Korištenje refleksivnih pokreta očiju za brzu biometrijsku provjeru autentičnosti

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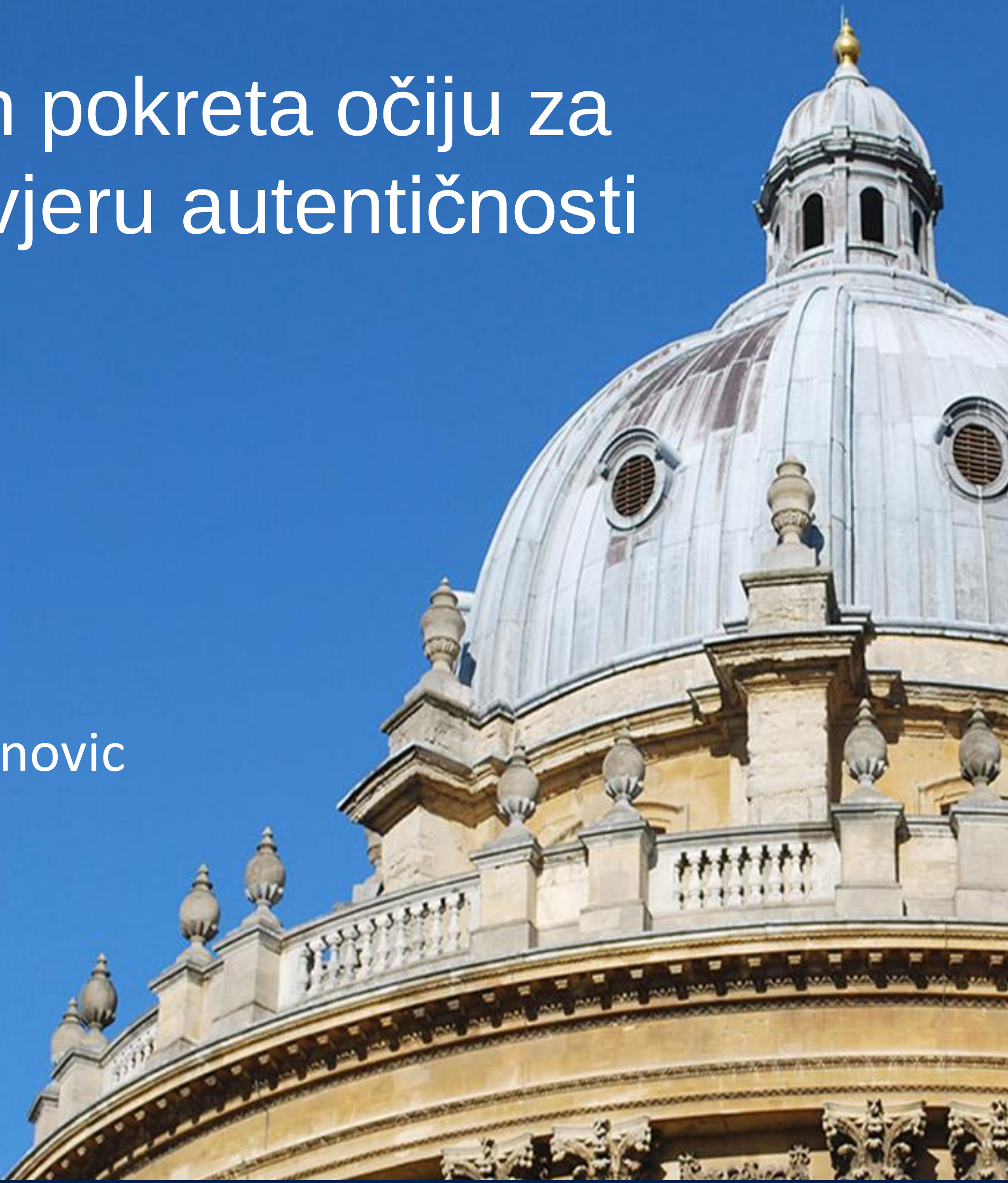
University of Oxford



ZIS, FER Zagreb, Travanj 2017

University of Oxford, Dept. of CS

- Oldest English speaking univ. (est. 1096)
- Consistently ranked in top 6
- Currently 1st worldwide (Times Higher Education ranking)

UNIVERSITY OF OXFORD

DEPARTMENT OF COMPUTER SCIENCE

CENTRE FOR DOCTORAL TRAINING *in* CYBER SECURITY

- By subject, **CS** currently ranked 3rd
- 150 academic and research staff
  - Just in: Touring Award to Tim Berners Lee
- 140 PhD (DPhil) students
- Growing fast, esp. in security (CDT!)

Systems Security Lab

- Prof. Ivan Martinovic
- 1 postdoc
  - Martin
- 10 PhD students:
  - Bushra, 2x Simon, Michal, Chris, Vincent, Richard, Matt, Marc, Ivo
- 2 visiting students:
  - Giulio & Kai
- Always looking for enthusiastic and driven researchers!

Systems Security Lab - areas

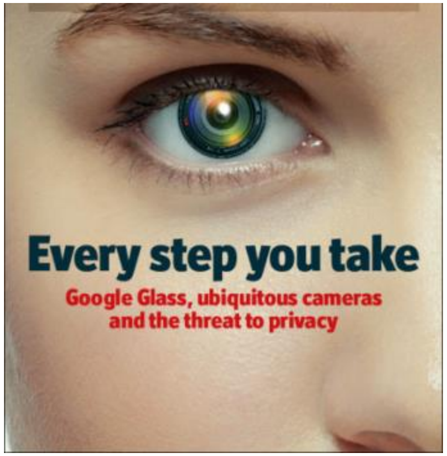
- Location-based Authentication
  - Authentication credentials using PHY-location information
  - Securing next generation **air traffic communication**

- Smartphone/Malware Traffic Analysis
  - Using **smartphone traffic** patterns to identify different smartphone users
  - Traffic based **malware detection**

- Resilient Anti-jamming Communication
  - Security & privacy of **drones** and related communication
  - Communication primitives against **jamming** attacks (intentional interference)
- User (De-)Authentication using Behavioral Biometrics
  - Eye-tracking and gaze-tracking as continuous biometrics
  - Using human bio-signals to authenticate users
  - Attacks on existing systems

Our Latest Collaboration

- **“Observation Resistant User and Device Authentication for Augmented Reality Devices”**
  - doc. dr. sc. Ante Đerek i Matej Šerbec

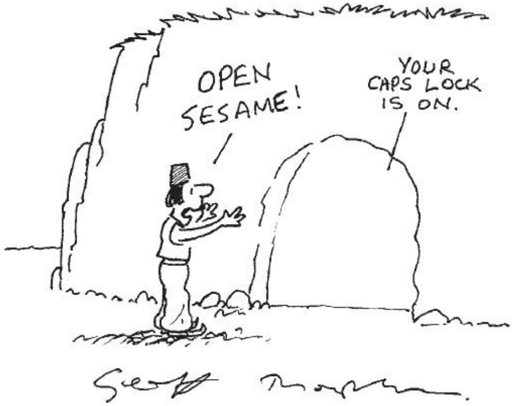


Korištenje refleksivnih pokreta očiju za brzu biometrijsku provjeru autentičnosti

User Authentication

3 main ways to authenticate*:*

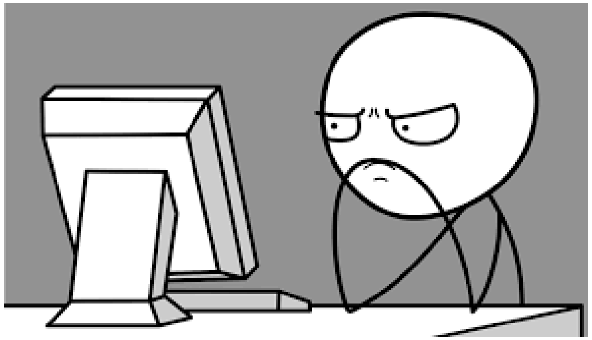
1. *What you **know*** *(e.g. passwords)*
2. *What you **have*** *(possessing the key)*
3. *Who you **are*** *(biometrics)*



"Rules for passwords":

1. A good password should be hard to remember
2. You should never write your password down
3. No password should ever be reused

??!? ☹



Biometric Authentication

- *"…distinctive, measurable characteristics used to label and describe individuals"*

- Authenticate by proving *WHO you are:*
  - Claimed identity proven by generating biometric data on demand
  - Not the same as **identification** (1:1 vs 1:n)

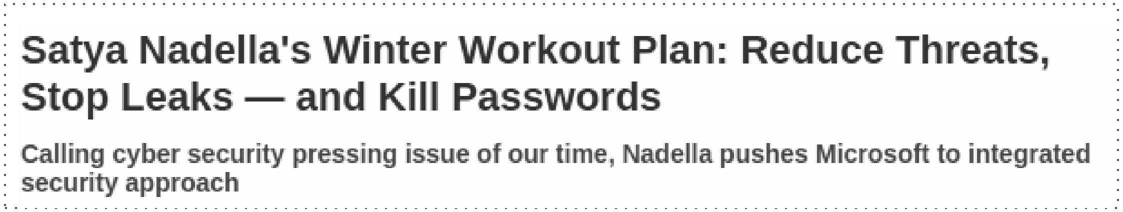
Ivan Vučetić, daktiloskopija

- **Multiple benefits:**
  - Impossible to forget or loose
  - Usually fast(er)
  - Stronger than most users' passwords
  - Less or no cognitive load
  - Non-transferable
    - Prevents phishing & other social engineering
    - Enforces accountability

Biometrics - The Future?

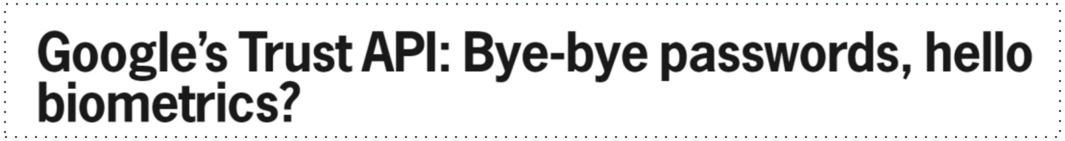
AADHAAR

- over 99% (1.133 billion) of Indians aged 18 and above had been enrolled
- world's largest biometric ID system



Satya Nadella's Winter Workout Plan: Reduce Threats, Stop Leaks — and Kill Passwords

Calling cyber security pressing issue of our time, Nadella pushes Microsoft to integrated security approach



Google's Trust API: Bye-bye passwords, hello biometrics?

Reuse of Biometric Data

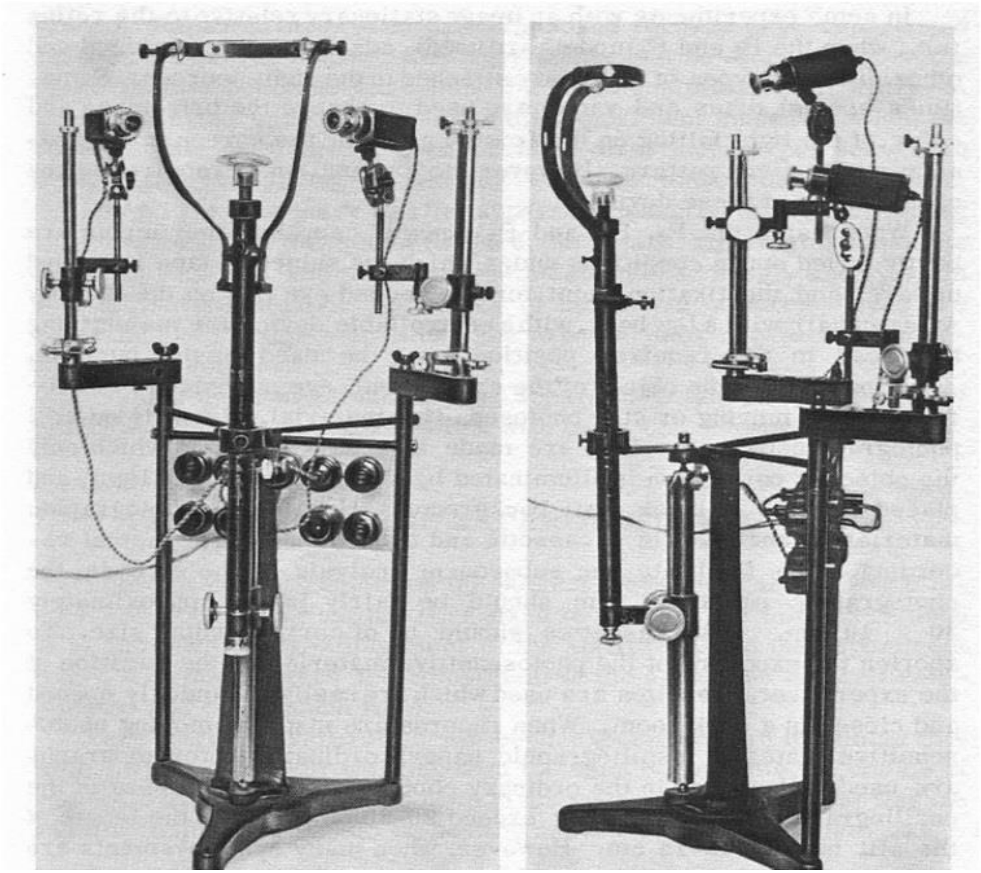
Biometrics seem to be everywhere recently

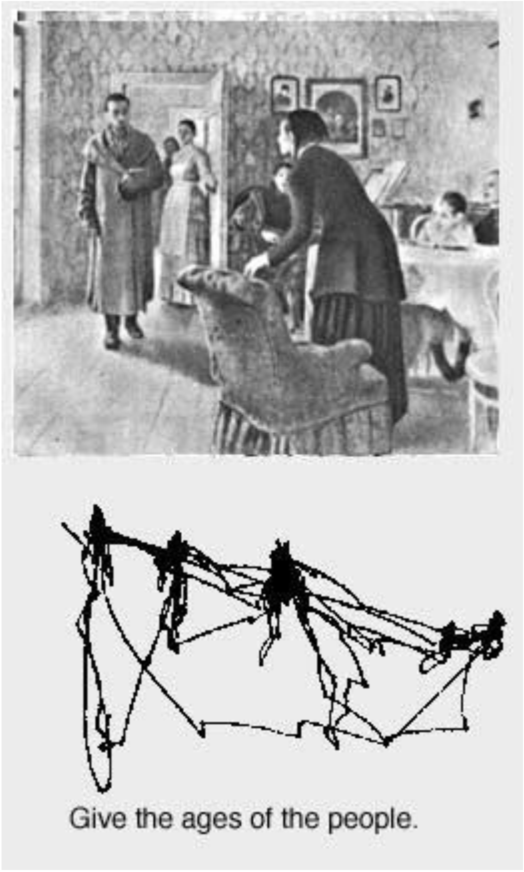
***…** however:*

How can we ***prevent the reuse*** *of eye movement biometric data?*

- Biometrics mostly implement *liveness detection* as a proxy
- Protocols typically prevent reuse by verification of freshness

Eye Tracking then…





Yarbus, 1967

… as a result of

Over 100 years:

- **Research:** visual perception, cognition, language comprehension
- **Medical**: detecting autism, concussions, depression
- **Interface:** disabled, design & marketing, gaming laptops

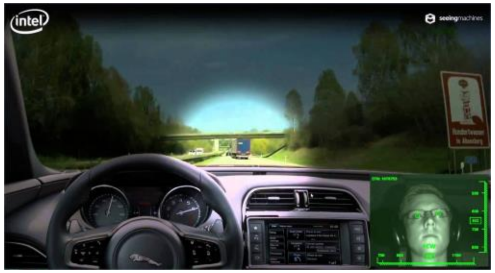
… now coming to …

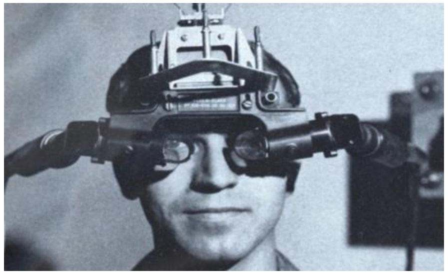
Mobile devices

- EyeScroll (Samsung S4, …, S7)
- Eye Tracking using commodity cameras (Krafka & Khosla, CVPR 2016)

Cars

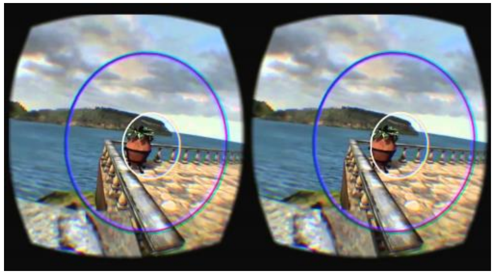
- Detecting drowsiness, focus
- GM, Cadillac in 2017



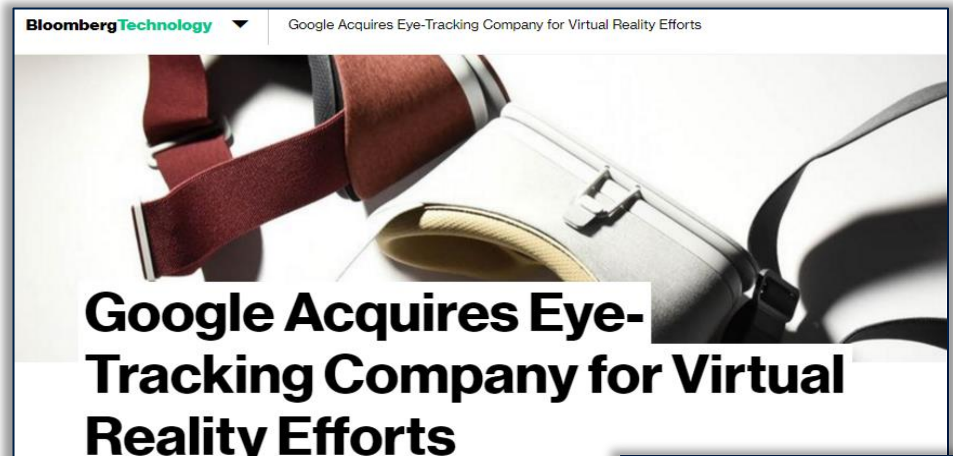


AR / VR systems

- New input channel
- Foveated rendering



...recently

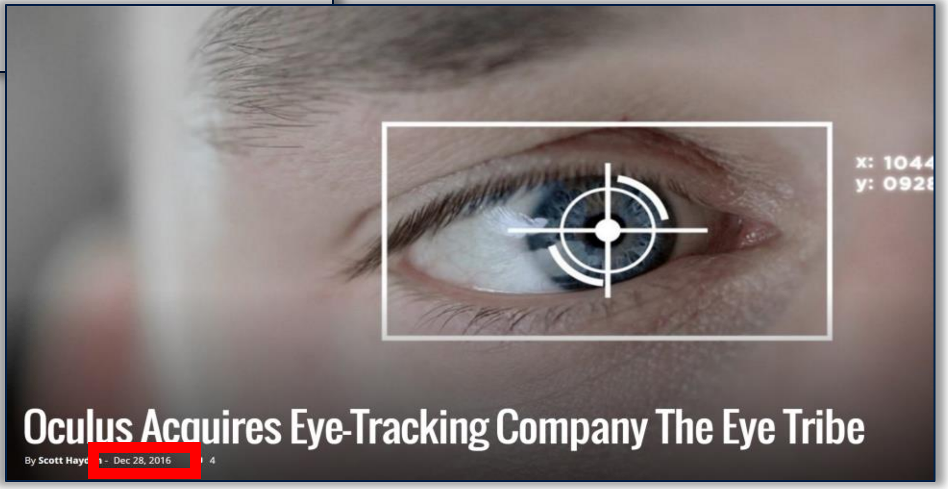


BloombergTechnology ▼ Google Acquires Eye-Tracking Company for Virtual Reality Efforts

Google Acquires Eye-Tracking Company for Virtual Reality Efforts

by Mark Bergen

October 24, 2016 — 9:40 PM EDT *Updated on* October 24, 2016 — 9:40 PM EDT



Oculus Acquires Eye-Tracking Company The Eye Tribe

By Scott Hay - Dec 28, 2016 4

Eye Movements

- 100 000 movements per day
- Responses in under 80 ms
- Fastest rotational movement in human body (900 deg/s)
- Can be both voluntary and reflexive
- Exhibit individual traits

Def: "An action that is performed without conscious thought, as a response to a stimulus."

In Authentication?

Use of eye movements

- As a control channel
  - Users input passwords or secret patterns

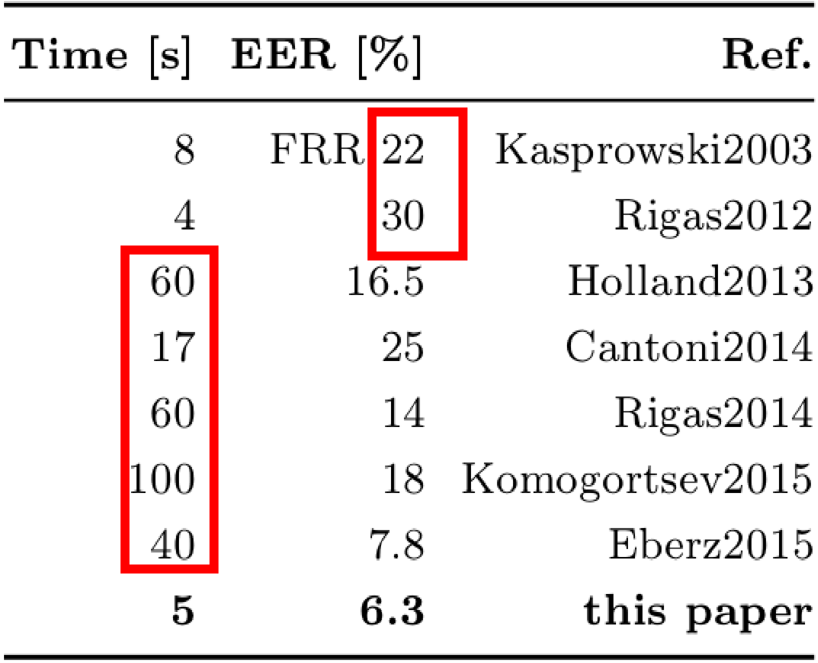
- **As a biometric**
  - Analyze characteristics of recorded eye movements
    - usually while showing a visual stimulus

1. “***what***” is one looking at
  - analysis of scan paths, areas of interest …

2. “***how***” do one’s eye movements look
  - speed, acceleration, latencies, curvatures & angles …

Eye Movement Biometrics

- Remains a **challenging problem**:



Time [s]	EER [%]	Ref.
8	FRR 22	Kasprowski2003
4	30	Rigas2012
60	16.5	Holland2013
17	25	Cantoni2014
60	14	Rigas2014
100	18	Komogortsev2015
40	7.8	Eberz2015
5	**6.3**	**this paper**

Visual stimulus …

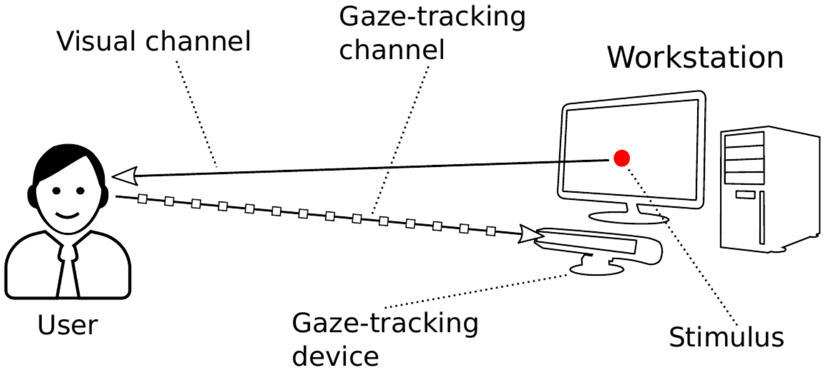
- *“Read the text”*
- *“Watch 30s of a movie trailer”*
- *“Look at the face”*
- <u>*“Look at the dot along these 9 positions”*</u>

Results in:

- Response depends on cognitive state
- Long authentication times
- User habituation

Our Assumptions

System Model



Threat Model

1. **Impersonation attack** ✓
   - Internal attacker
   - External attacker

2. **Replay attack** ✓
   - Attacker **observes** and directly replays legitimate authentication attempts
   - Not usually considered

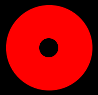
3. **Targeted attacks** ✓/ X
   - Very strong adversary: nothing is secret
   - Build an generative interactive model

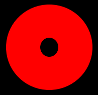
Design Goals

- General authentication goals:
  - Low error rates
  - Short authentication time
  - Low cognitive load
  - **Resistance against replay attacks**

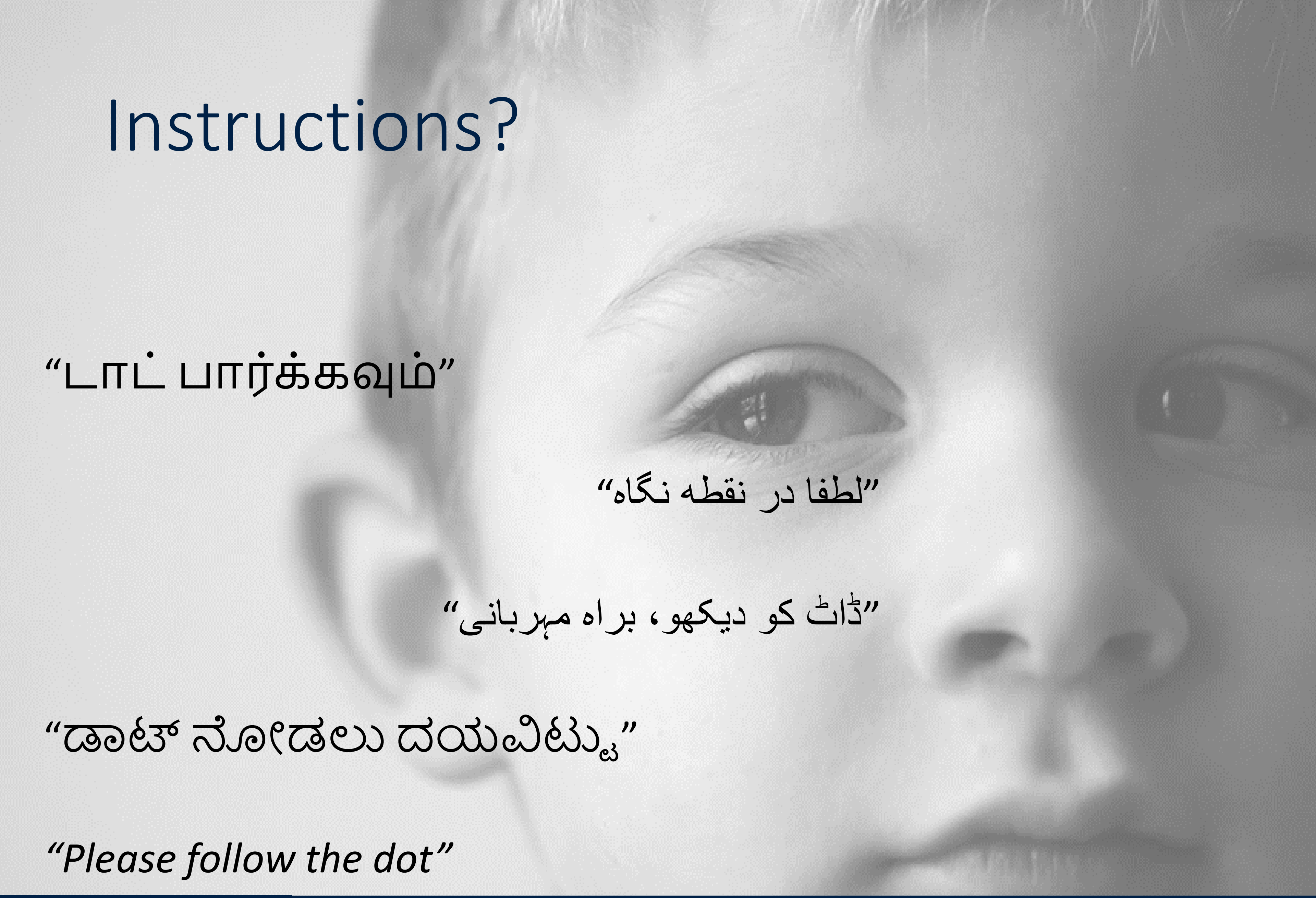
- Characteristics of an *ideal* visual stimulus?
  - Extracts predominately **physiological** responses
  - Requires **short**, **simple** interaction
  - **Fresh** every time and allows verification of the **response**

- **Core idea**: specific stimuli can elicit **reflexive** eye movements





Wasn’t that easy?



Instructions?

“டாட் பார்க்கவும்”

“لطفا در نقطه نگاه”

“ڈاٹ کو دیکھو، براہ مہربانی”

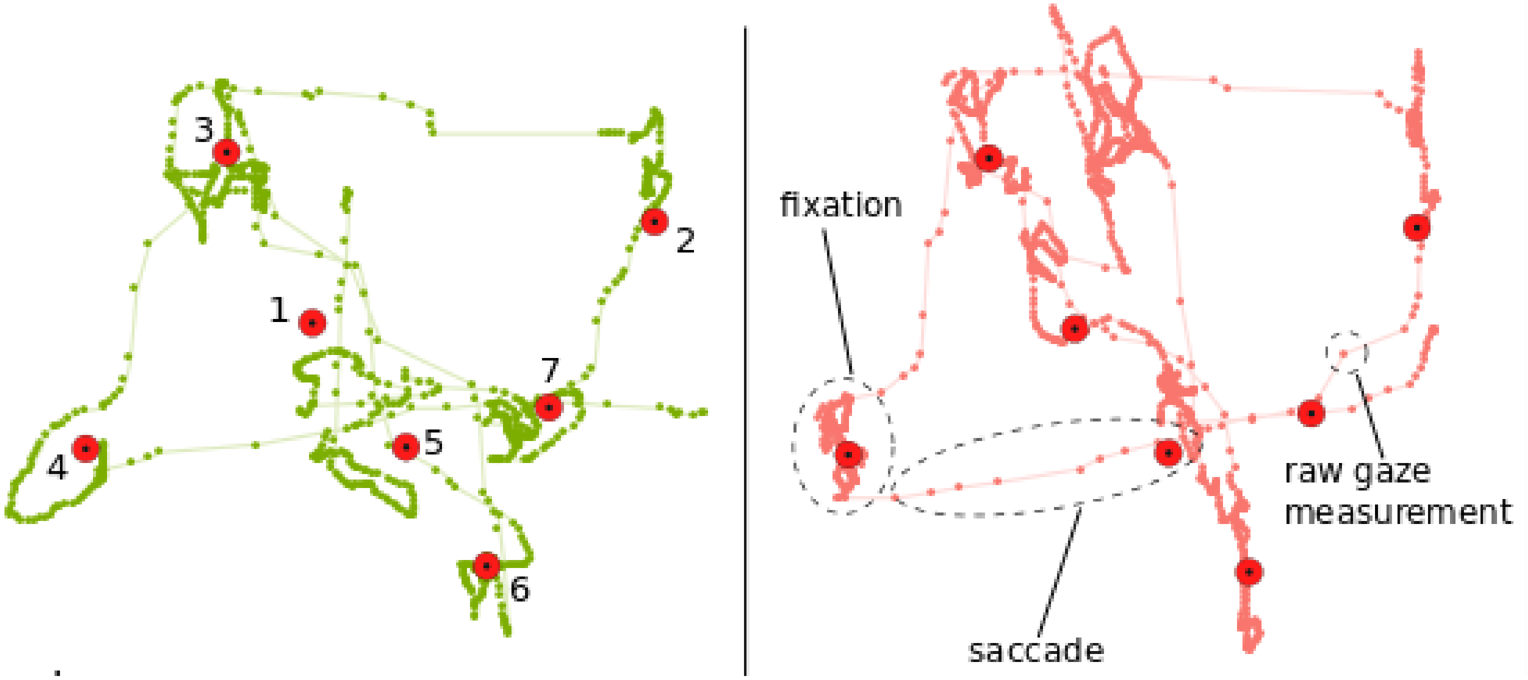
“ಡಾಟ್ ನೋಡಲು ದಯವಿಟ್ಟು”

“Please follow the dot”

Reflexive & Predictable Response

Core idea:

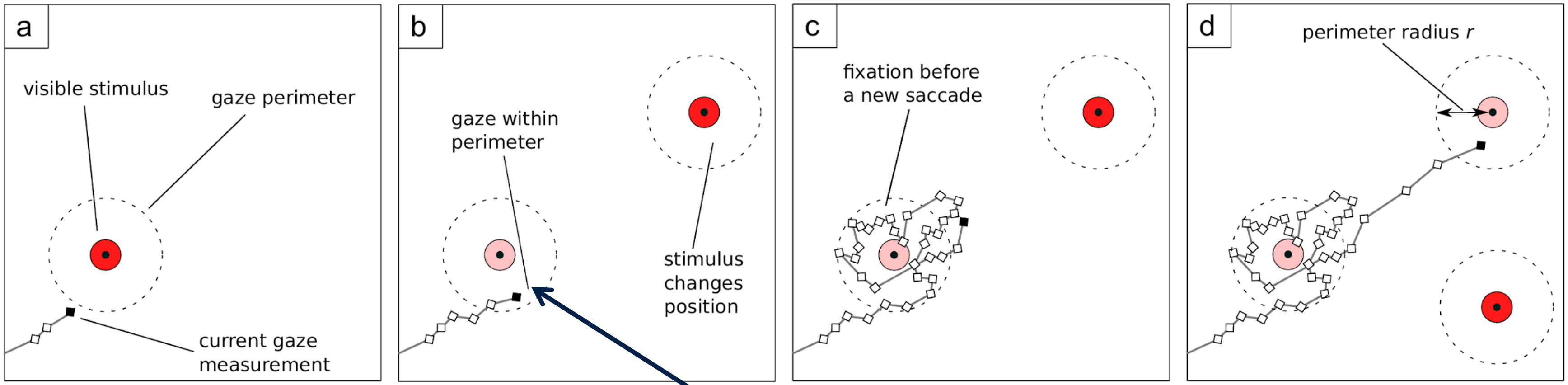
- While most are conscious, some eye movements can be **reflexively triggered** to elicit a **predictable response**



Sluganovic et al. - *Using Reflexive Eye Movements for Fast Challenge-Response Authentication*

Stimulus for Reflexive Saccades

How often should the position change?

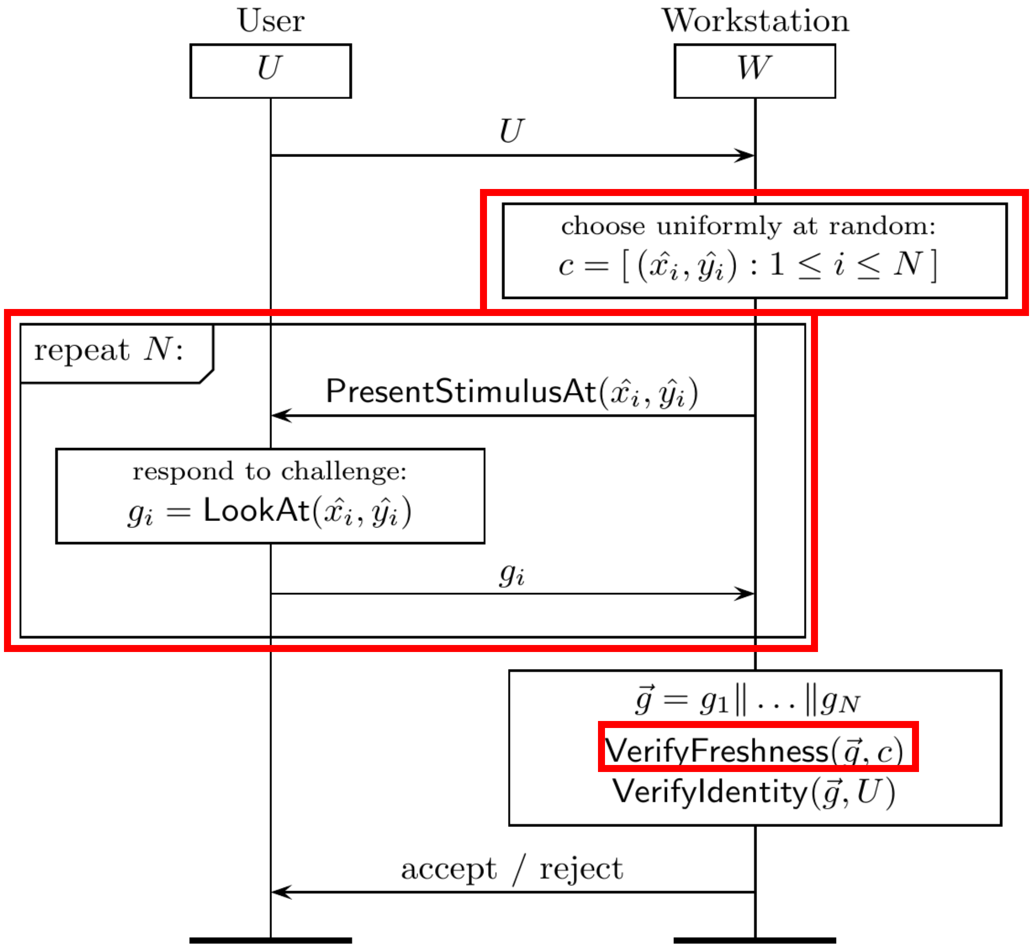


Successfully “gazed”

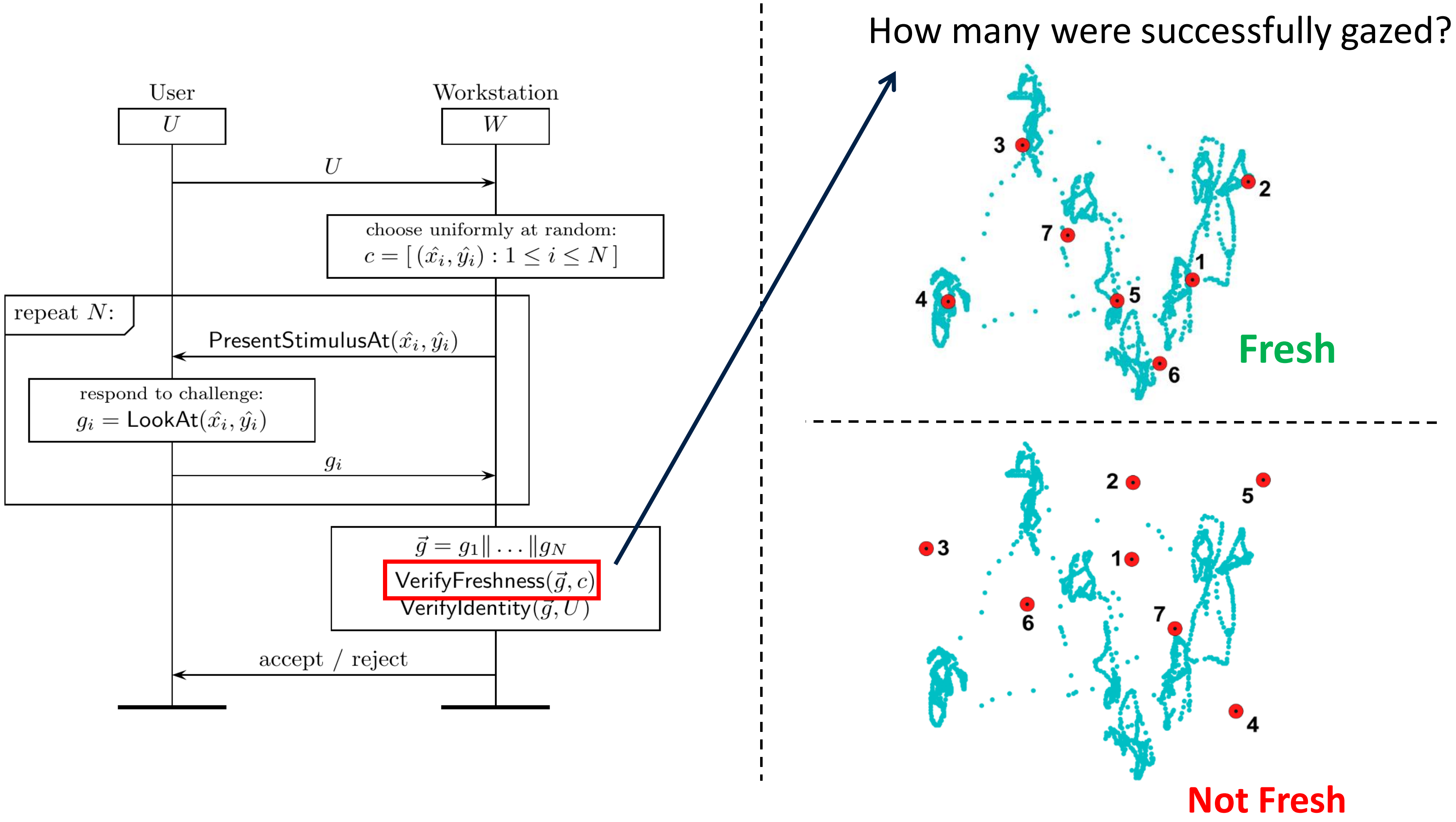
Making the stimulus **interactive**:

- Minimizes dwell time, maximizes number of extracted saccades
- Reduces habituation (unpredictable), increases reflexiveness
- Increases required effort for an attacker!

Biometric Authentication Protocol


User
U
Workstation
W
U
choose uniformly at random:
$c = [\,(\hat{x}_i, \hat{y}_i) : 1 \leq i \leq N\,]$
repeat N:
$\mathsf{PresentStimulusAt}(\hat{x}_i, \hat{y}_i)$
respond to challenge:
$g_i = \mathsf{LookAt}(\hat{x}_i, \hat{y}_i)$
g_i
$\vec{g} = g_1 \| \ldots \| g_N$
$\mathsf{VerifyFreshness}(\vec{g}, c)$
$\mathsf{VerifyIdentity}(\vec{g}, U)$
accept / reject

Biometric Authentication Protocol



User

U

Workstation

W

U

choose uniformly at random:
$c = [\,(\hat{x}_i, \hat{y}_i) : 1 \leq i \leq N\,]$

repeat N:

$\mathsf{PresentStimulusAt}(\hat{x}_i, \hat{y}_i)$

respond to challenge:
$g_i = \mathsf{LookAt}(\hat{x}_i, \hat{y}_i)$

g_i

$\vec{g} = g_1 \| \ldots \| g_N$

$\mathsf{VerifyFreshness}(\vec{g}, c)$

$\mathsf{VerifyIdentity}(\vec{g}, U)$

accept / reject

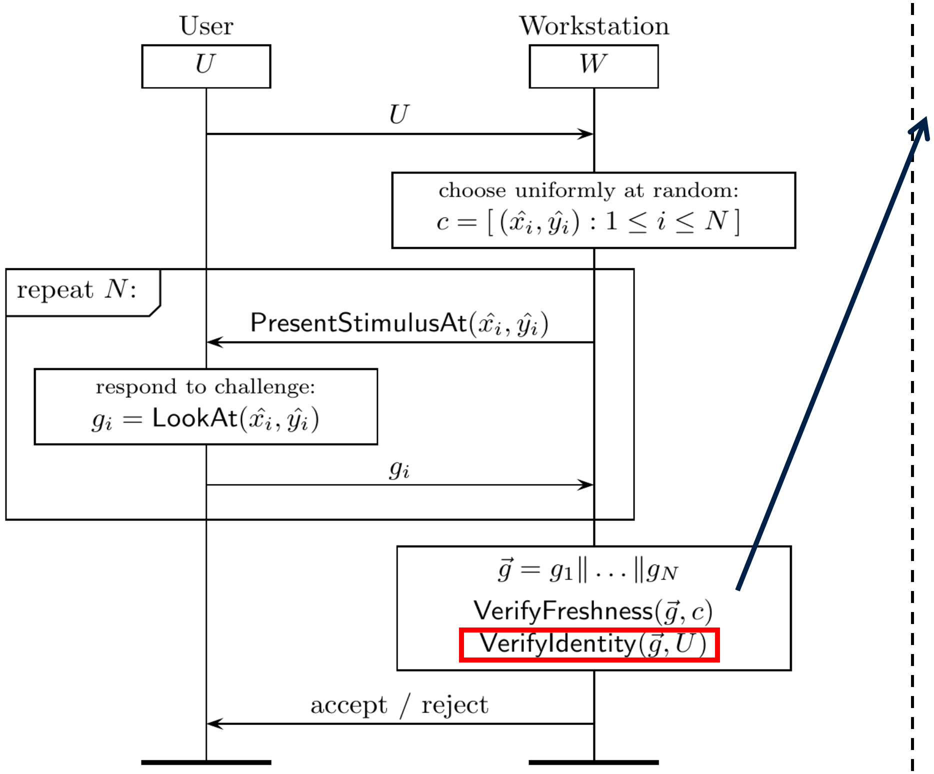
How many were successfully gazed?

Fresh

Not Fresh

Sluganovic et al. - *Using Reflexive Eye Movements for Fast Challenge-Response Authentication*

Biometric Authentication Protocol



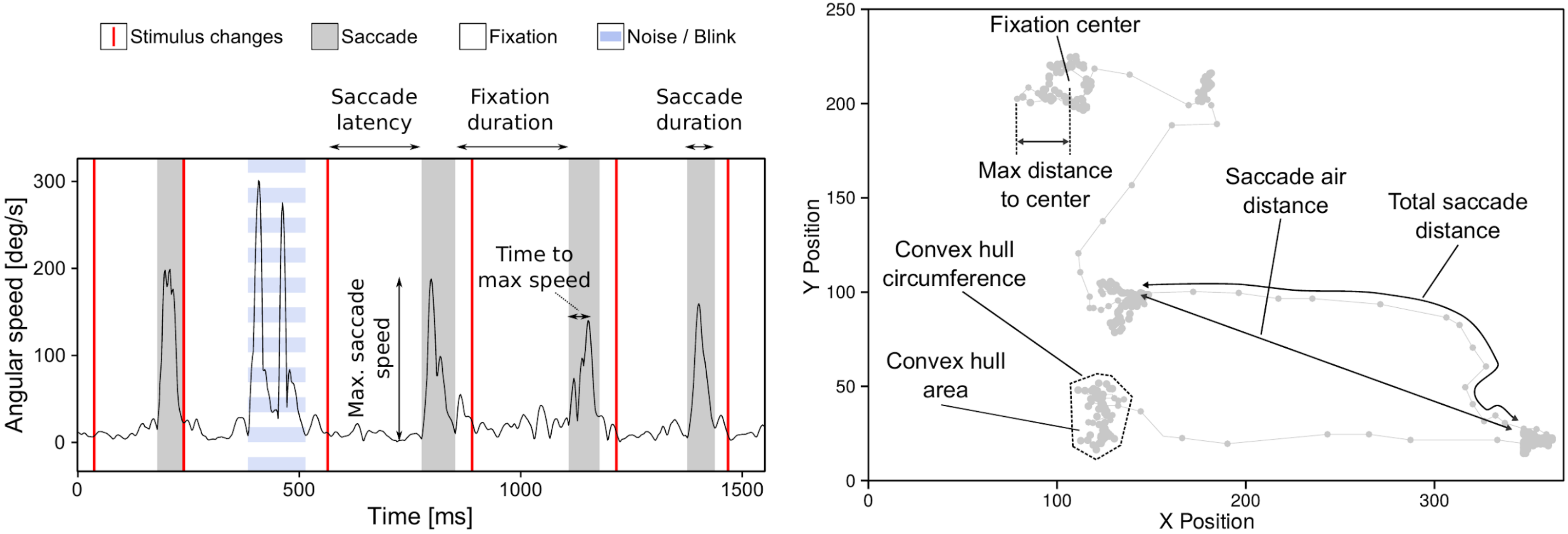
User
Workstation
U
W
U
choose uniformly at random:
$c = [\,(\hat{x}_i, \hat{y}_i) : 1 \le i \le N\,]$
repeat N:
$\mathsf{PresentStimulusAt}(\hat{x}_i, \hat{y}_i)$
respond to challenge:
$g_i = \mathsf{LookAt}(\hat{x}_i, \hat{y}_i)$
g_i
$\vec{g} = g_1 \| \ldots \| g_N$
$\mathsf{VerifyFreshness}(\vec{g}, c)$
$\mathsf{VerifyIdentity}(\vec{g}, U)$
accept / reject

Do observed gaze characteristics correspond to the claimed identity?

1. Extract multiple temporal and spatial features

2. Train/use a binary classifier for each user (SVM)

Features for Classification



(a) Temporal Features

(b) Spatial Features

- No physiological features (pupil sizes, distance between eyes, etc.)

Experimental Evaluation

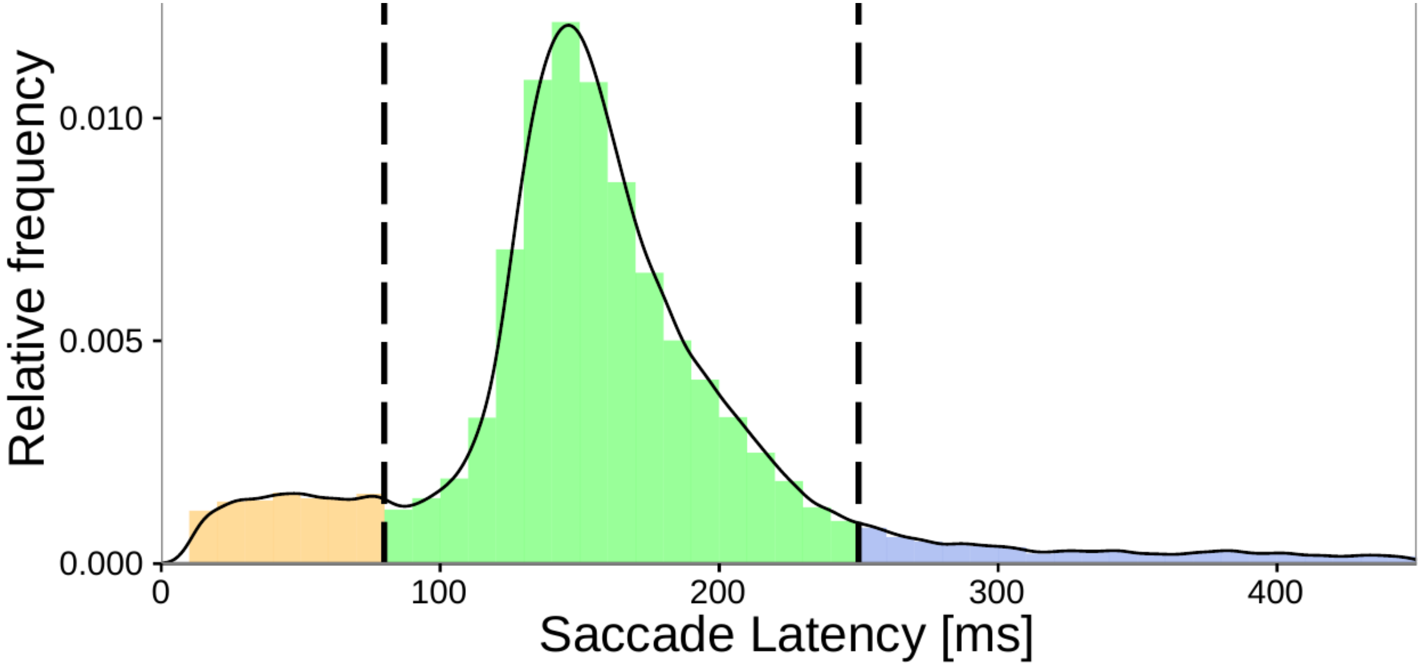
- Main questions:
  - Responses **predominately reflexive?**
  - Influence of challenge complexity on **errors** and **authentication times?**
  - Resistance against **impersonation attacks?**
  - Resistance against **replay attacks?**

- 4 sessions
  - Each with 15 authentication attempts
- 30 participants
- Total of 1 602 authentication attempts

Cognitive Effort

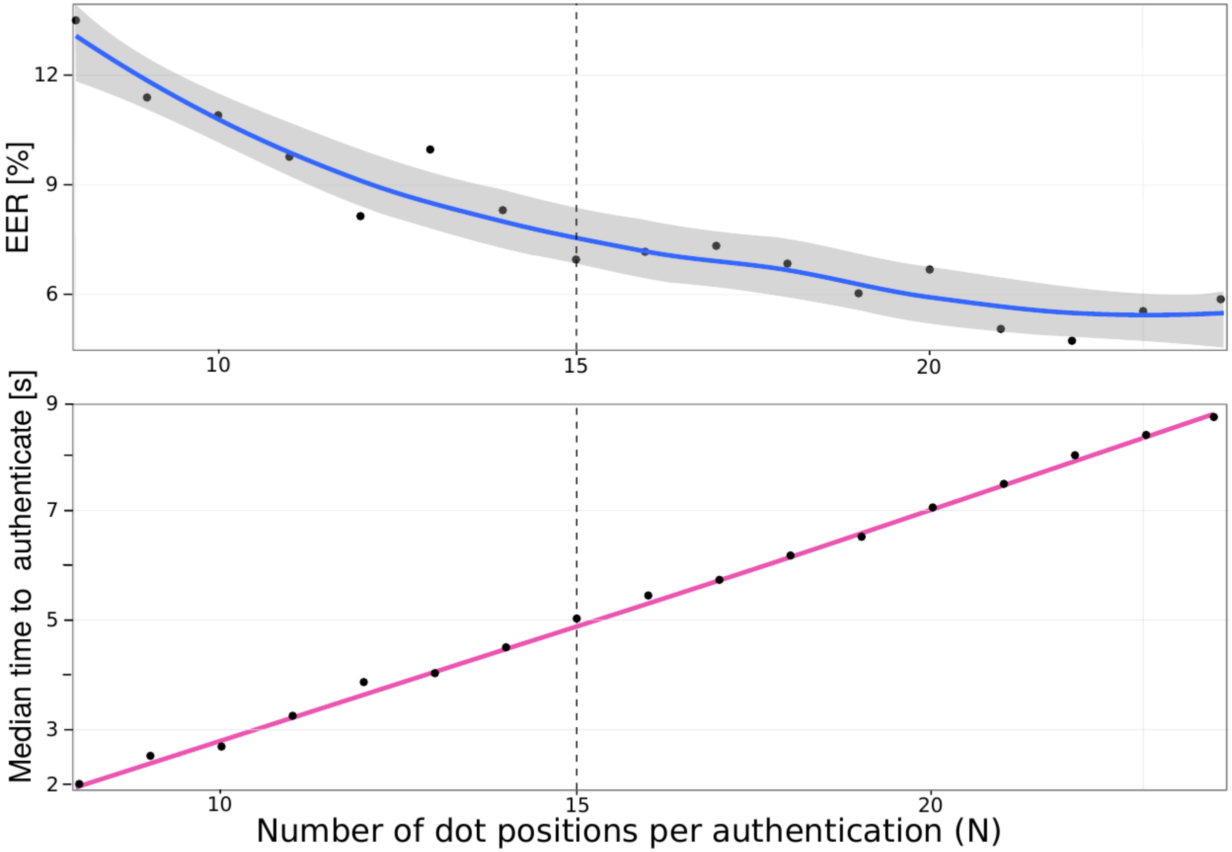
- *Are elicited saccades indeed reflexive?*
- Distinguished by their latencies:

noise < 80ms < **reflexive** < 250ms < **voluntary**



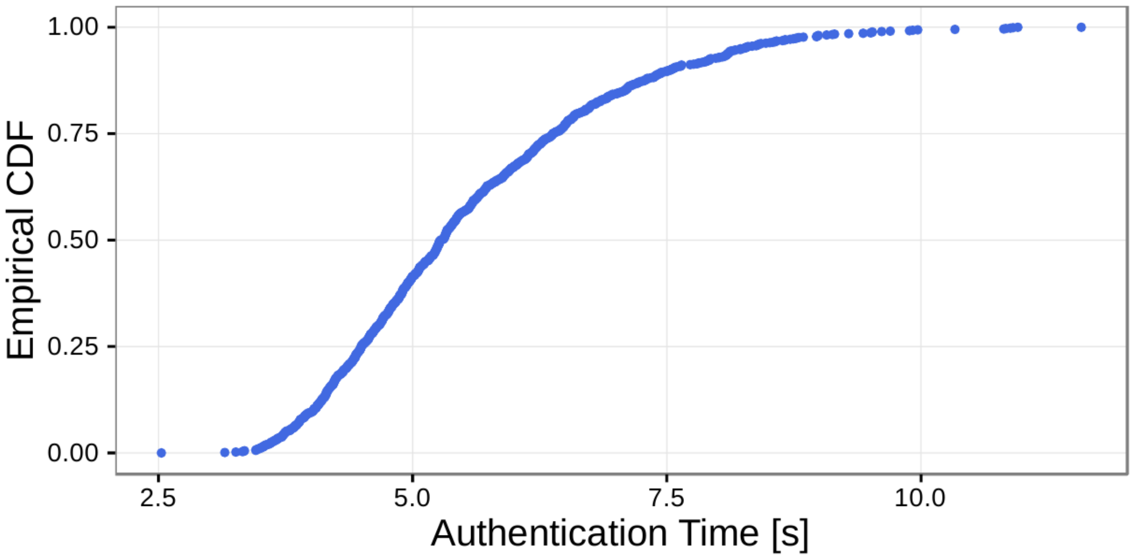
Stimulus complexity

- *How do errors and auth. times depend on stimulus complexity?*



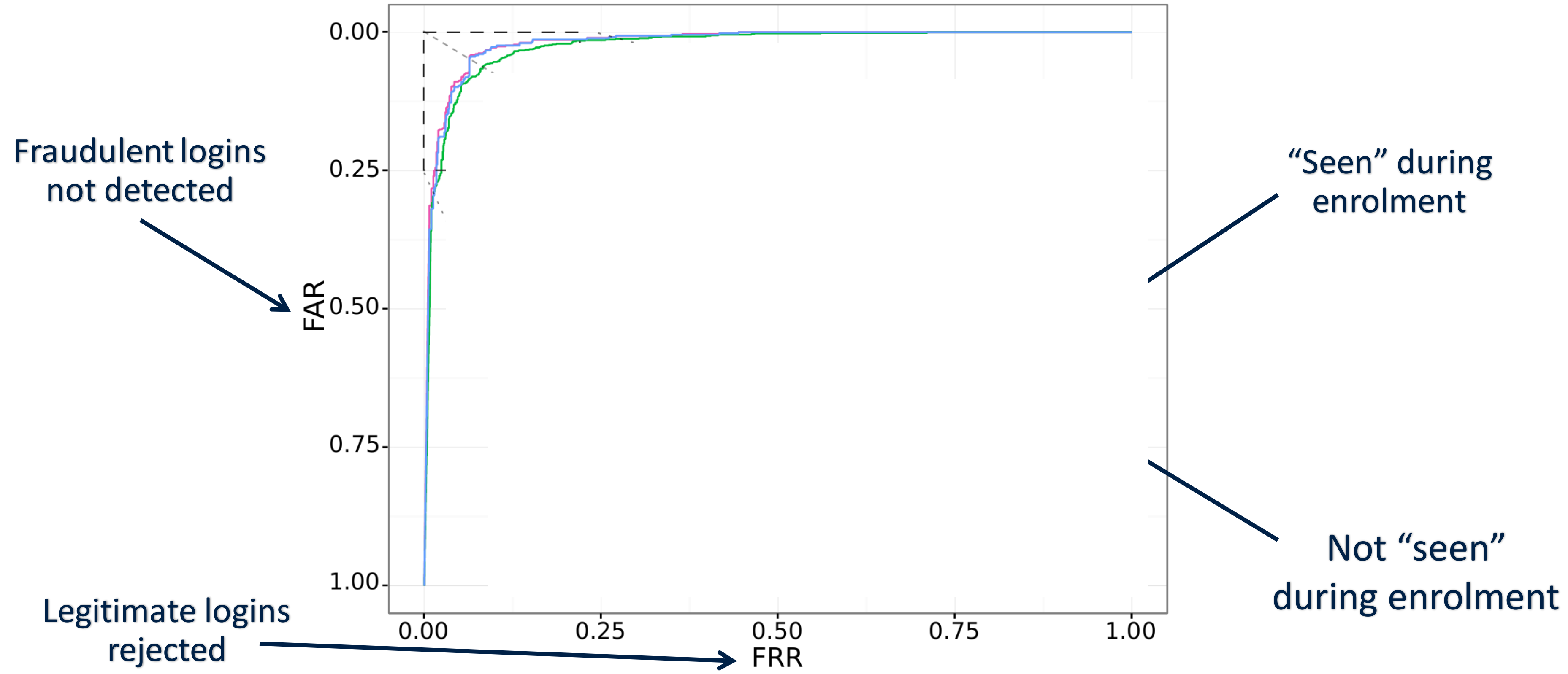
Authentication Time

- Distribution of auth. times when ***N = 15:***
  - *50% in under 5s, 90% in under 7.5s*
- *How fast is fast enough?* For passwords (Shay, ACM CHI 2014)
  - Authentication times: 11.6 – 16.2s
  - Input errors: 4-7%
  - 20% had problems recalling; 35% said "*remembering was hard*"



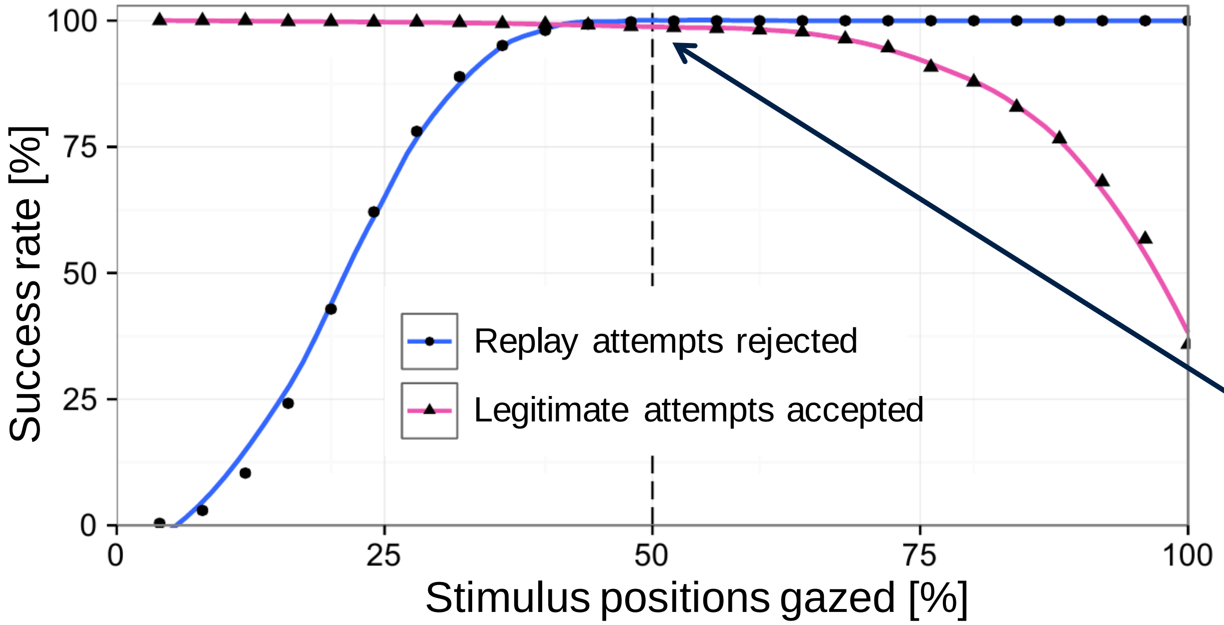
Impersonation Attacks

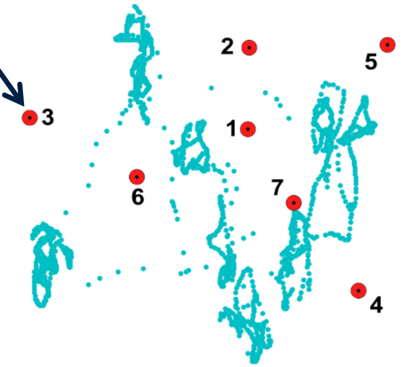
- Binary classifier trained for each user
- Varying decision threshold yields the ROC curve:



Replay Attacks

- Evaluated replay attempts for 10^6 pairs (*challenge*, *response*)





0.06% FAR

1.47% FRR

Conclusion

- **Reflexive eye movements** enable fast biometric user authentication
- Improved **authentication time** and **error rates**
  - **Median of 5 seconds**
  - **6-7% EER**
- Implemented challenge-response protocol to **prevent biometric replay**
  - **FAR of 0.06%**
- Applicability to systems which allow eye tracking

Future Work

- Evaluation on other devices
  - Mobile eye trackers (glasses)
  - Consumer devices
- Impact of different stimuli configurations
- Use of “static” features
  - pupil size, face
- Stability over time
- Evaluation of generative attacks

- Application of reflexiveness to other biometrics?

Other Recent Work

- *“Using **EEG-Based BCI** Devices to **Subliminally** Probe for Private Information”*
- *“Generating **Secret Keys from Biometric** Body Impedance Measurements”*
- “STASH: Securing **transparent authentication** schemes using prover-side **proximity verification**”
- **Security & privacy of AR devices (FER Zagreb)**

Hvala na pažnji!

Pitanja? ☺

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