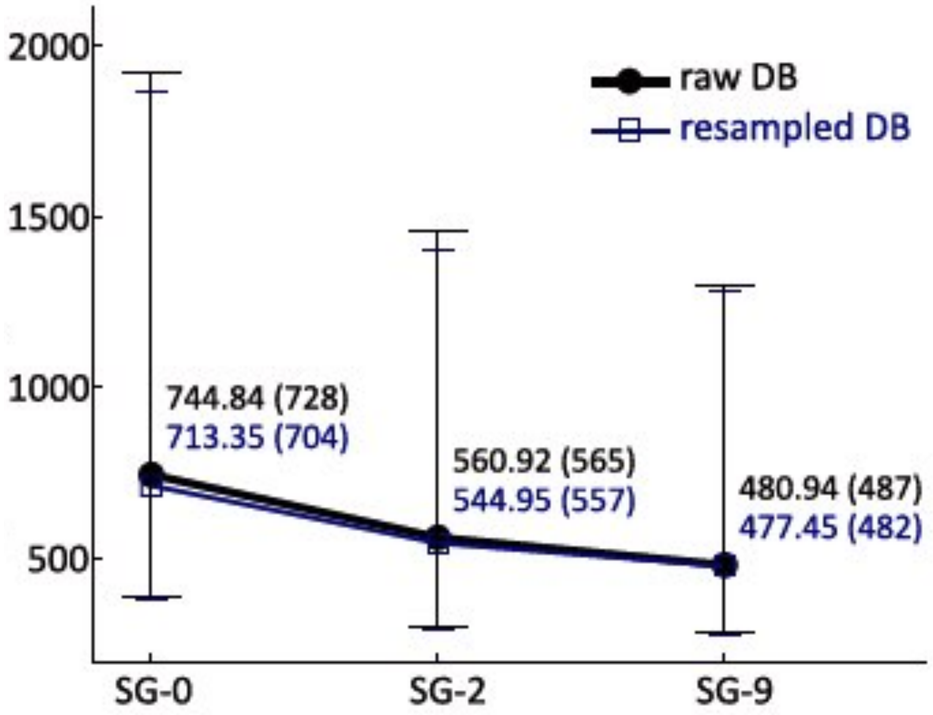
UNIVERSITY OF NOTRE DAME

Why Irises?

Permanence (3/8)
How easily does the trait change?

Needed Research
There seems to be a degradation of True Match Rate (TMR) as a function of time.

A. Czajka
Influence of Iris Template Aging on Recognition Reliability
Springer CCIS, 2014



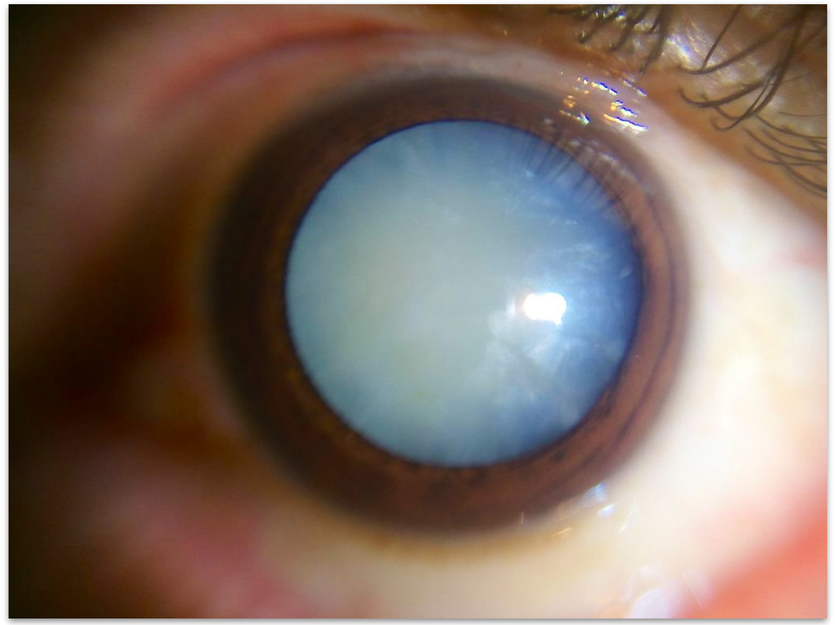
UNIVERSITY OF NOTRE DAME

Why Irises?

Permanence (3/8)
How easily does the trait change?

Traumas and Diseases
Some traumas and diseases might degrade/change the iris.

commons.wikimedia.org



E.g., cataracts.

UNIVERSITY OF NOTRE DAME

Why Irises?

Measurability (4/8)
How easy is it to acquire and digitize the trait?

Probably

>

Not there yet.

UNIVERSITY OF NOTRE DAME

Why Irises?

Acceptability (5/8)
Will individuals collaborate during data collection?

Probably

>

UNIVERSITY OF NOTRE DAME

Why Irises?

Acceptability (5/8)
Will individuals collaborate during data collection?

Privacy Concerns

Whose fingerprint is this?

Whose iris is this?

UNIVERSITY OF NOTRE DAME

Why Irises?

Circumvention (6/8)
How hard can the trait be forged or imitated?

Jain, Ross, and Nadakumar
Introduction to Biometrics
Springer Books, 2011

UNIVERSITY OF NOTRE DAME

Why Irises?

Circumvention (6/8)
How hard can the trait be forged or imitated?

Probably

>

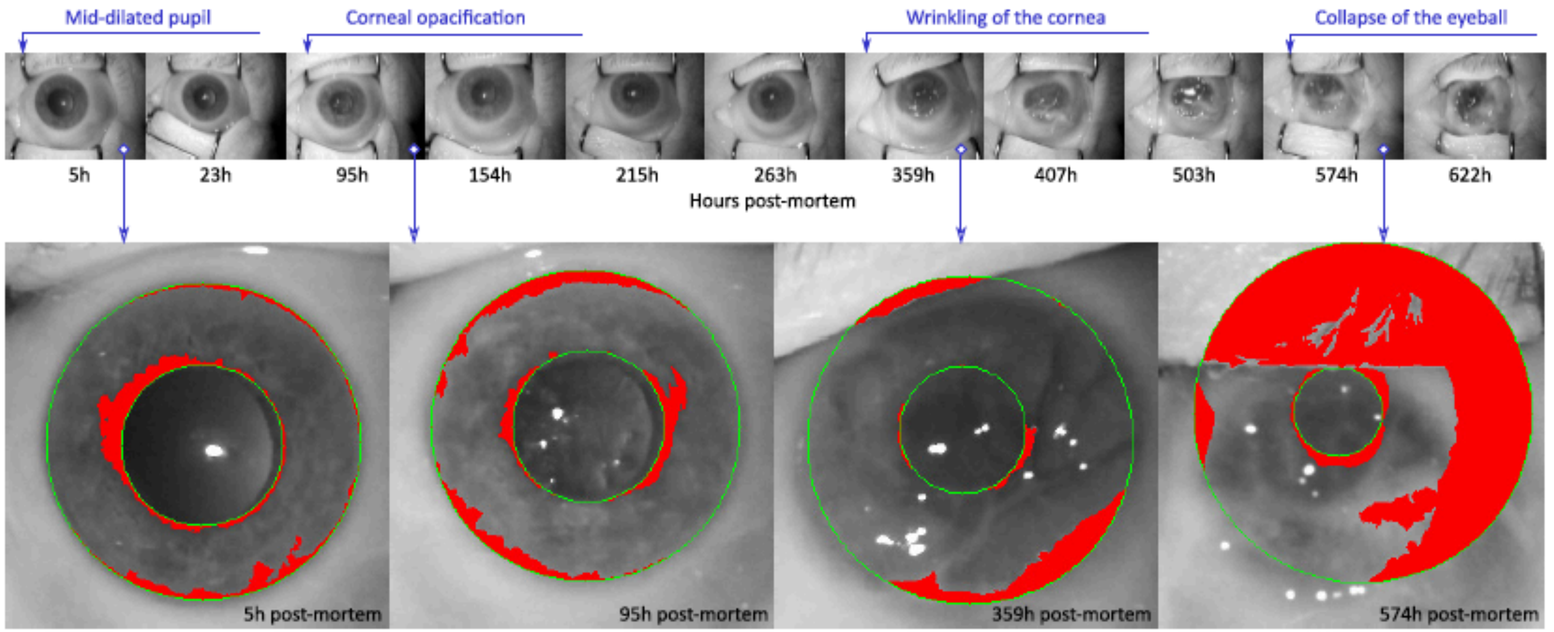
Egad, would it work?

UNIVERSITY OF NOTRE DAME

Why Irises?

Circumvention (6/8)
Irises can be used in identification soon after death.

Trokielewicz, Czajka,
and Maciejewicz
Iris Recognition After Death
IEEE TIFS, 2019



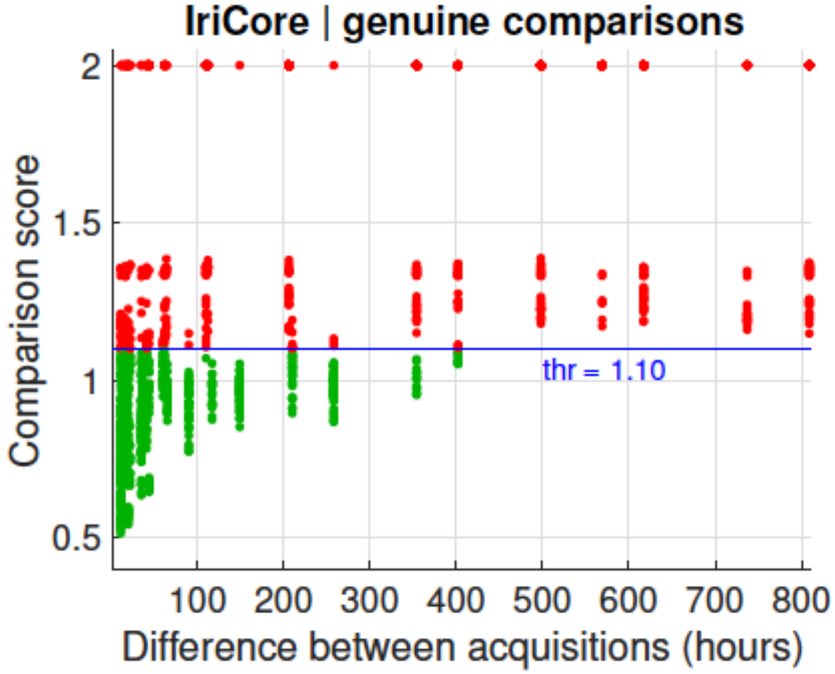
UNIVERSITY OF NOTRE DAME

Why Irises?

Circumvention (6/8)
Irises can be used in identification soon after death.

Trokielewicz, Czajka,
and Maciejewicz
Iris Recognition After Death
IEEE TIFS, 2019

If body is kept in a mortuary,
iris recognition is successful even
17 days after death!



UNIVERSITY OF NOTRE DAME

Why Irises

Performance (7/8)
How good is the trait quantitatively according to objective metrics?

Probably
(Needed investigation)

>

UNIVERSITY OF NOTRE DAME

Why Irises

Performance (7/8)
How good is the trait quantitatively
according to objective metrics?

J. Daugman, 2006
Probing the Uniqueness and Randomness of IrisCodes
IEEE Proceedings, vol. 94, no. 11

200 billion
comparisons

Nearly perfect
match rates

UNIVERSITY OF NOTRE DAME

Why Irises?

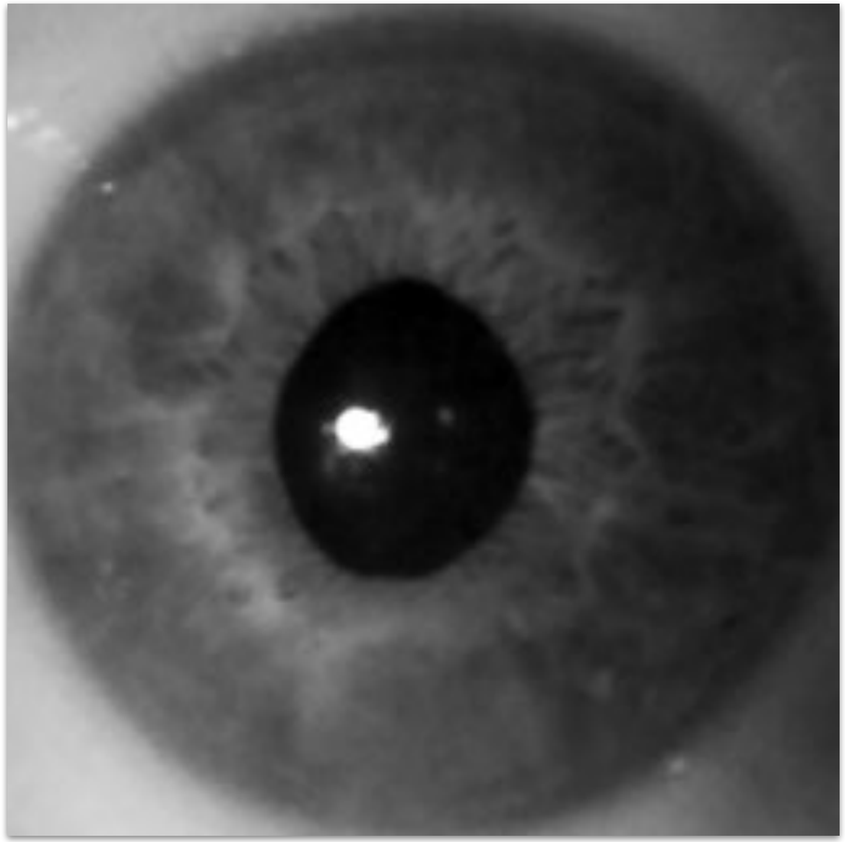
Accountability (8/8)
How easy is it for the everyman to understand the trait comparison?

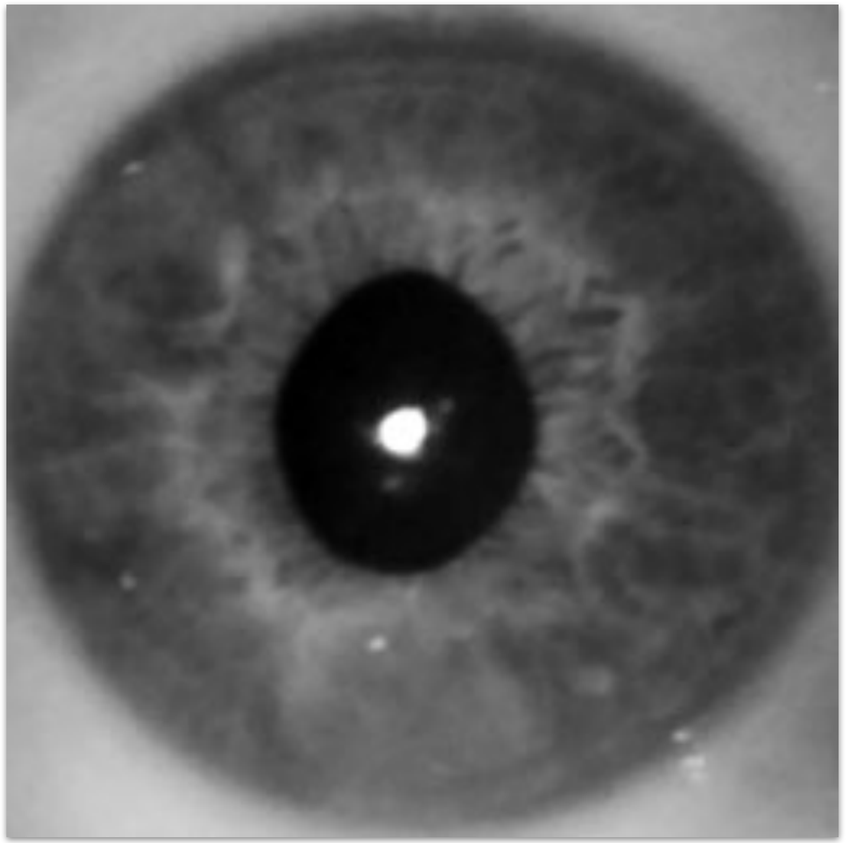
Probably

>

UNIVERSITY OF NOTRE DAME

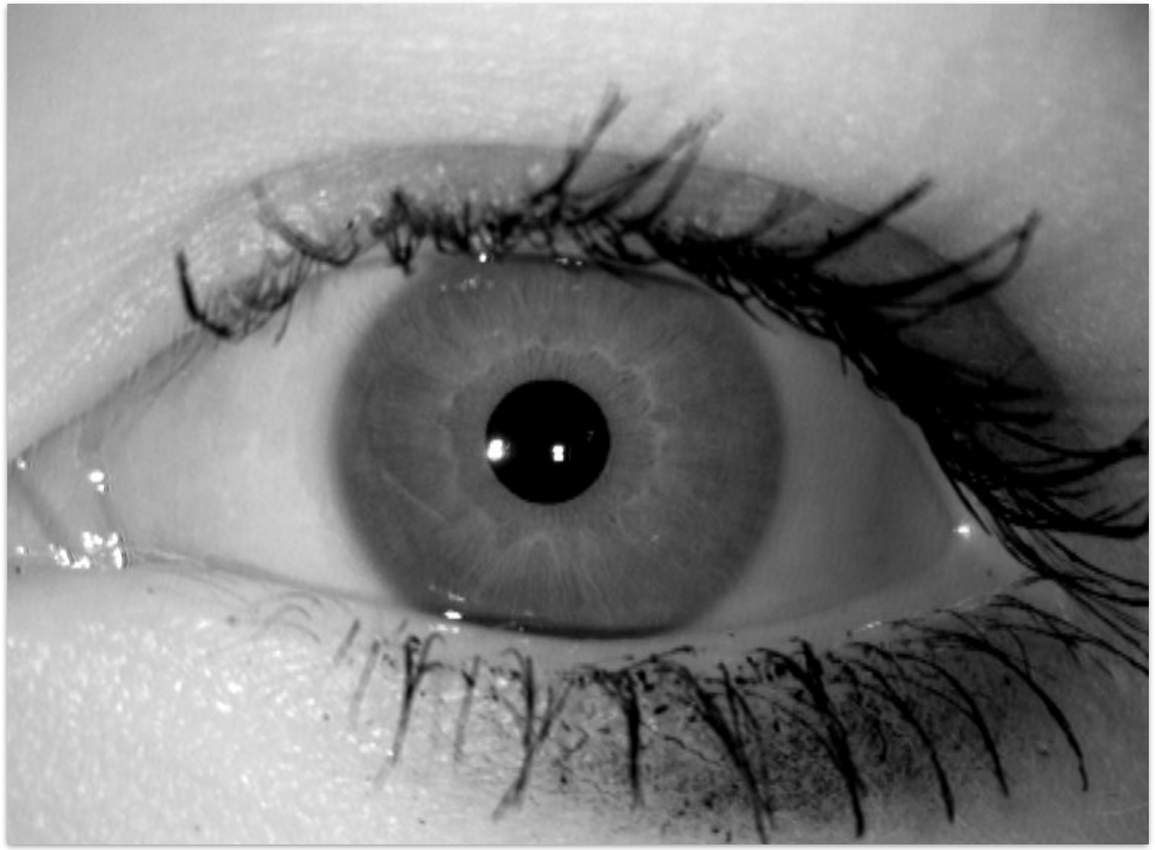
Same Person?

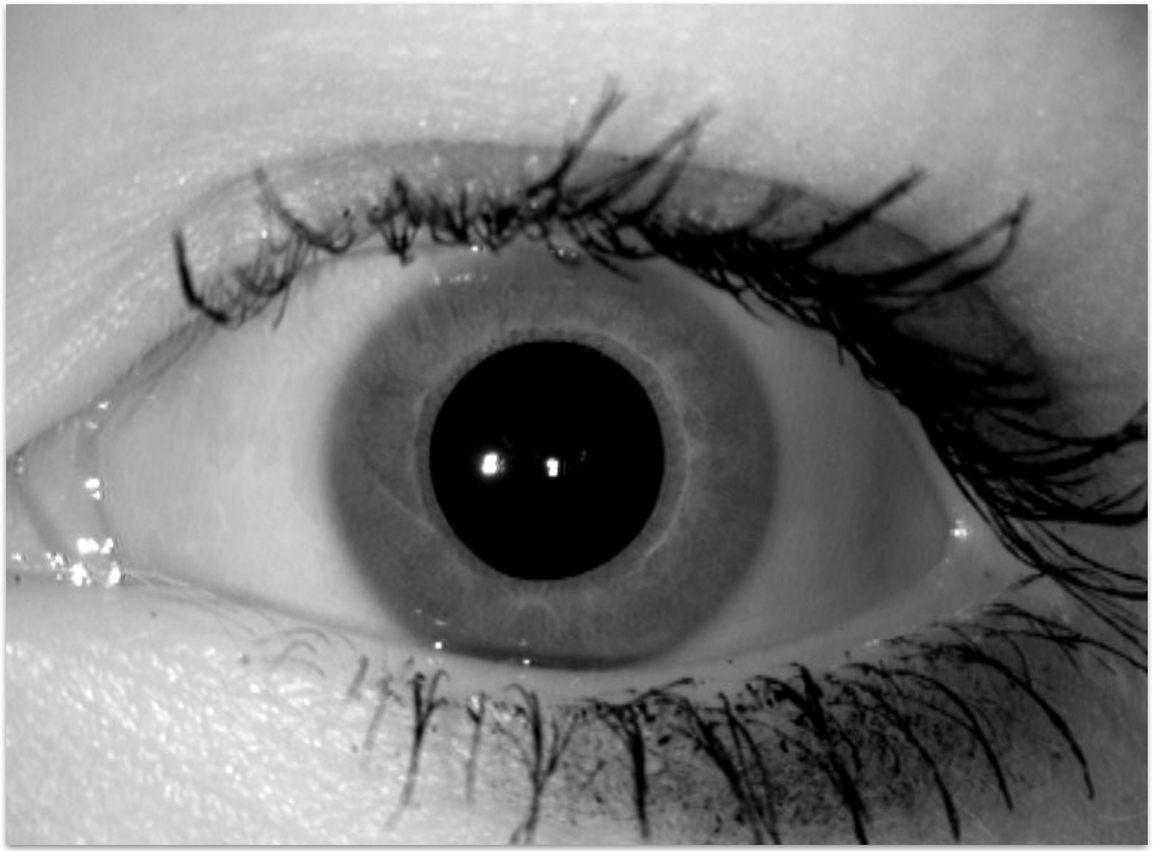




UNIVERSITY OF NOTRE DAME

Same Person?

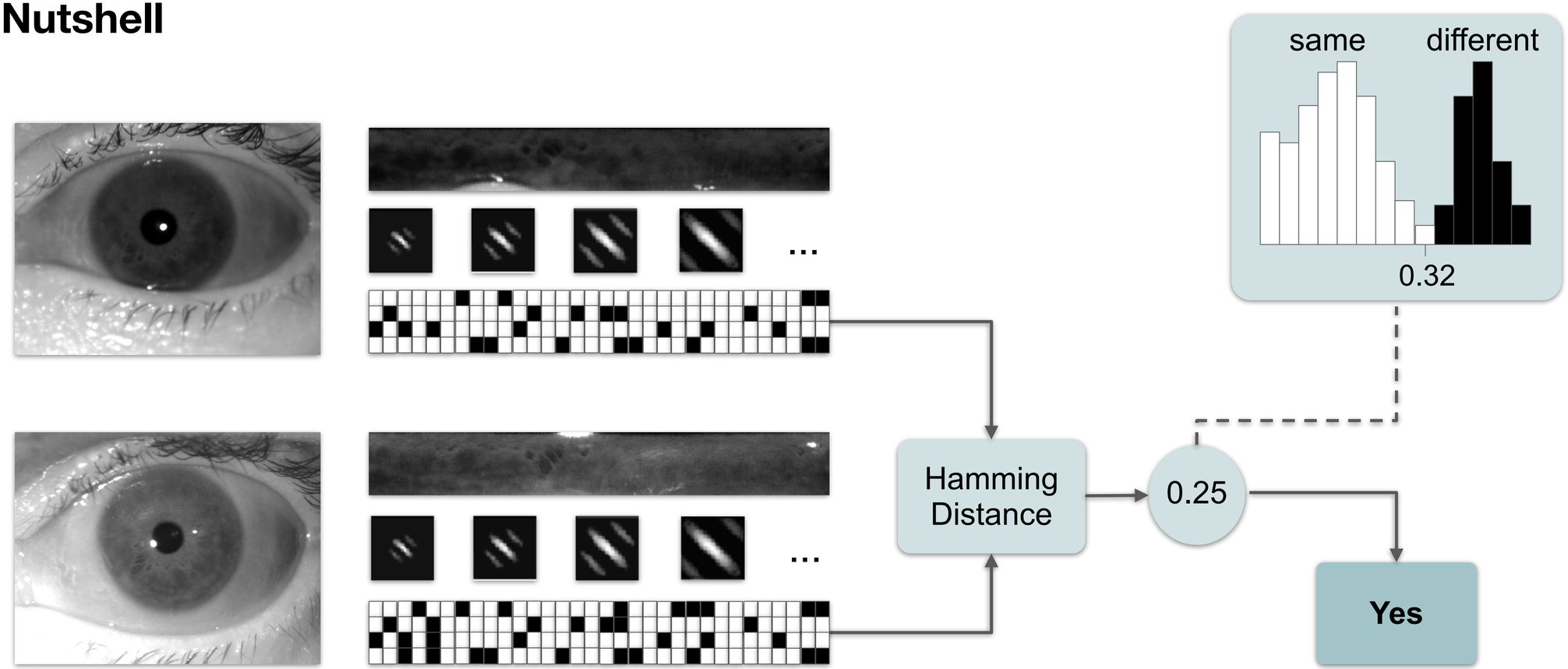




UNIVERSITY OF NOTRE DAME

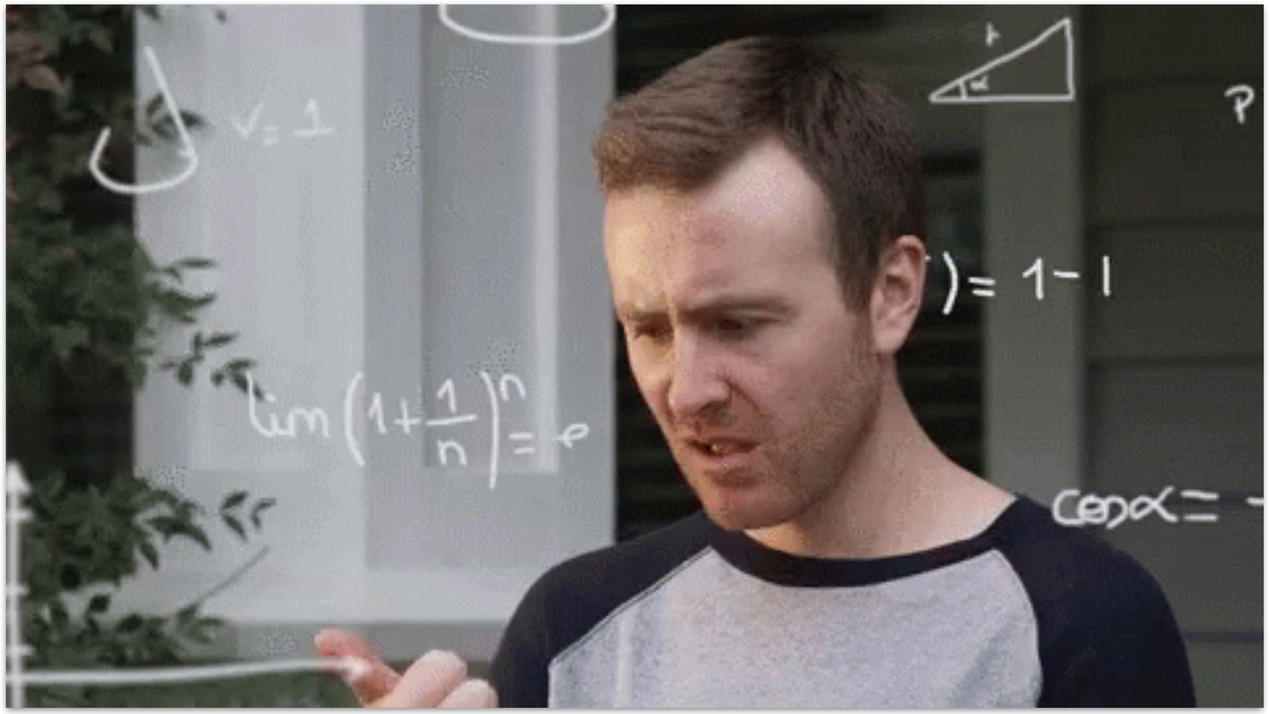
Iris Recognition

In a Nutshell



UNIVERSITY OF NOTRE DAME

Easy, right?



UNIVERSITY OF NOTRE DAME

Accountable Iris Recognition

How can we make it meaningful to the everyman?

UNIVERSITY OF NOTRE DAME

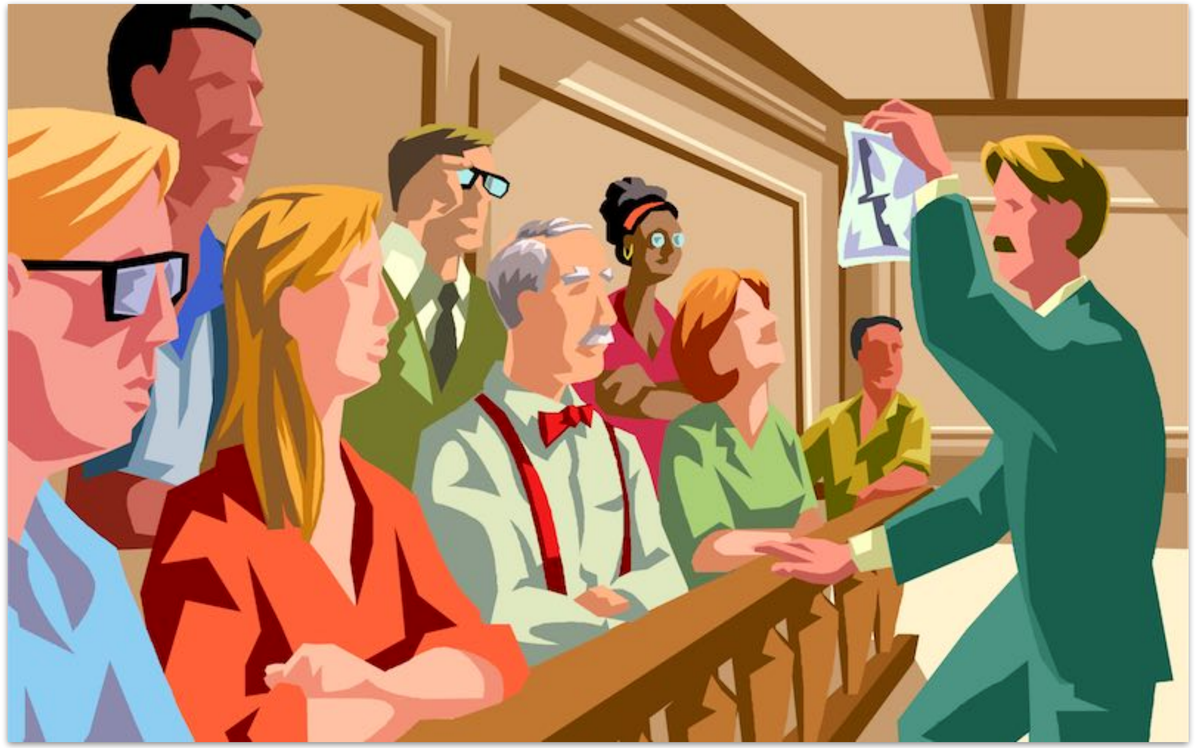
Accountable Iris Recognition

General Data Protection Regulation

People have the right to obtain **an explanation of decisions** made about them by algorithms.

UNIVERSITY OF NOTRE DAME

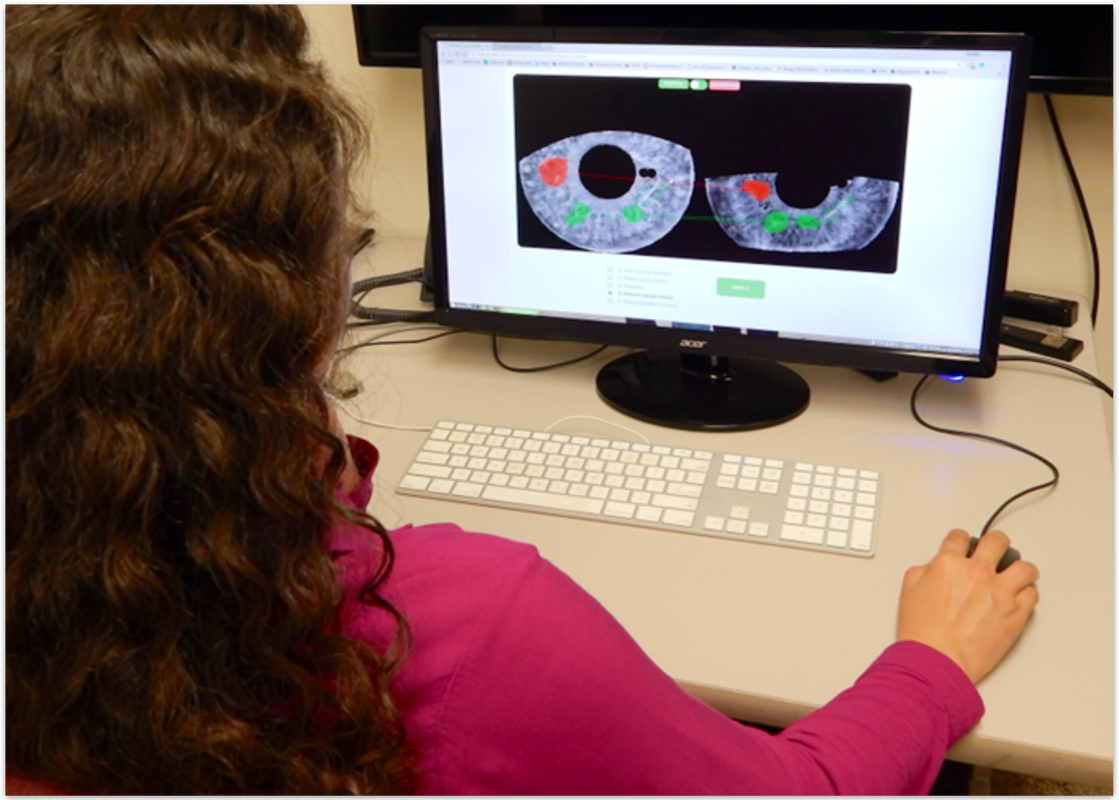
Accountable Iris Recognition



How to convince people who do not possess image processing expertise?

UNIVERSITY OF NOTRE DAME

Accountable Iris Recognition



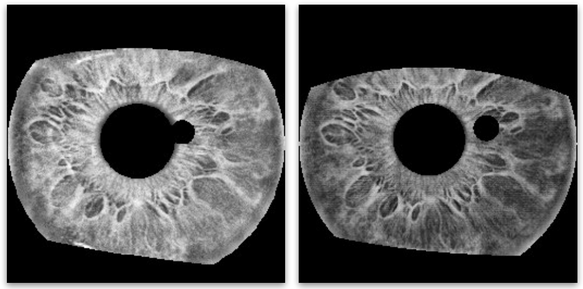
How should we start?

Ask a human:
How do people perform iris recognition?

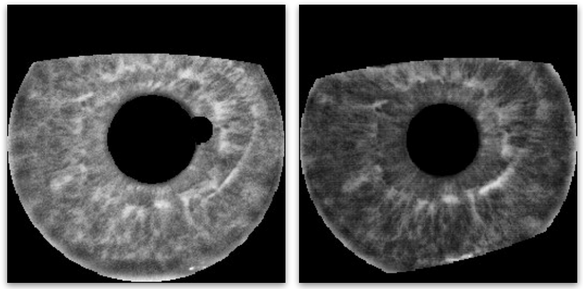
UNIVERSITY OF NOTRE DAME

Human Experiments

Dataset



Easy for an automated solution

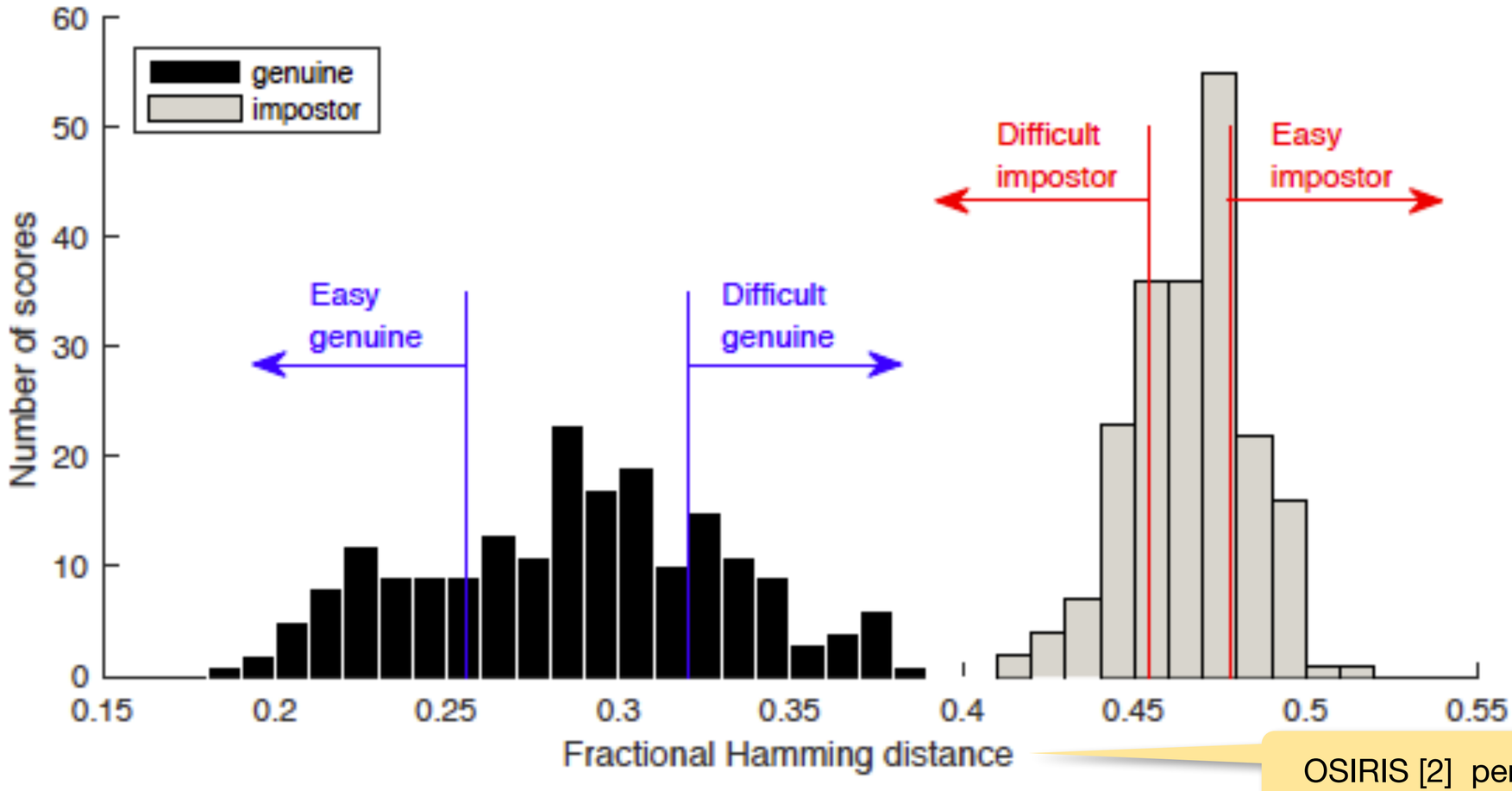


Hard for an automated solution

Source:
NDCrossSensor-Iris-2013 dataset [1].

[1] Collection ND-CrossSensor-Iris-2013
Computer Vision Research Laboratory at the University of Notre Dame, 2013.

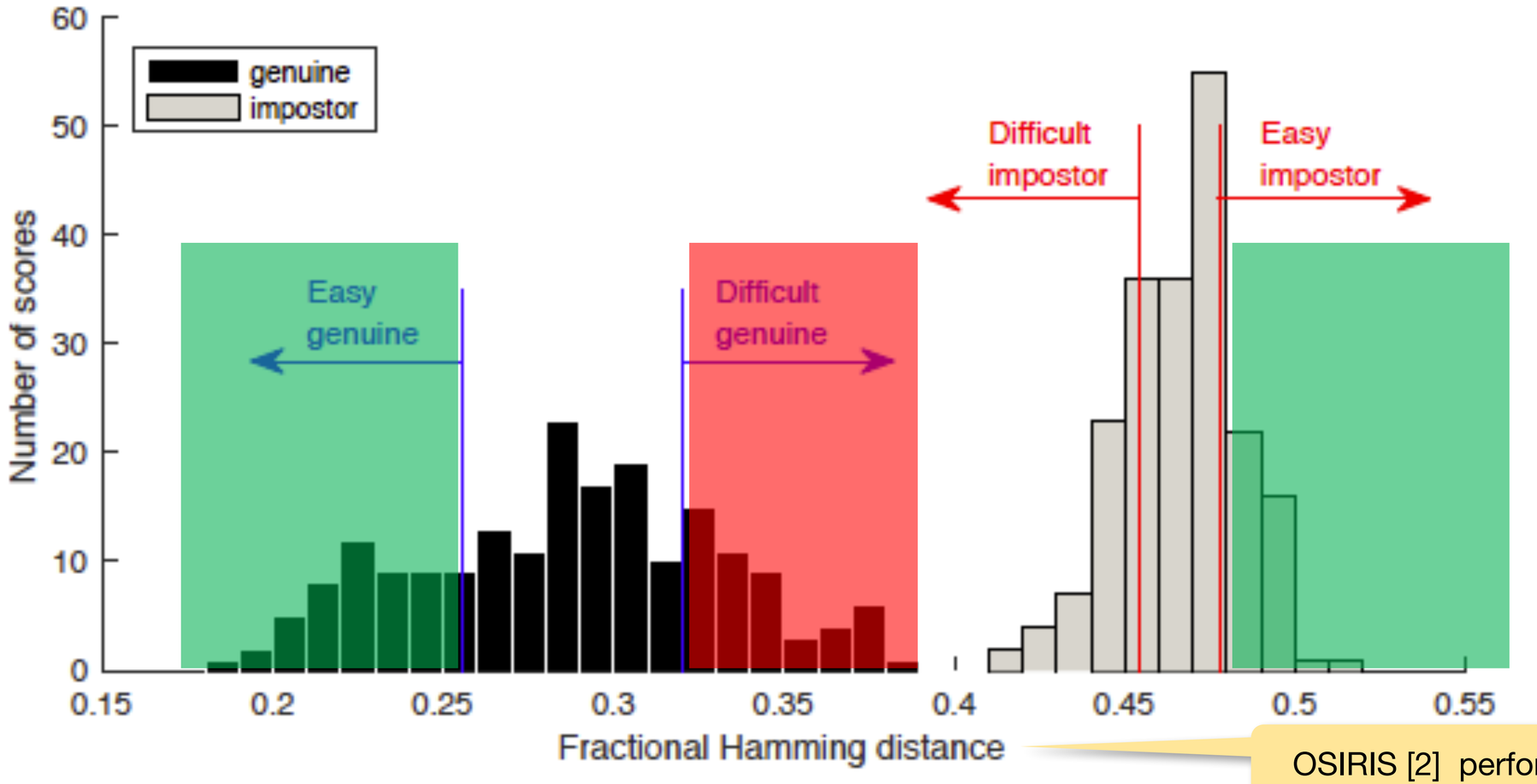
UNIVERSITY OF NOTRE DAME



OSIRIS [2] performance.

[2] OSIRIS: An open source iris recognition software.
Othman et al. Elsevier Pattern Recognition Letters, 82(2):124–131, 2016

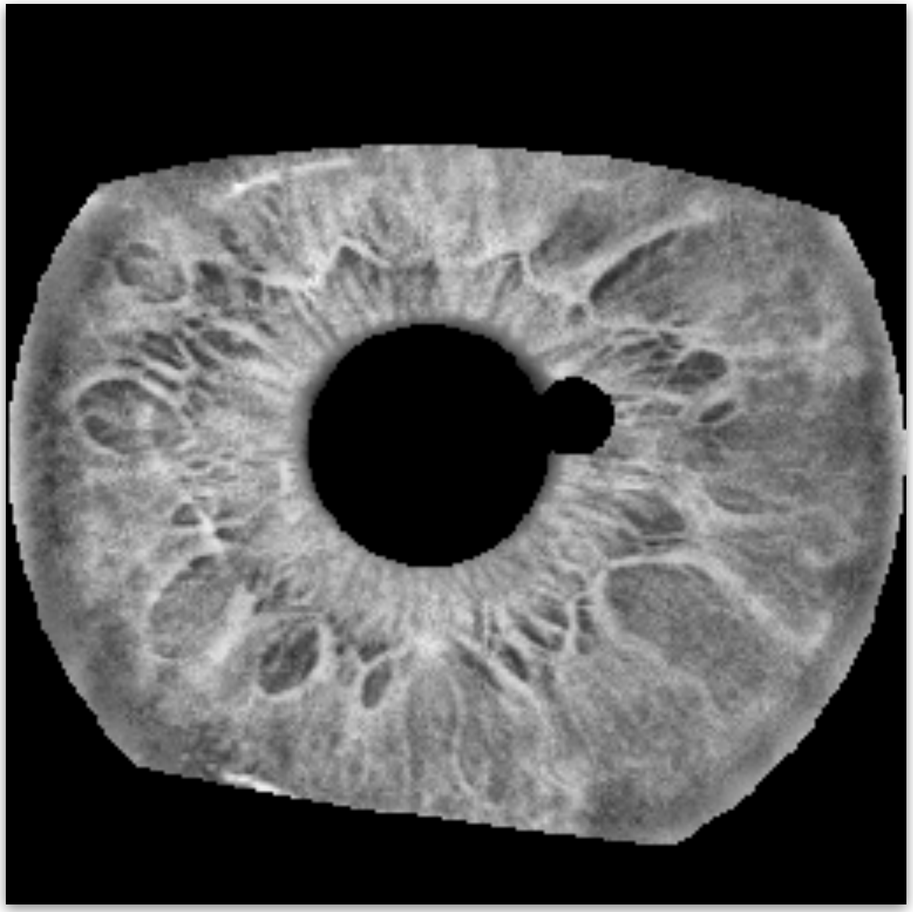
UNIVERSITY OF NOTRE DAME

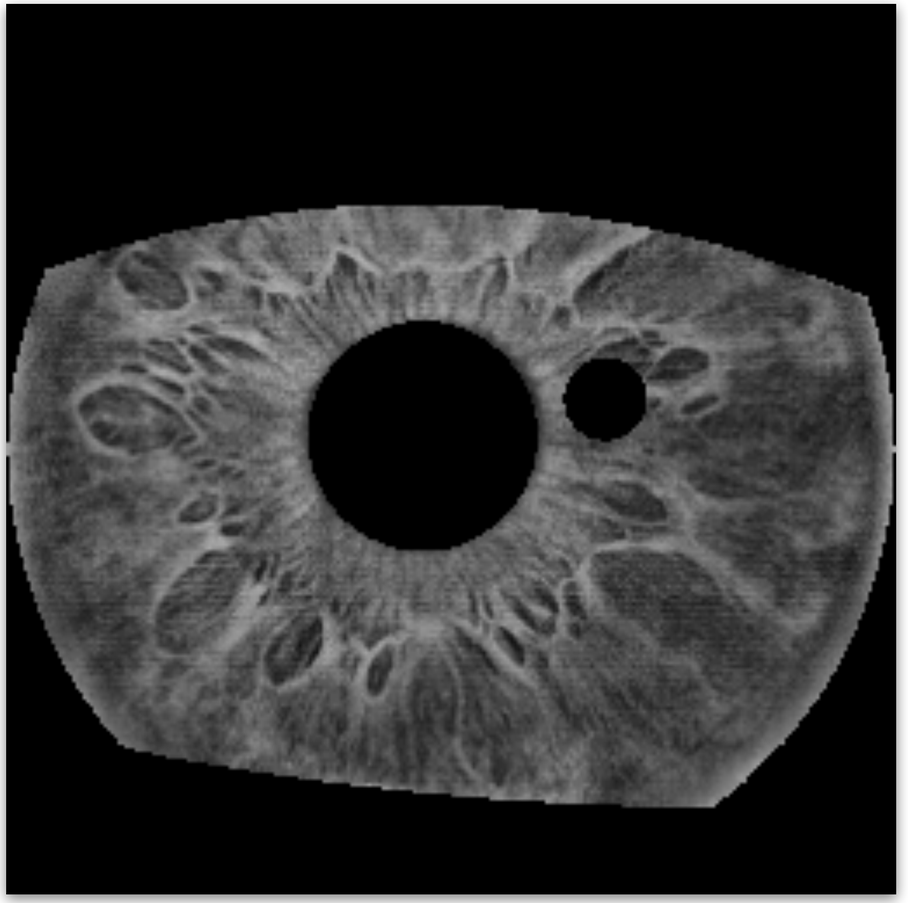


OSIRIS [2] performance.

[2] OSIRIS: An open source iris recognition software.
Othman et al. Elsevier Pattern Recognition Letters, 82(2):124–131, 2016

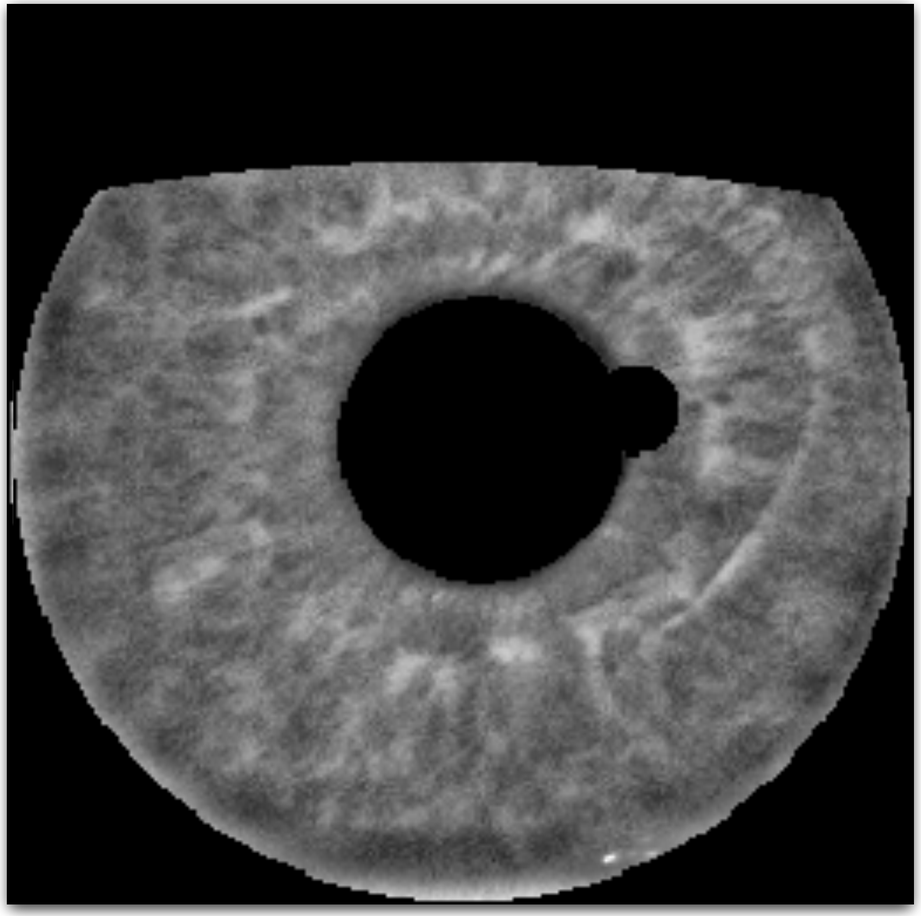
UNIVERSITY OF NOTRE DAME

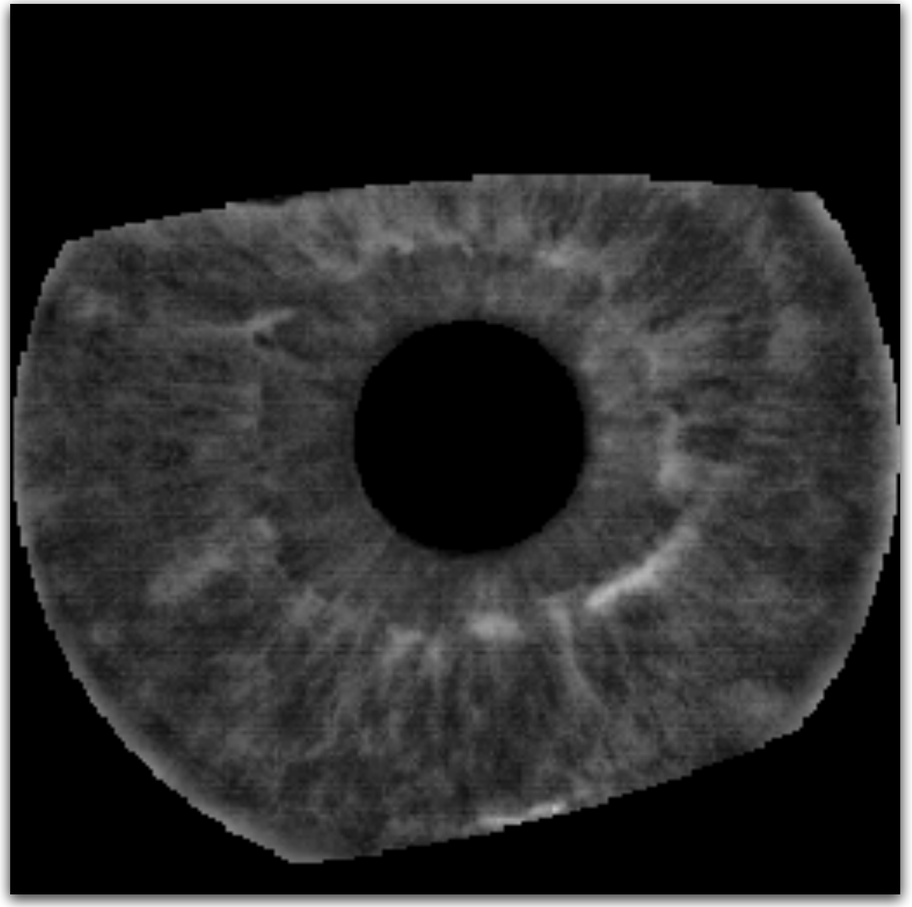




Easy for an automated solution

UNIVERSITY OF NOTRE DAME



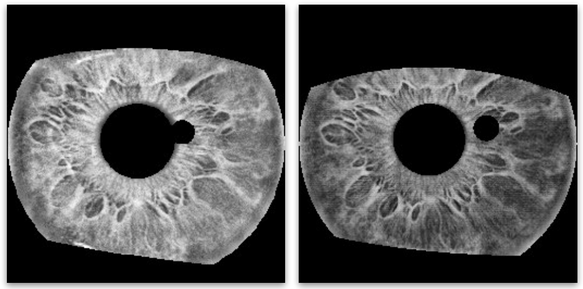


Hard for an automated solution

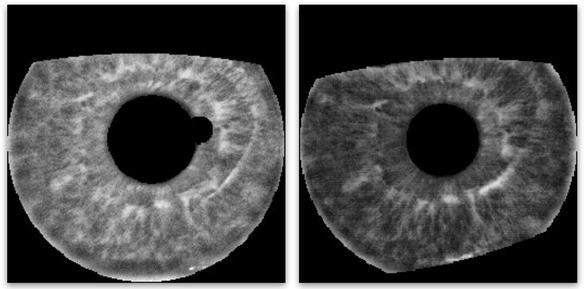
UNIVERSITY OF NOTRE DAME

Human Experiments

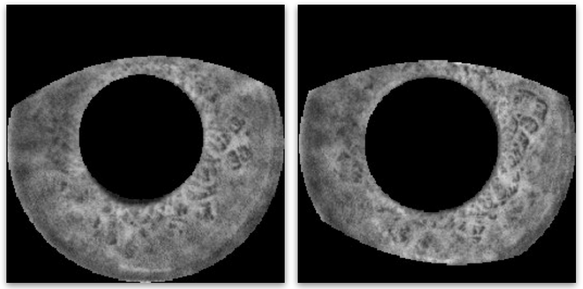
Dataset



Easy for an automated solution



Hard for an automated solution

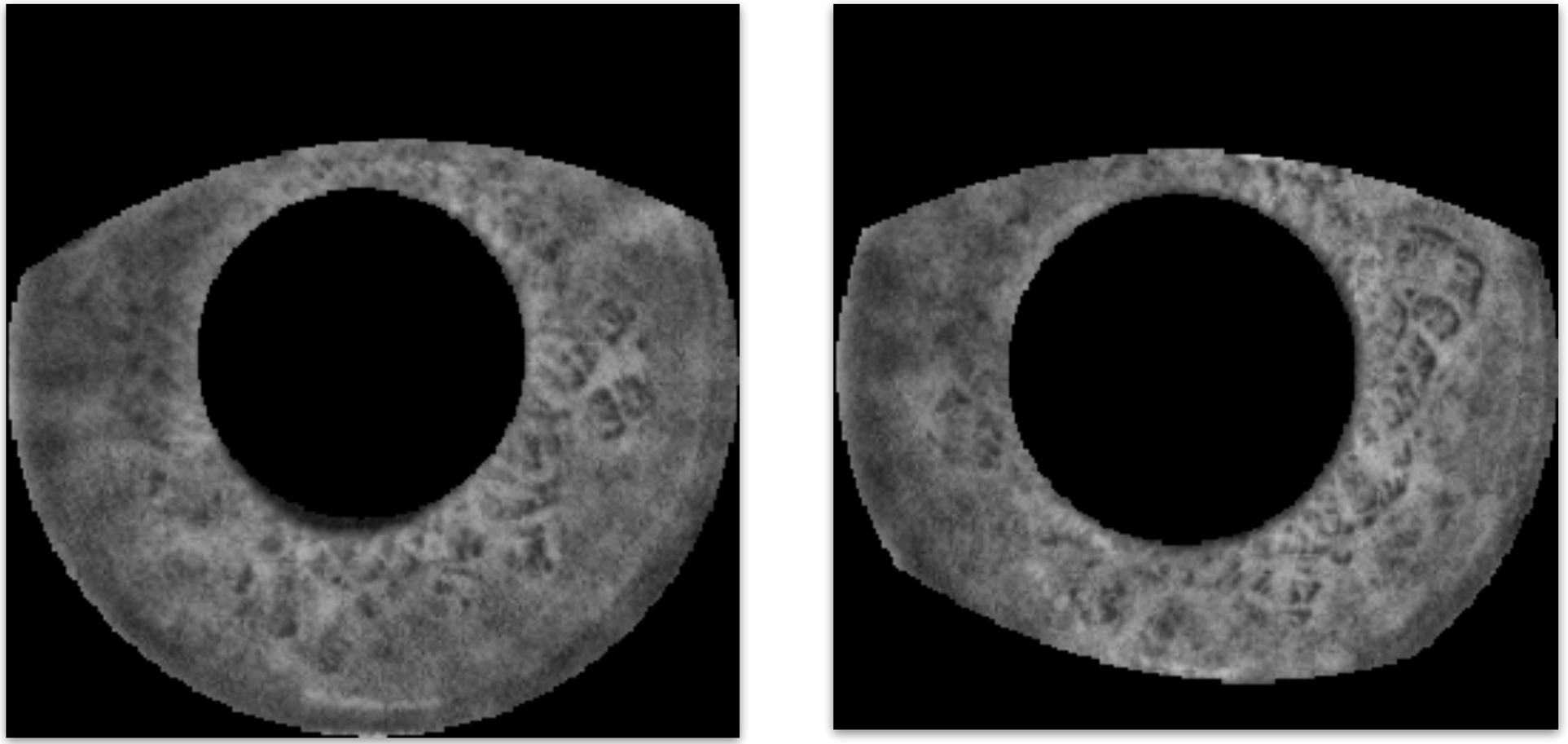


Twins'

Source:
Hollingsworth et al. [3]

[3] Genetically identical irises have texture similarity that is not detected by iris biometrics.
Hollingsworth et al. Elsevier Computer Vision and Image Understanding, 115(11):1493–1502, 2011.

UNIVERSITY OF NOTRE DAME

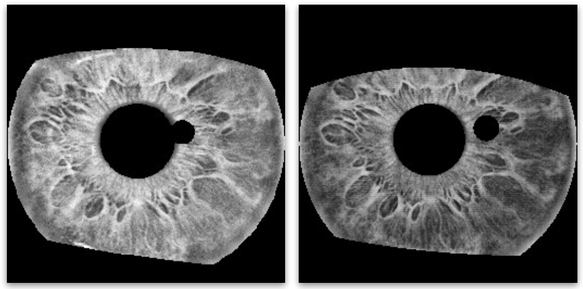


Twins’

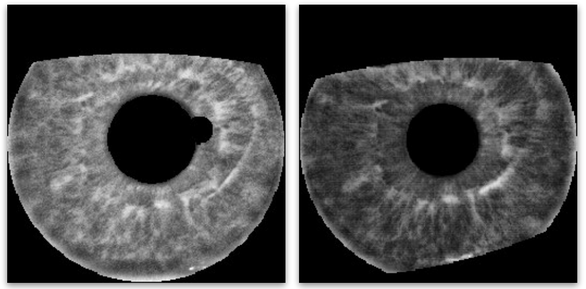
UNIVERSITY OF NOTRE DAME

Human Experiments

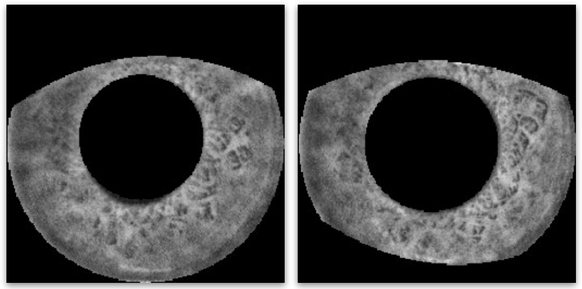
Dataset



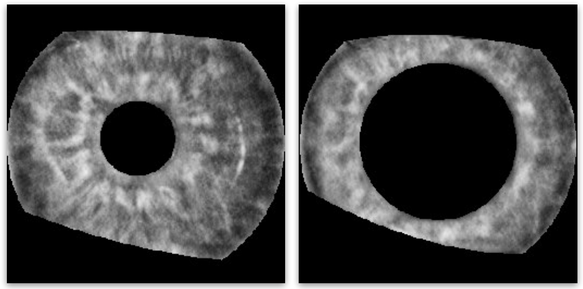
Easy for an automated solution



Hard for an automated solution



Twins'

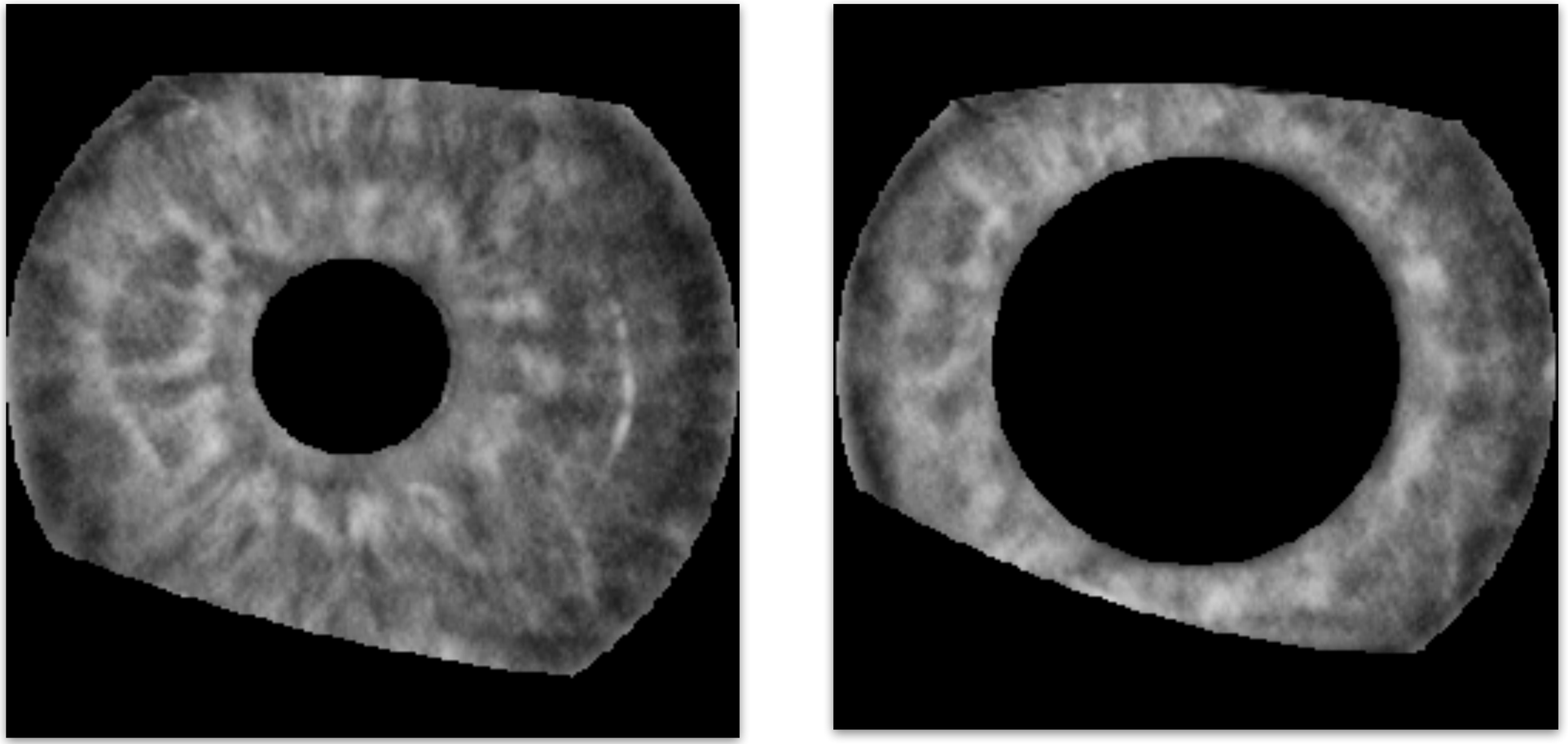


Pupil dynamic

Source:
Hollingsworth et al. [3]

[3] Genetically identical irises have texture similarity that is not detected by iris biometrics. Hollingsworth et al.
Elsevier Computer Vision and Image Understanding, 115(11):1493–1502, 2011.

UNIVERSITY OF NOTRE DAME

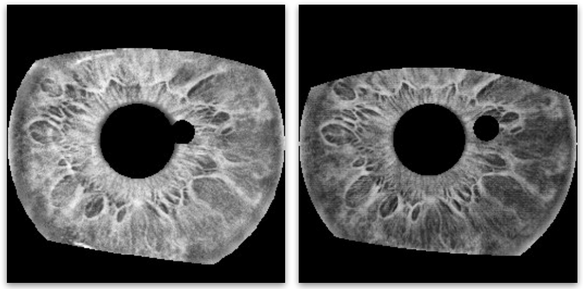


Pupil-dynamic

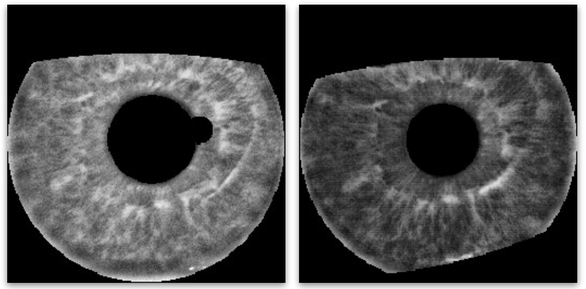
UNIVERSITY OF NOTRE DAME

Human Experiments

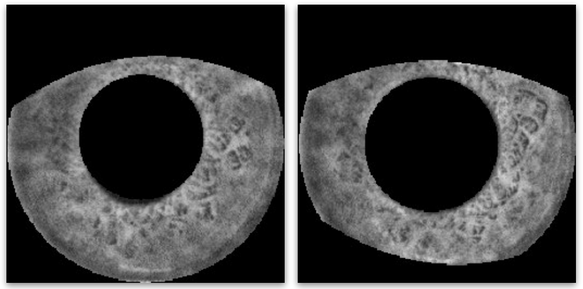
Dataset



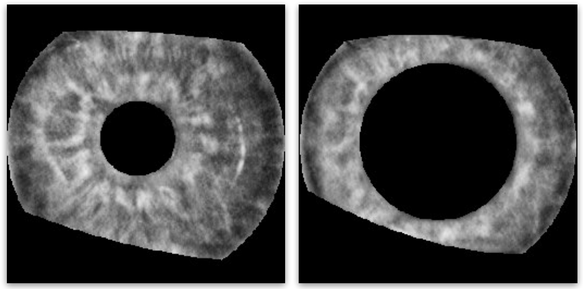
Easy for an automated solution



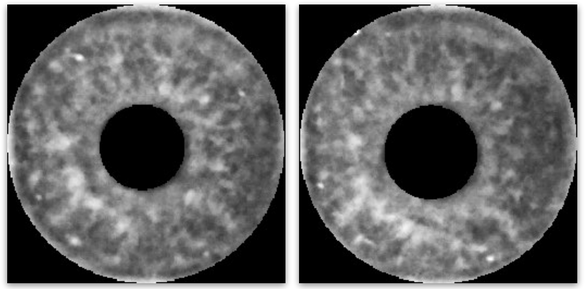
Hard for an automated solution



Twins'



Pupil dynamic

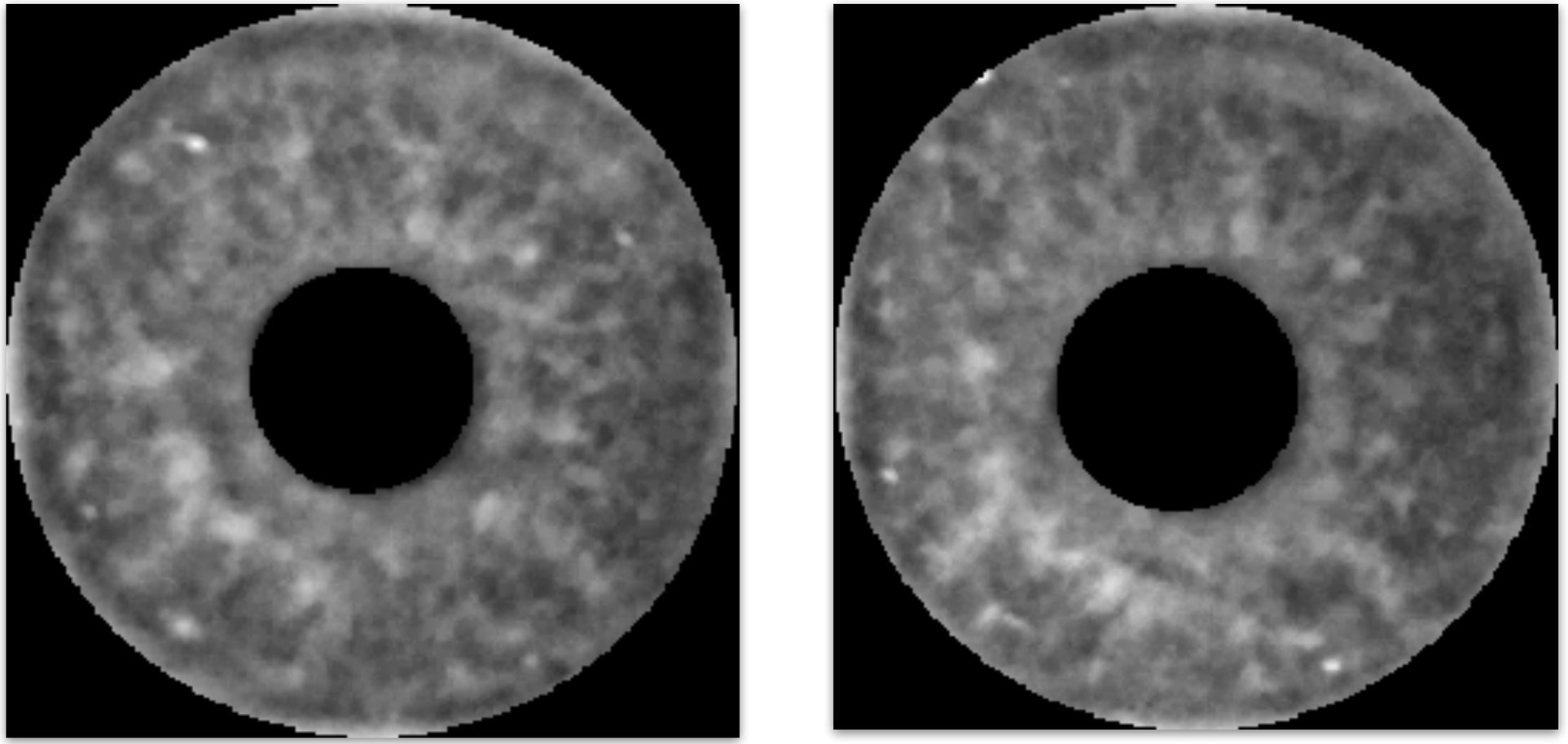


Deceased

Source:
Warsaw-BioBase-Disease-Iris v2.1 [4]

[4] Database of iris images acquired in the presence of ocular pathologies and assessment of iris recognition reliability for disease affected eyes. Trokielewicz et al. IEEE Intl. Conference on Cybernetics, 2015.

UNIVERSITY OF NOTRE DAME



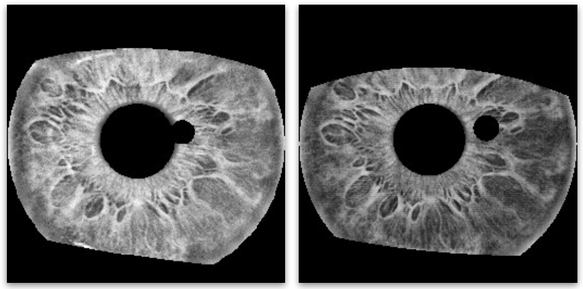
Deceased

UNIVERSITY OF NOTRE DAME

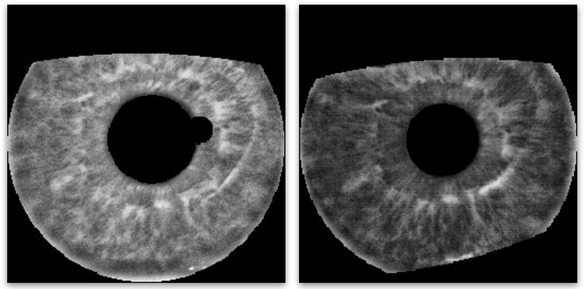
Human Experiments

Dataset

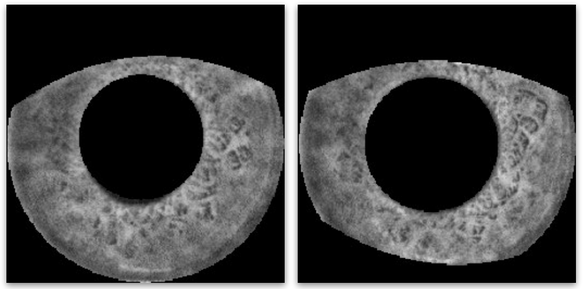
[5] Human iris recognition in post-mortem subjects: Study and database.
Trokielewicz et al. IEEE Intl. Conference on Biometrics: Theory, Applications and Systems, 2016.



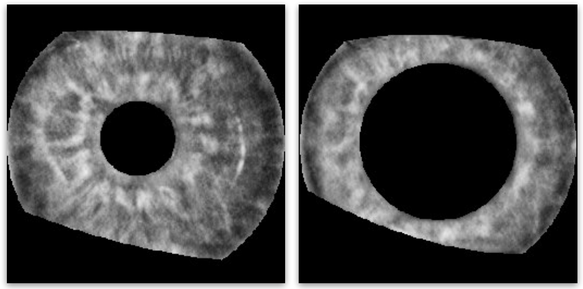
Easy for an automated solution



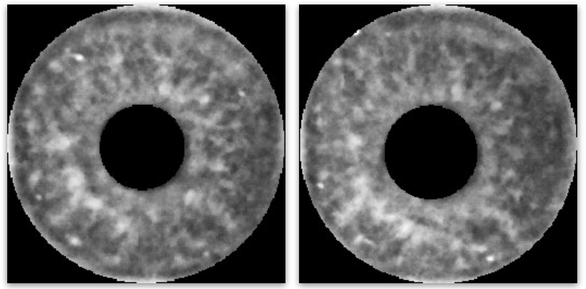
Hard for an automated solution



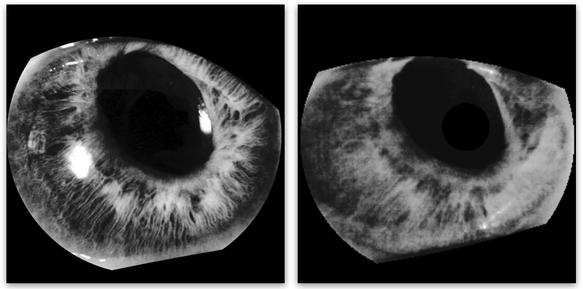
Twins'



Pupil dynamic



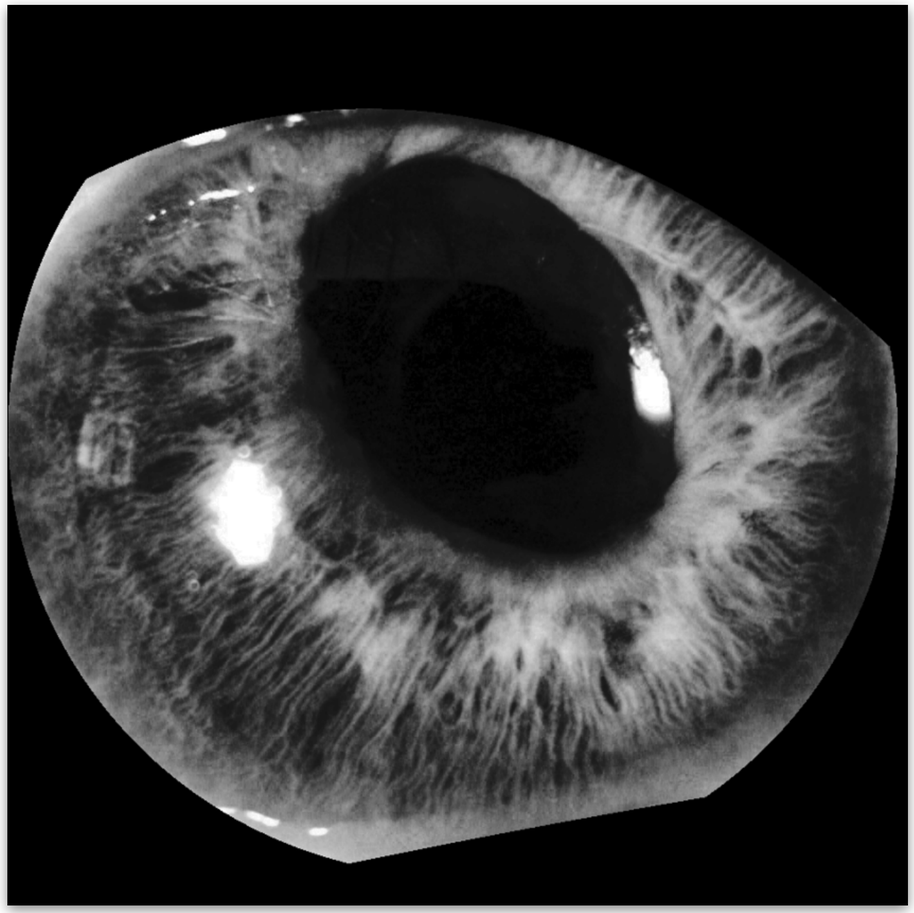
Deceased

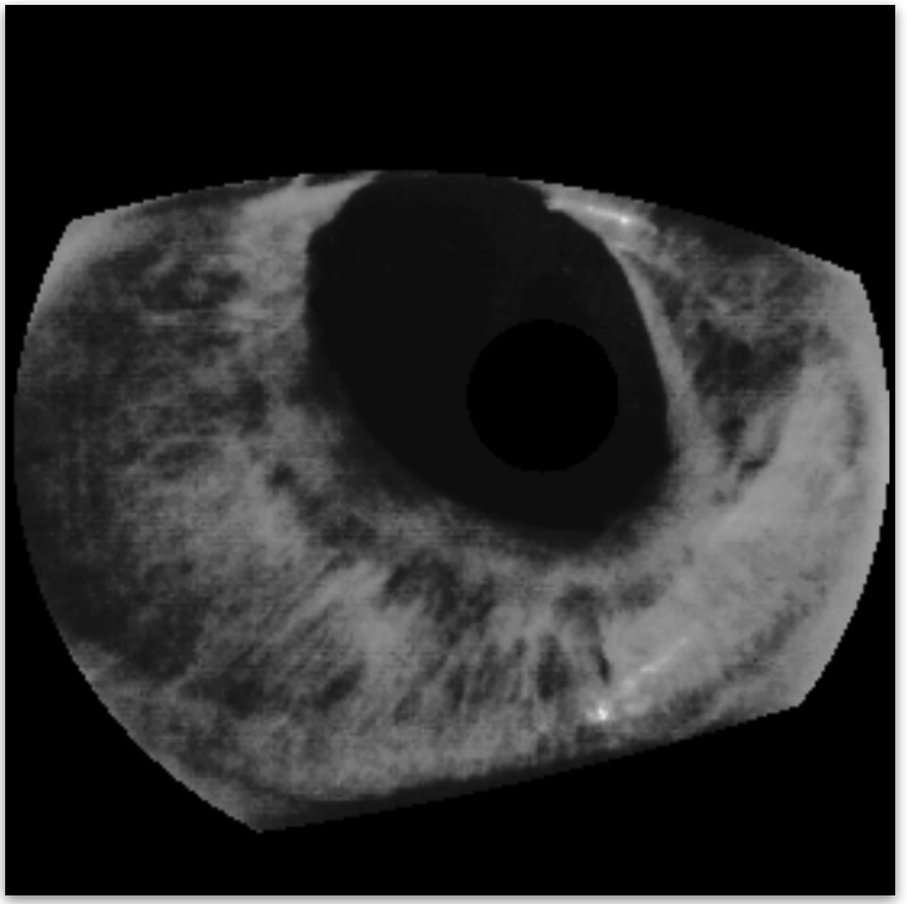


Disease-affected

Source: Warsaw-BioBase-Post-Mortem-Iris v1.0 [5]

UNIVERSITY OF NOTRE DAME



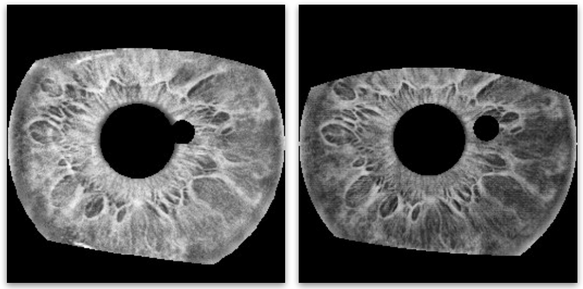


Disease-affected

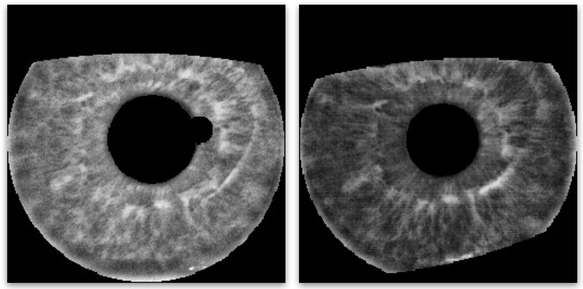
UNIVERSITY OF NOTRE DAME

Human Experiments

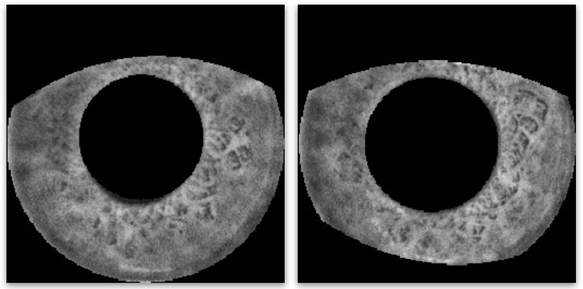
Dataset



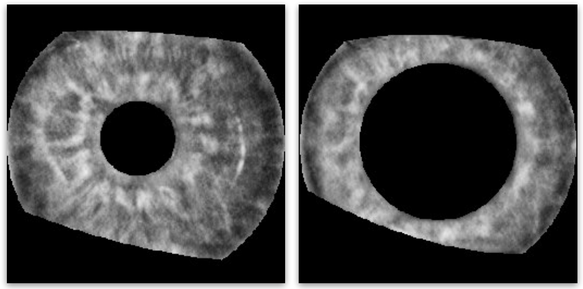
Easy for an automated solution



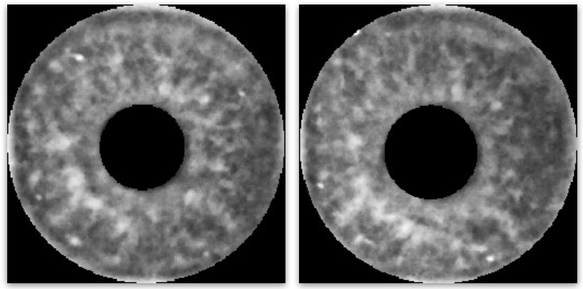
Hard for an automated solution



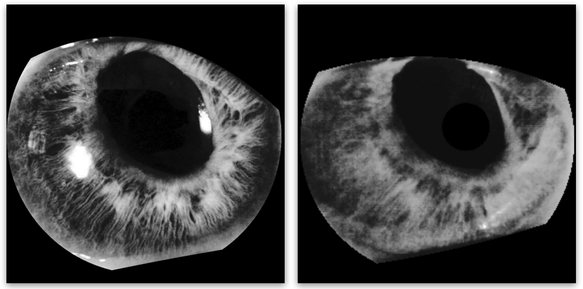
Twins’



Pupil dynamic



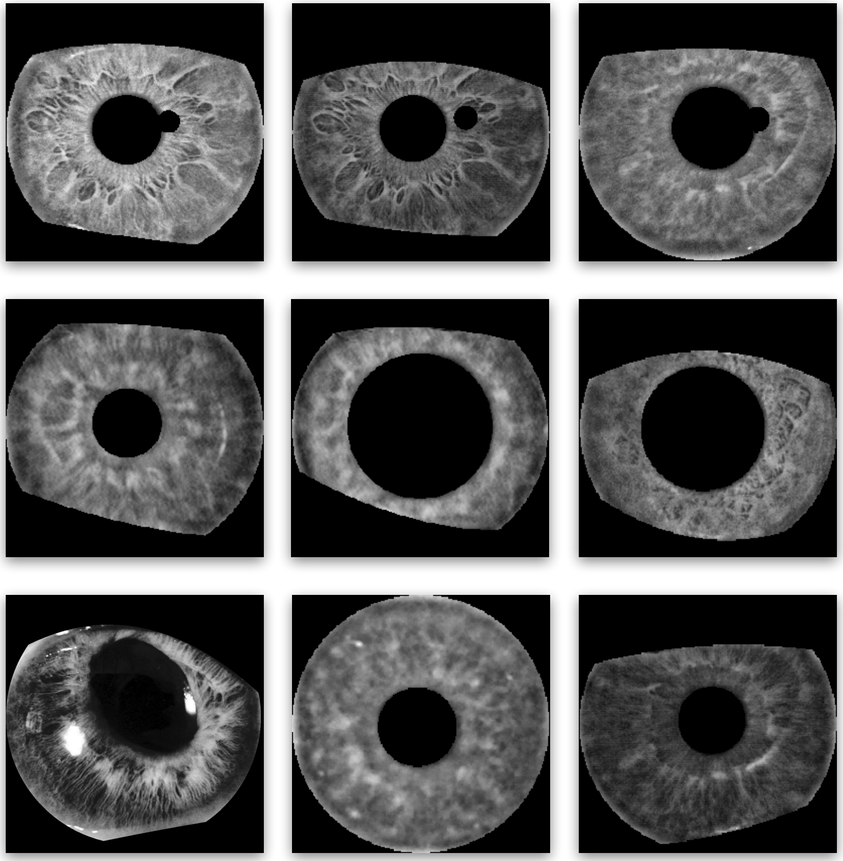
Deceased



Disease-affected

UNIVERSITY OF NOTRE DAME

Human Experiments



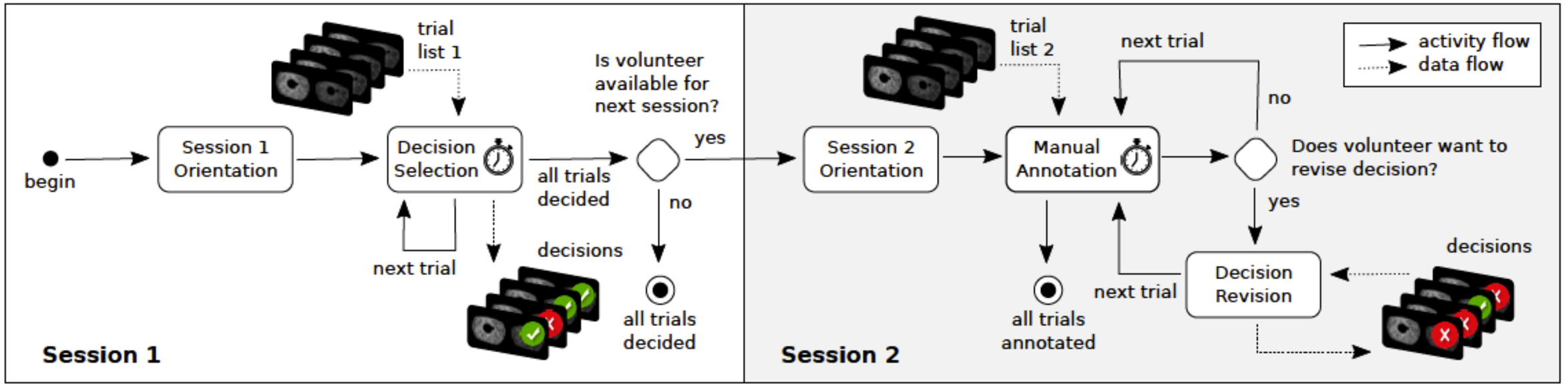
1360 iris images
(NIR and manually segmented)

512 distinct irises
512 individuals

Iris-pair types
Genuine (not taken at the same day)
Impostor (not mixing different categories)

UNIVERSITY OF NOTRE DAME

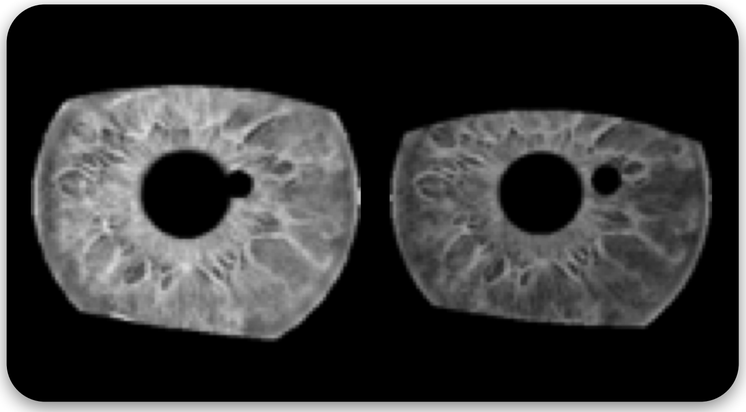
Human Experiments



Moreira et al.,
Performance of Humans in Iris Recognition: The Impact of Iris Condition and Annotation-driven Verification
WACV 2019

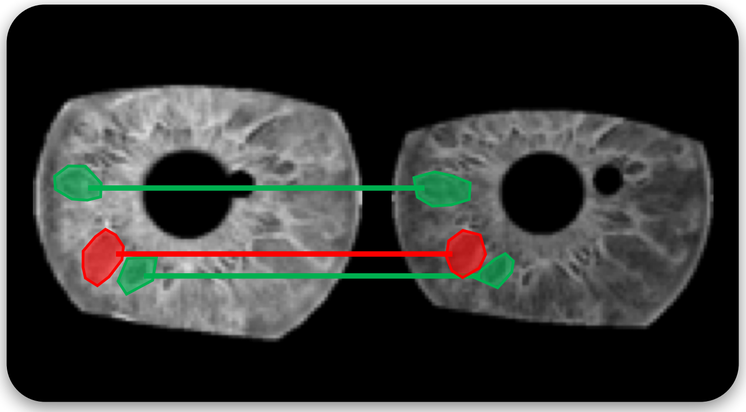
UNIVERSITY OF NOTRE DAME

Human Experiments



Session 1

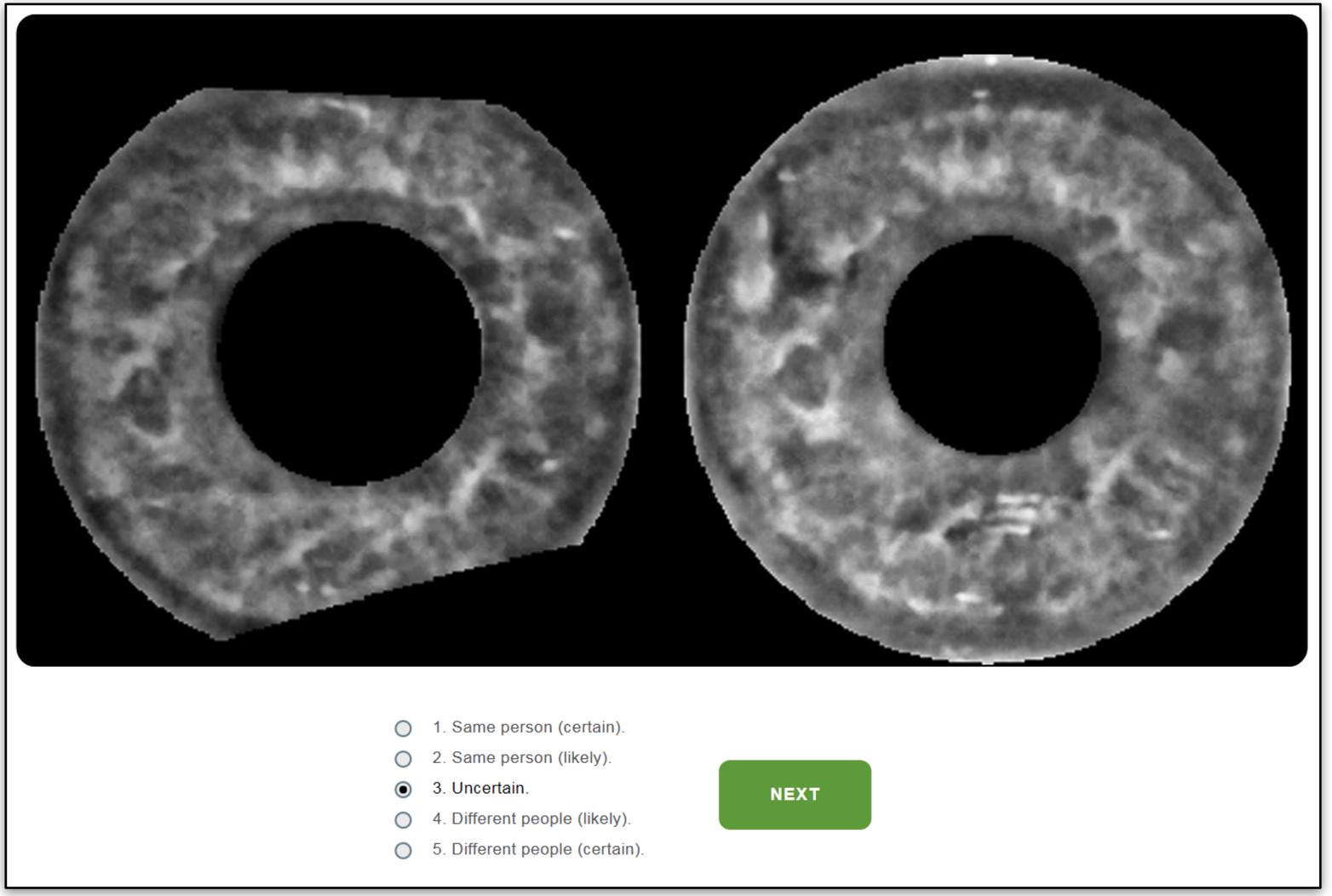
- ○ 1. Same person (certain).
- ○ 2. Same person (likely).
- ◉ 3. Uncertain.
- ○ 4. Different person (likely).
- ○ 5. Different person (certain).



Session 2

Manual annotation of **matching** and **missing** features

UNIVERSITY OF NOTRE DAME



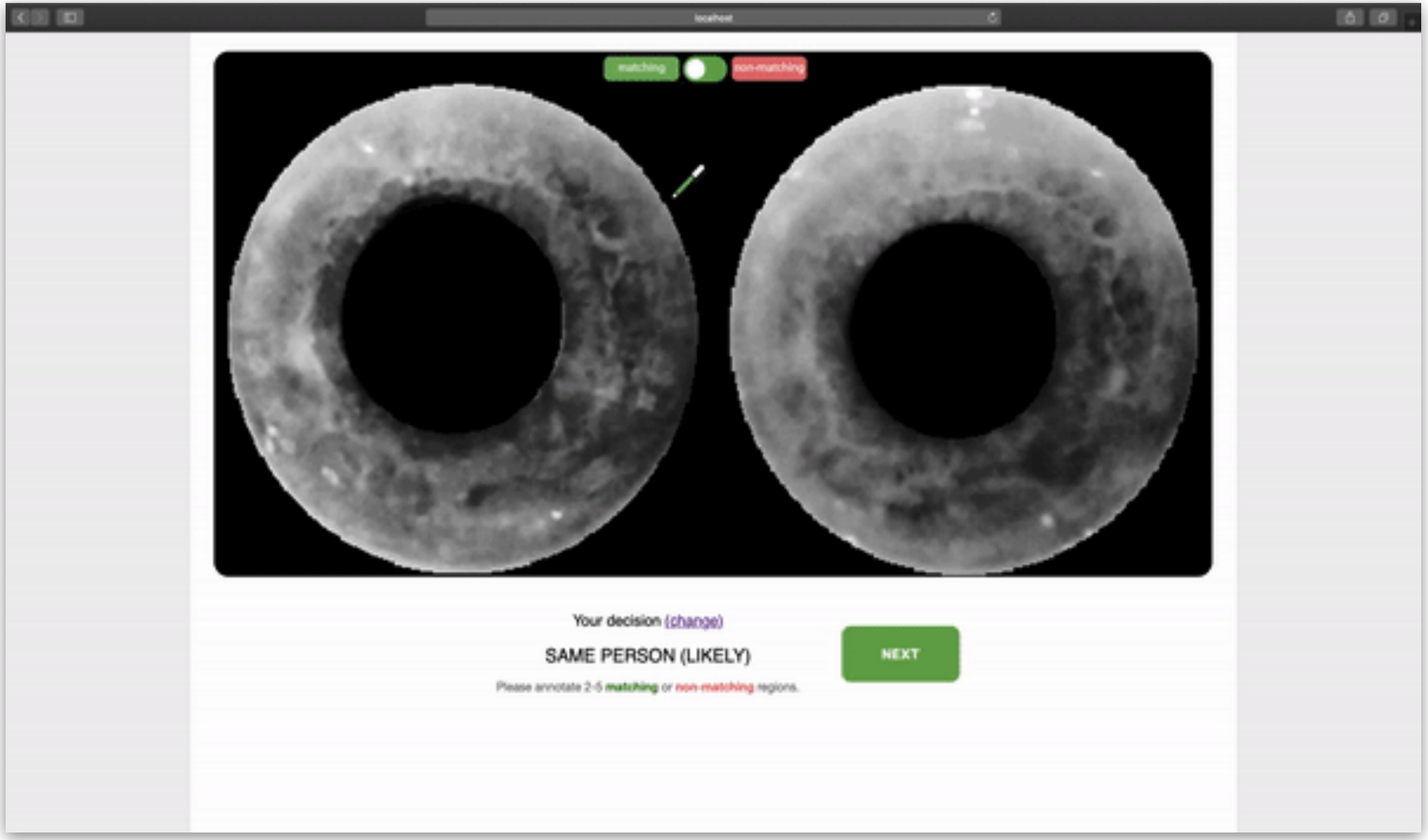
114 people
(age 18 to 65)

For each person
20 trials

Average session time
7 min

Balanced distribution
Category wise
Pair-type wise
Random presentation

UNIVERSITY OF NOTRE DAME



85 people

For each person
10 trials

Average session time
10 min

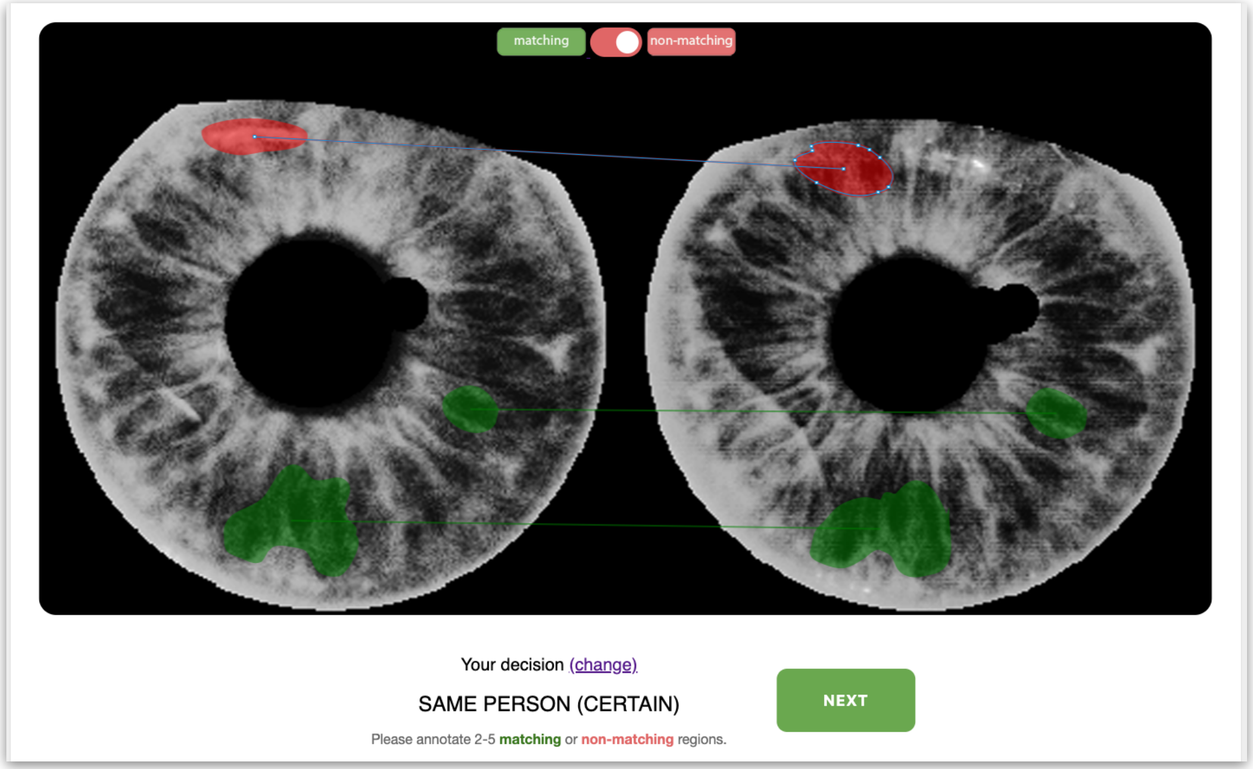
Balanced distribution
Category wise
Pair-type wise
Session-1 answer wise

UNIVERSITY OF NOTRE DAME

Annotation Tool

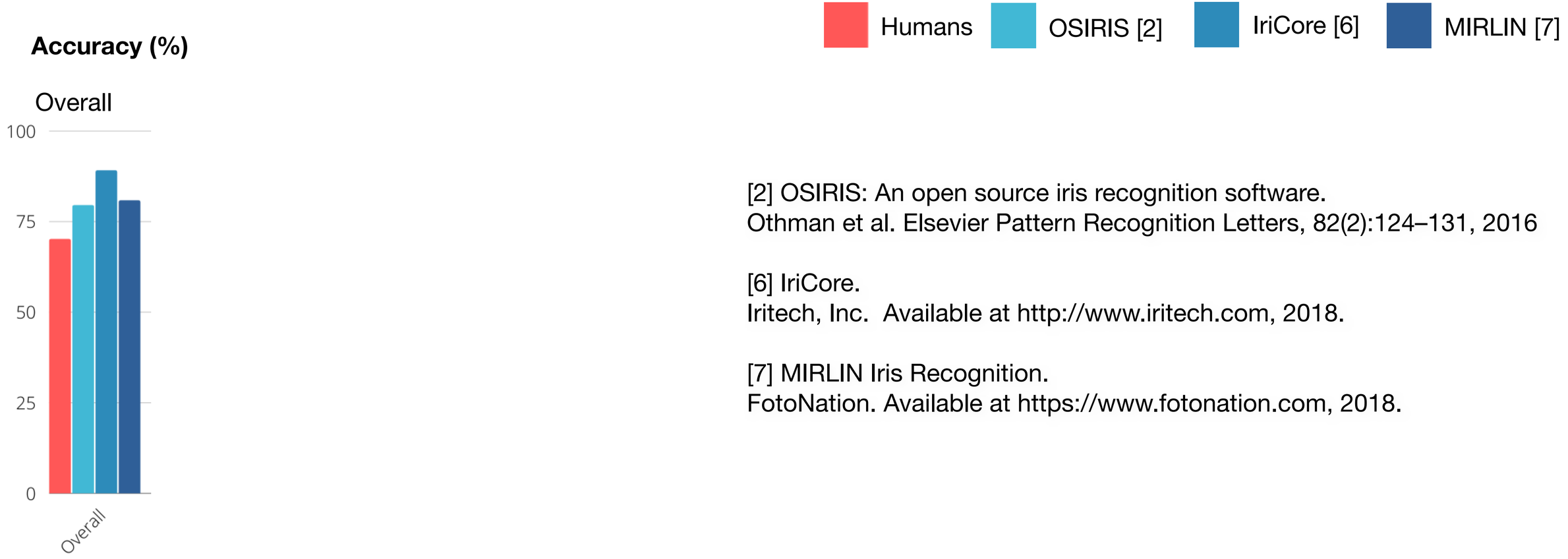
Available at
https://github.com/
danielmoreira/iris-examination

Paper.js
Web-browser drawing
library.



UNIVERSITY OF NOTRE DAME

Human Experiments



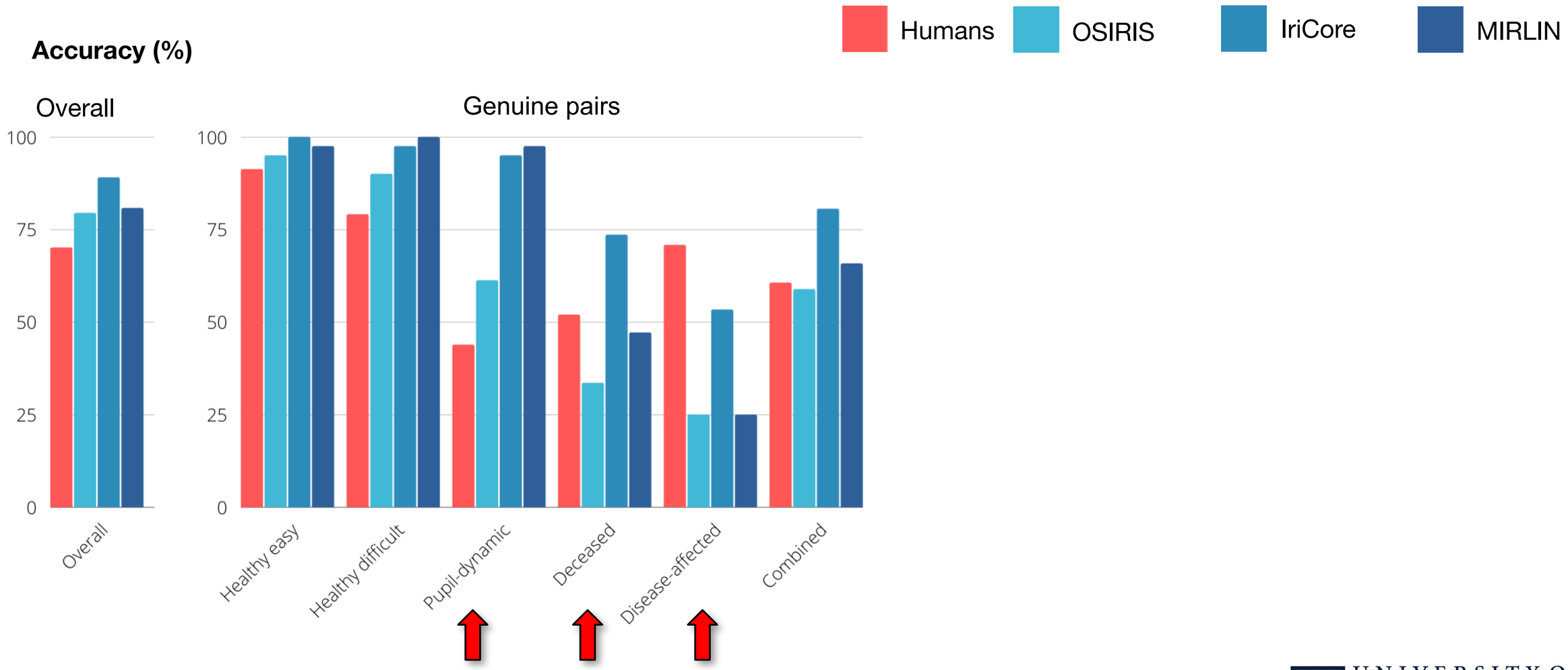
[2] OSIRIS: An open source iris recognition software.
Othman et al. Elsevier Pattern Recognition Letters, 82(2):124–131, 2016

[6] IriCore.
Iritech, Inc. Available at http://www.iritech.com, 2018.

[7] MIRLIN Iris Recognition.
FotoNation. Available at https://www.fotonation.com, 2018.

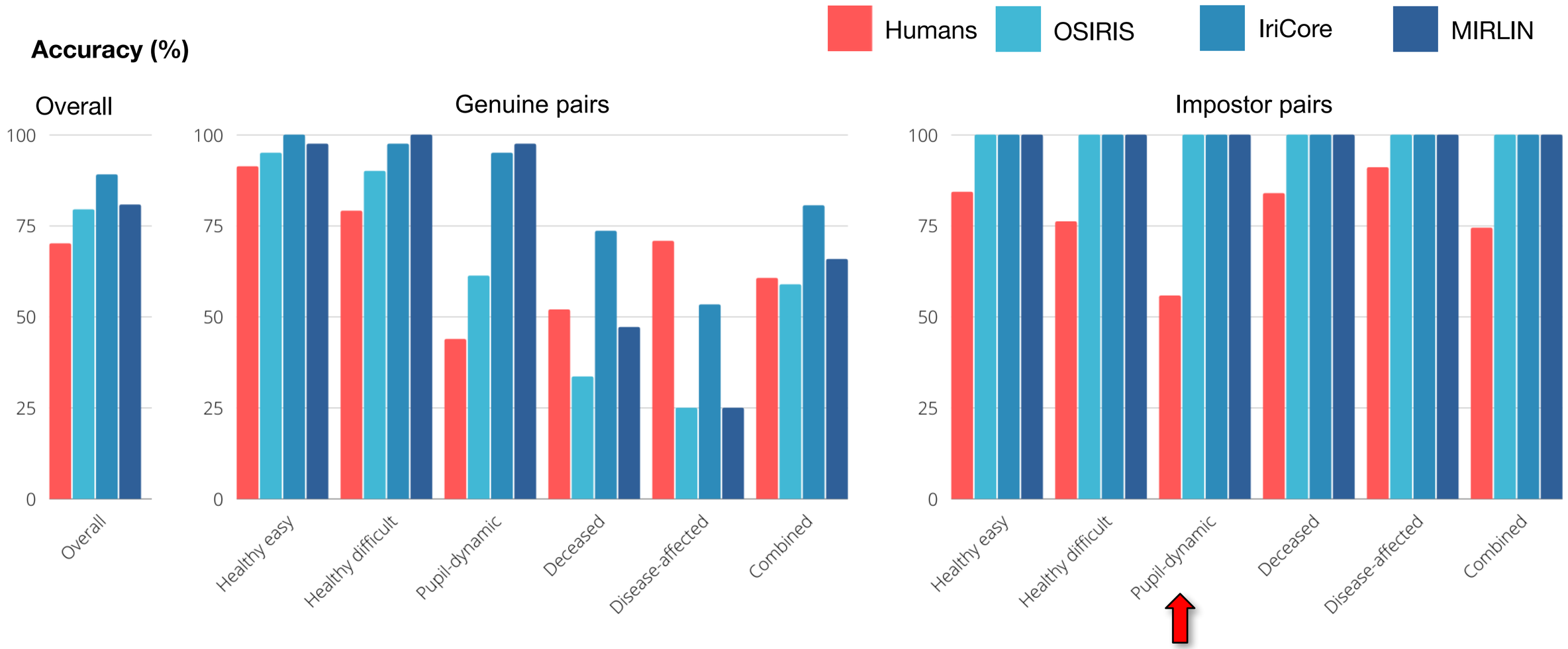
UNIVERSITY OF NOTRE DAME

Human Experiments



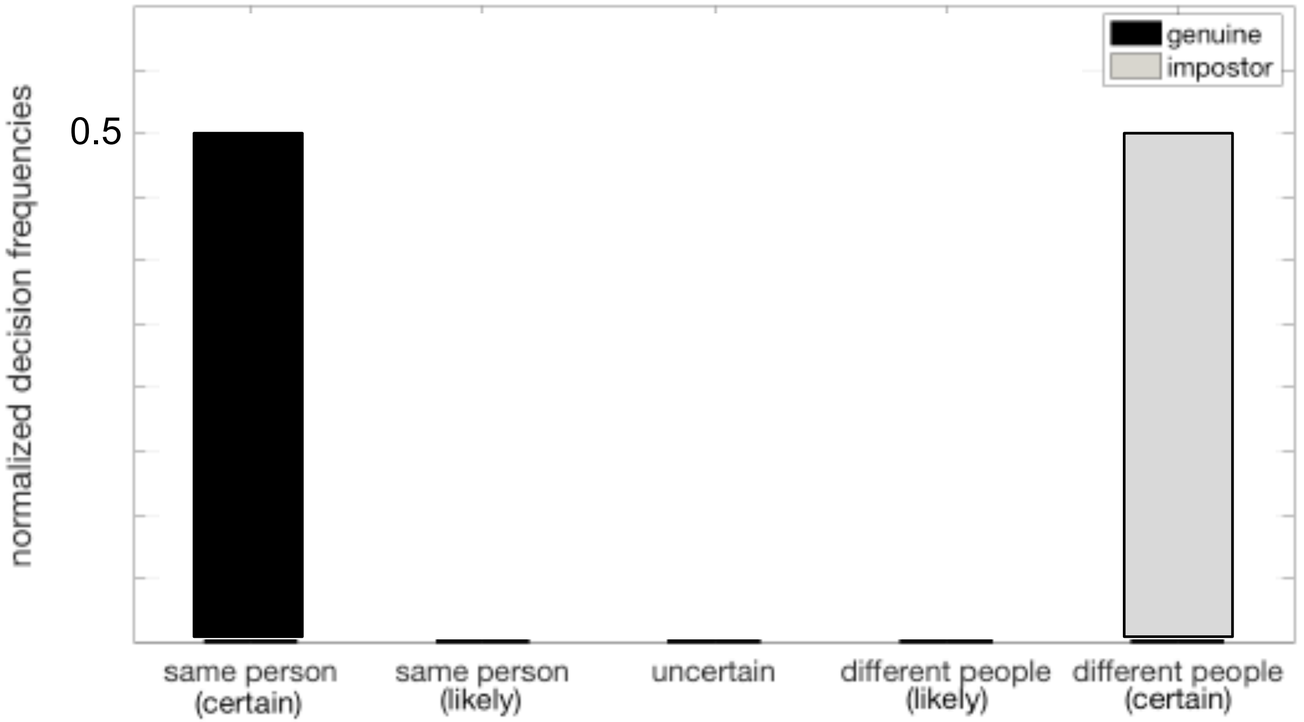
UNIVERSITY OF NOTRE DAME

Human Experiments



UNIVERSITY OF NOTRE DAME

Human Experiments

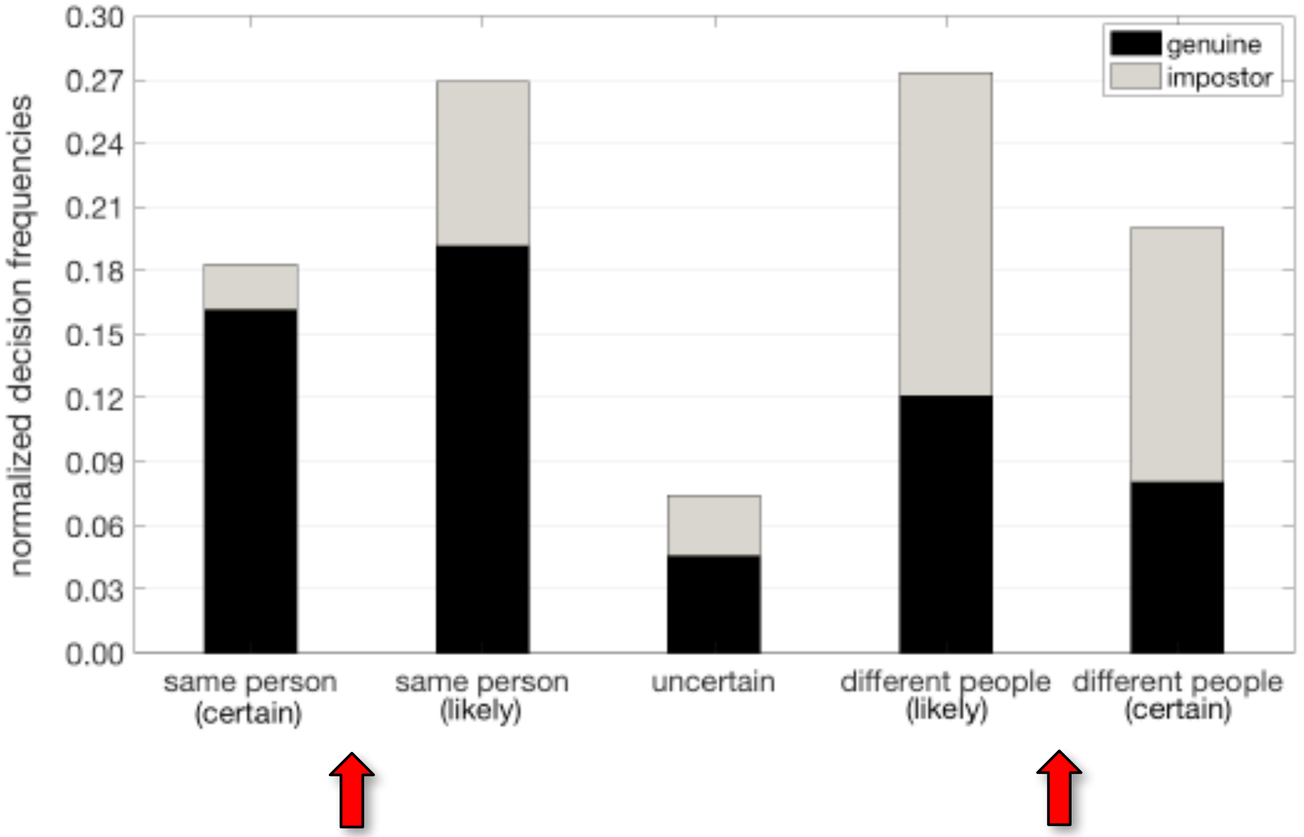


How confident were people?

Ideal graph

UNIVERSITY OF NOTRE DAME

Human Experiments

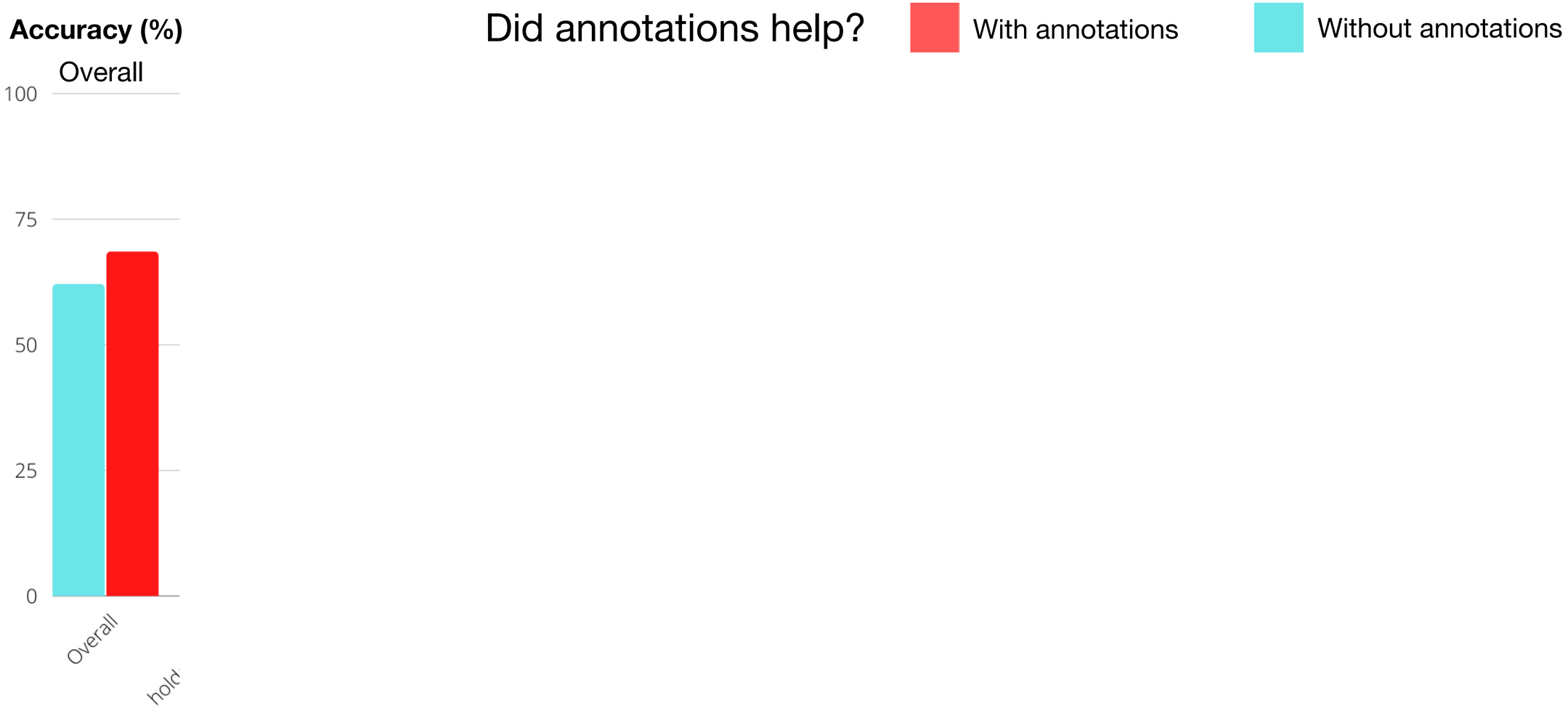


How confident were people?

Obtained graph

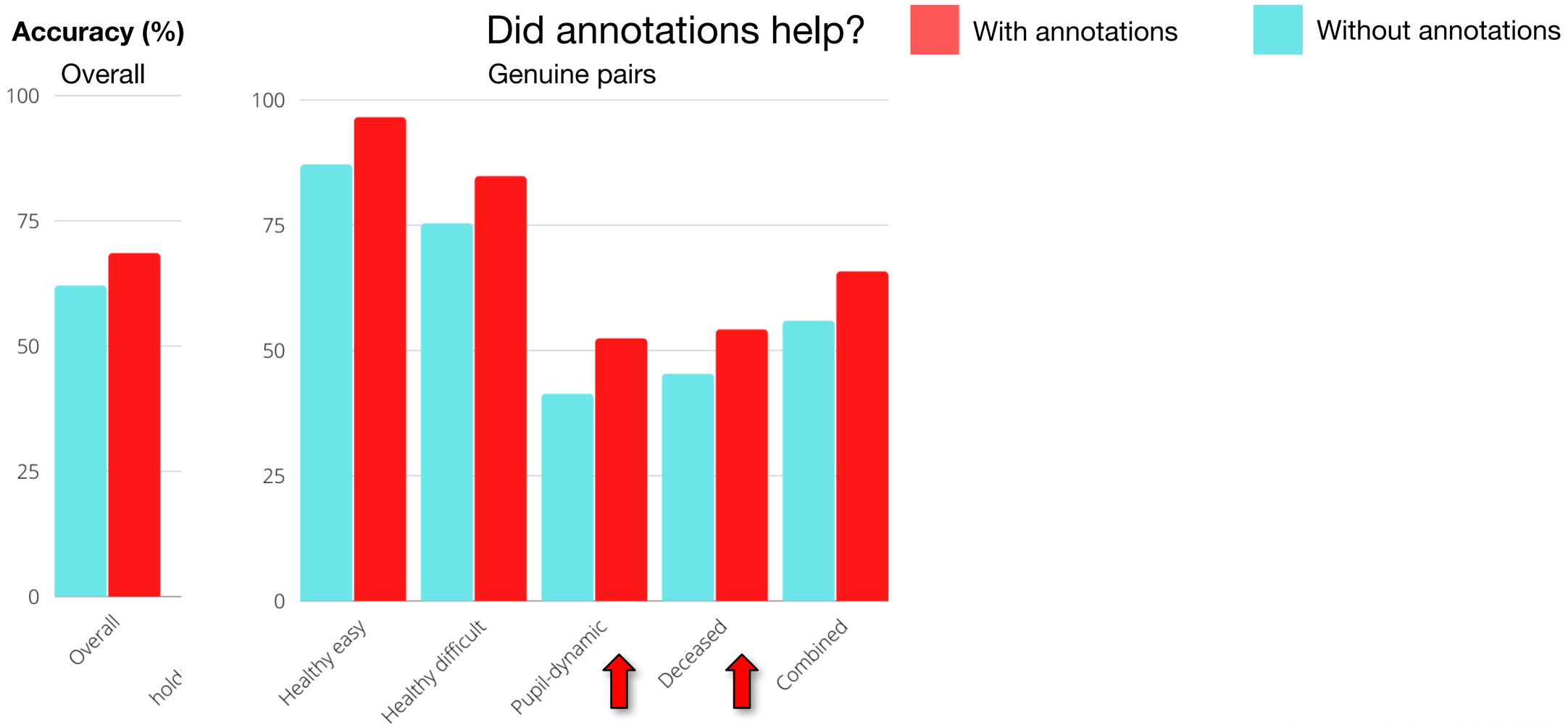
UNIVERSITY OF NOTRE DAME

Human Experiments



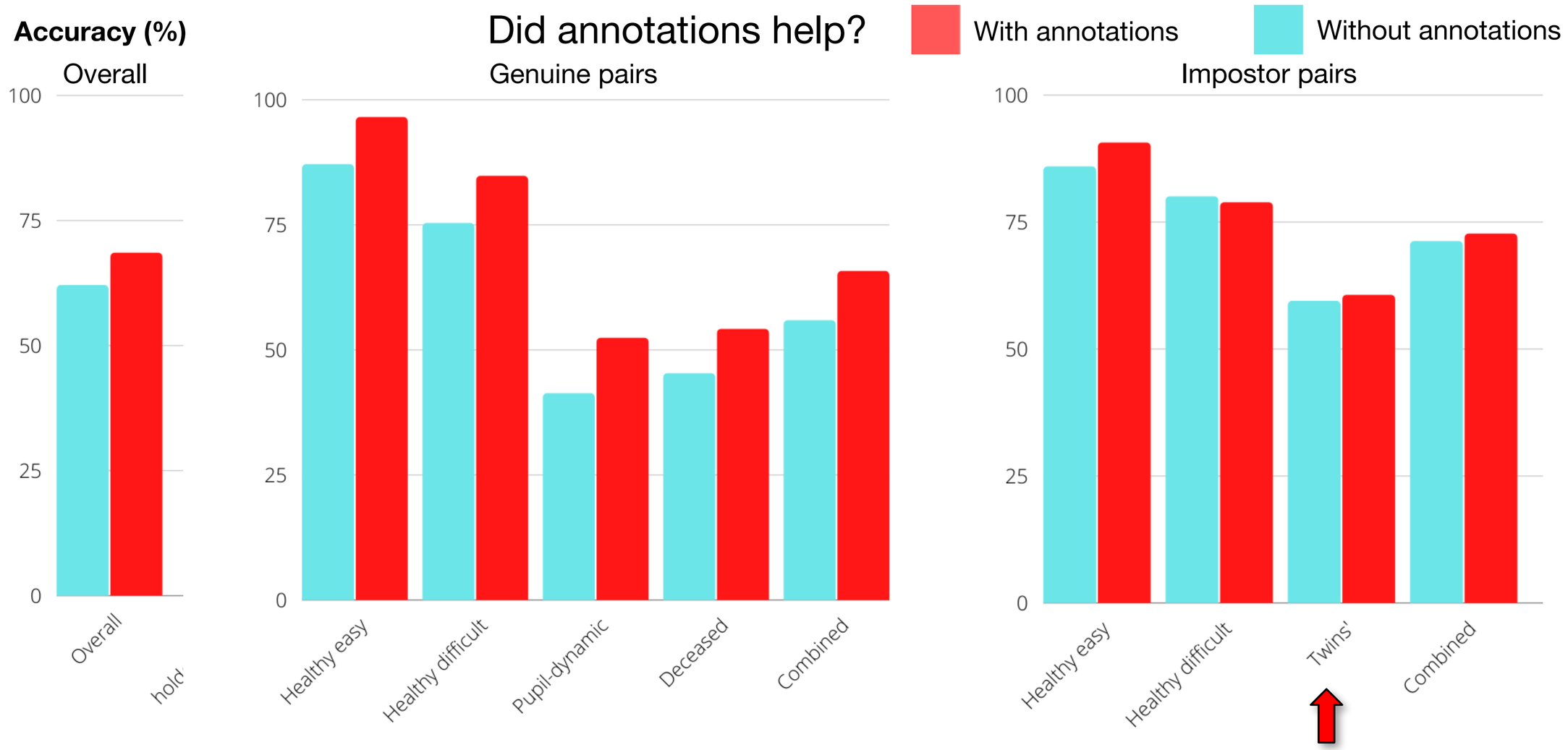
UNIVERSITY OF NOTRE DAME

Human Experiments

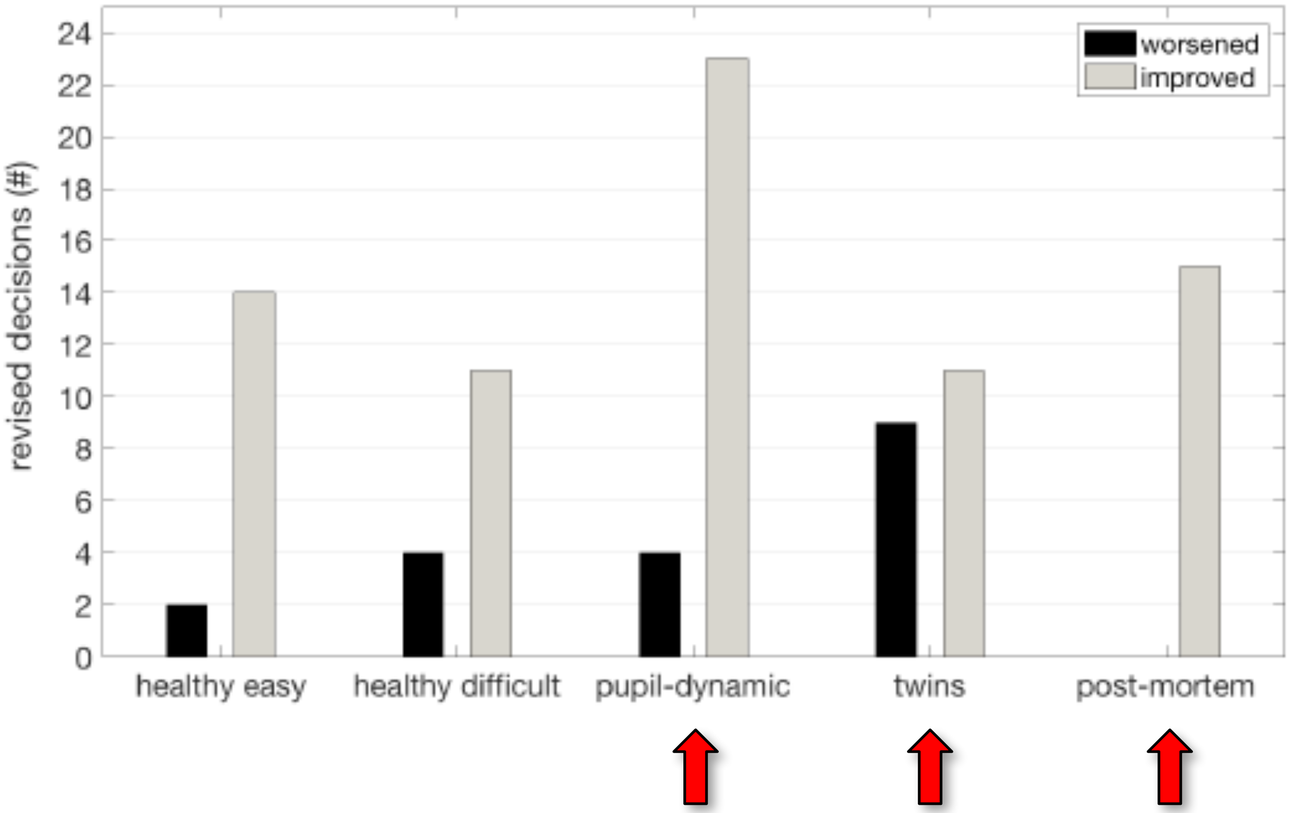


UNIVERSITY OF NOTRE DAME

Human Experiments



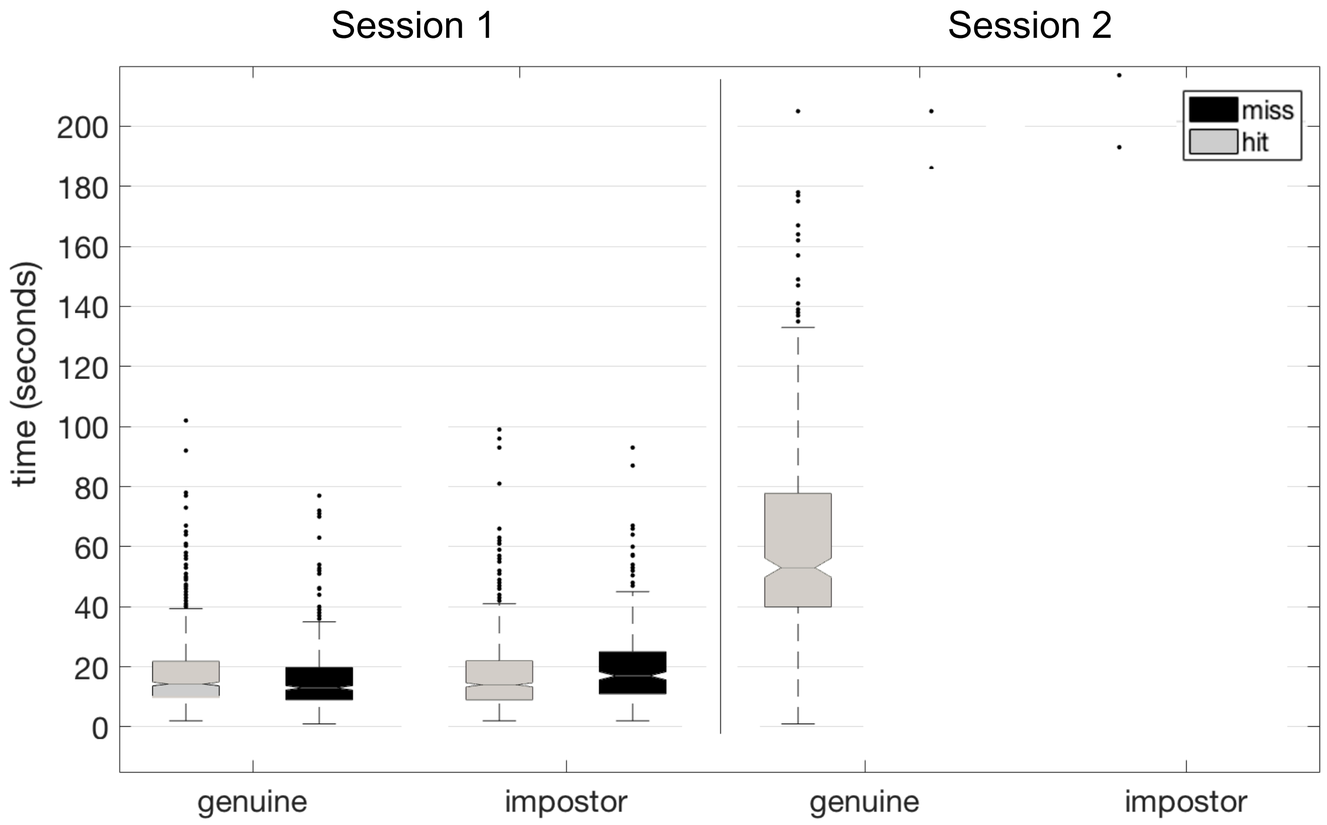
Human Experiments



Did annotations help?

UNIVERSITY OF NOTRE DAME

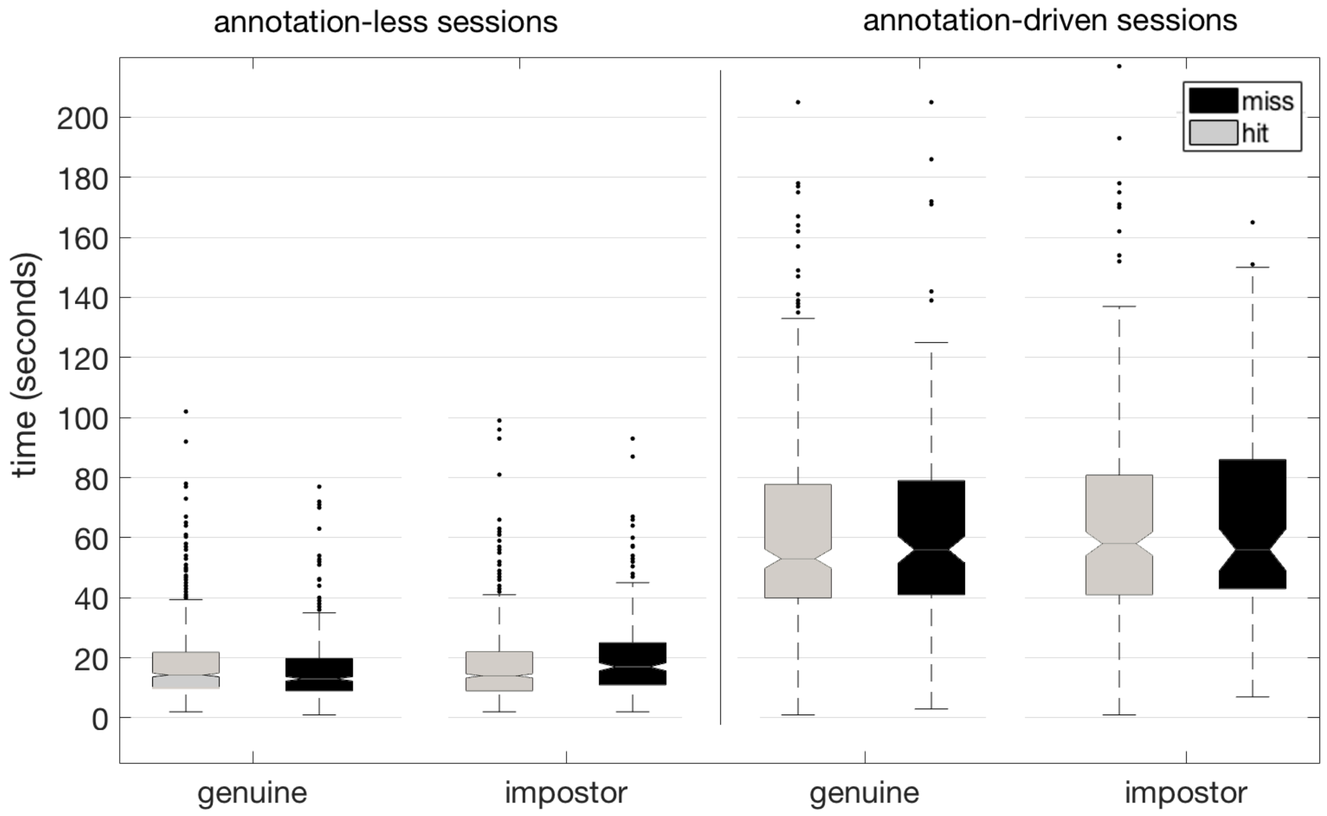
Human Experiments



Was time important?

UNIVERSITY OF NOTRE DAME

Human Experiments

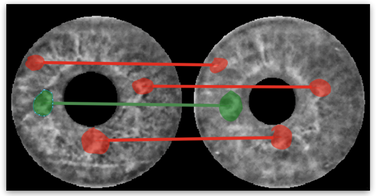


Was time important?

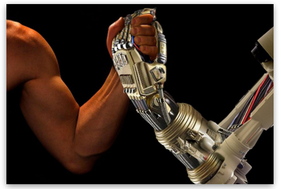
UNIVERSITY OF NOTRE DAME

Human Experiments

Findings



People performed better when they annotated the irises.



People were better than machines in deceased and disease-affected cases.

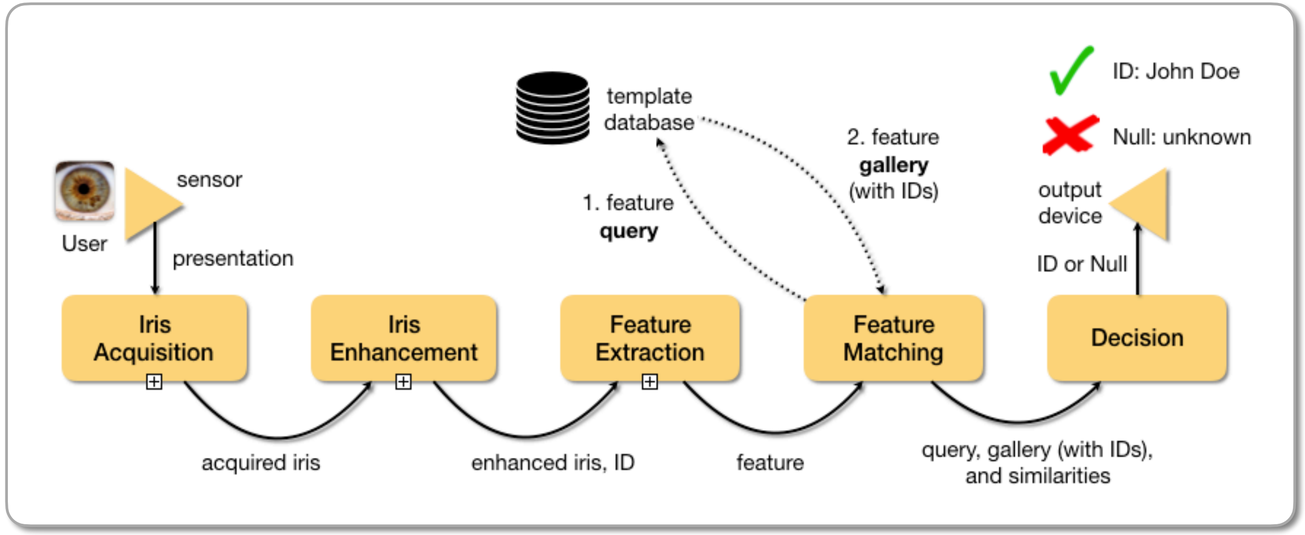
Most challenging cases to people: with **pupil dilation** and **twins.**

- Annotating pupil dilation helps.
- Annotating twins' doesn't.

UNIVERSITY OF NOTRE DAME

S’up Next?

Iris Recognition Pipeline
Acquisition, enhancement, feature extraction, matching, and decision.



UNIVERSITY OF NOTRE DAME