Eye-Shield: Real-Time Protection of Mobile Device Screen Information from Shoulder Surfing

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What's Shoulder Surfing?

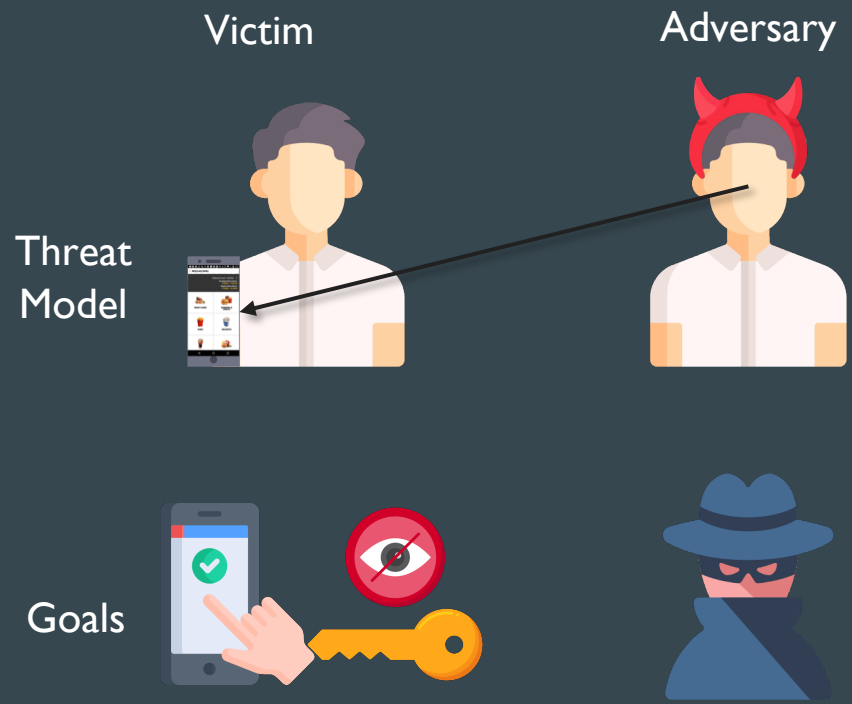
- Shoulder Surfing (Visual Hacking)
  - Social engineering attack
  - Pervasive, effective, low-budget
- Adversaries
  - Mostly curious, sometimes malicious
  - Use eyes, camera, binoculars, etc.

Shoulder Surfing in the News

- PIN-Stealing
  - Phone access, personal information
  - Thief stole £22k
  - Can successfully obtain 6-digit PIN with just one glance 10.8% of the time [Aviv et al.]
- Users only aware of 7% of shoulder surfing instances [Eiband et al.]
- 85% of shoulder surfers observed sensitive or private information [Honan et al.]

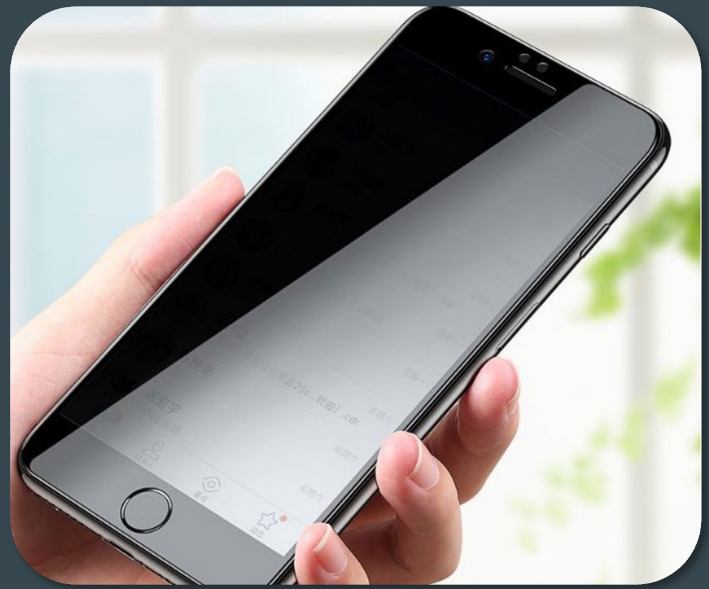
Threat Model

- Users want: Security, privacy, usability
- Adversary: Obtain information from victim's device screen without getting noticed
  - Resources: eyes, phone camera, quick glances, longer stares



A Key Research Question

- How do we protect users from shoulder surfing?



Privacy film

Privacy Films

- Advantages
  - Pervasive
  - Darkens the screen
  - Little to no usability cost

- Drawbacks
  - Protects only at angles >30-45°
  - Added cost ($7-30)
  - Requires (re)installation when switching device
  - Not easily “deactivated”
  - Incompatible with other screen protectors or matte/antiglare addons
  - Annoying to install or use in private settings
  - Does not protect landscape view

A Key Research Question

- How can we build a shoulder surfing protection mechanism for mobile devices?

- In a manner that addresses most of the limitations of privacy films

- Solution: Eye-Shield

(Only $49.99)

A Key Research Question

- How can we build shoulder surfing protection into mobile devices?
- In a manner that is:
  - Lightweight
  - Continually active
  - Protects information on the entire screen
  - Little impediment on the user's tasks

Our Solution: Eye-Shield

Protects on-screen information by making it appear blurry at a distance/angle.

Advantages:

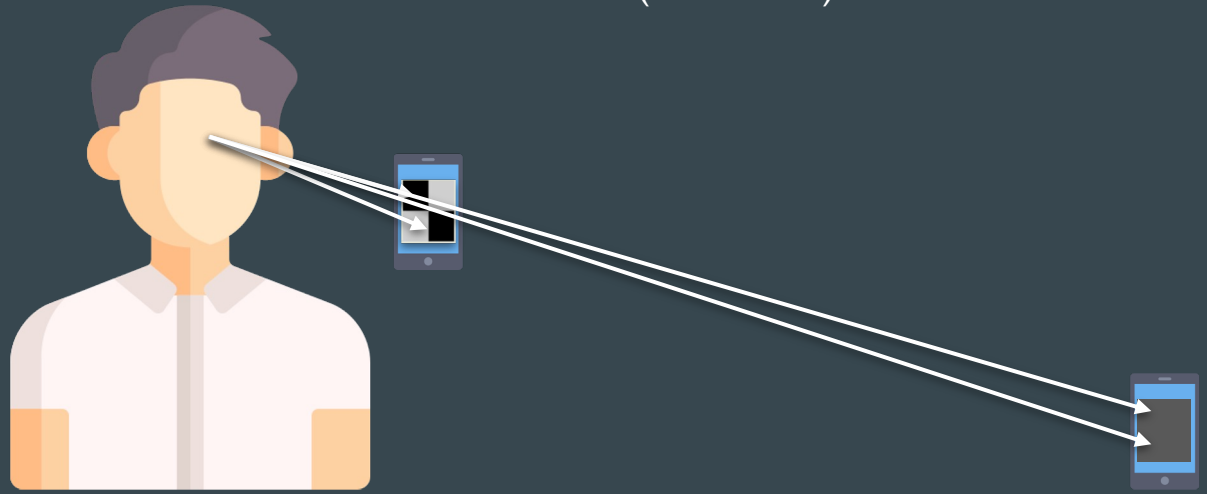
- Easy to use
- Real-time operation
- Acceptable CPU, energy and memory usage
- Free & built-in!

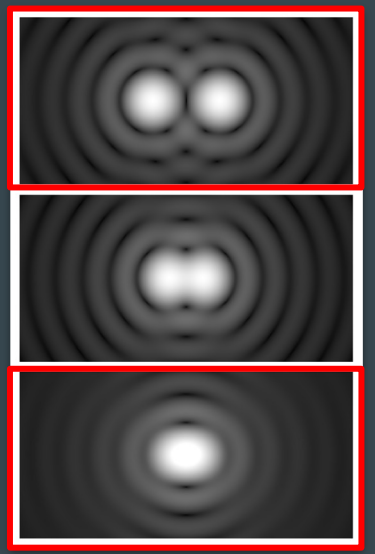
Original, unprotected screen

Protected screen with Eye-Shield

Design - Grids

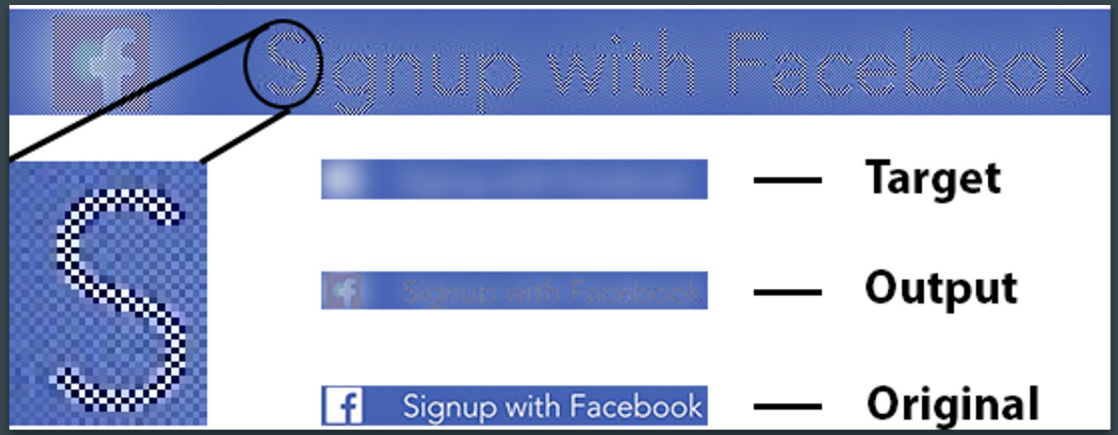
- Resolving Power
  - $\theta = 1.22\lambda / D$
  - Observation from HideScreen (Chen *et al.*)





Design - Blurred Target

- Use blurred version of original image
  - Design checkered grid such that colors average out to be a blurred version.



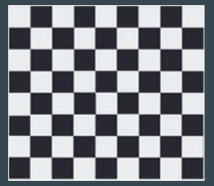
Design - Overview

1. Blur/pixelate image
2. Generate grid of image size
3. Run Eye-Shield algorithm

Algorithm 1 Where img is the original $w \times h \times 3$ image
where grid is a $w \times h$ checkered grid of 1s and 0s
where targ is the $w \times h \times 3$ image, blurred or pixelated

procedure EYE-SHIELD ALGORITHM(img, grid, targ)
    complement = $(targ^2 * 2) - img^2$
    delta = (complement - img^2) * grid
    newimg = $\sqrt{img^2 + delta}$
    clip(newimg, 0, 255)

(1)



(2)

(3)

Inverse average of 2 RGB colors (RMS)

Implementation (Weakest Protection)

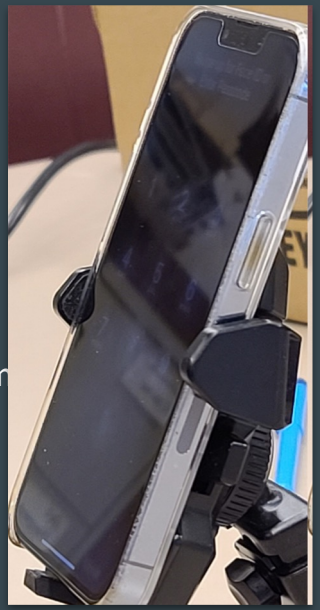
19.7”, 45°, Protected

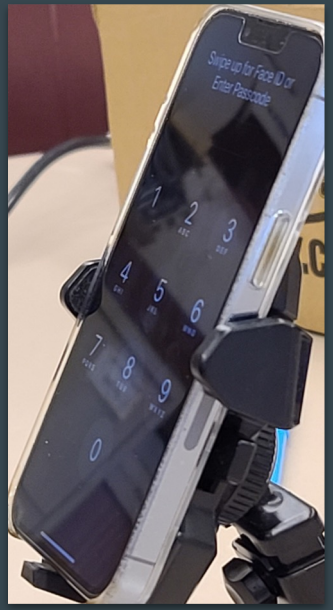
19.7”, 45°, Unprotected

41”, Protected

41”, Unprotected

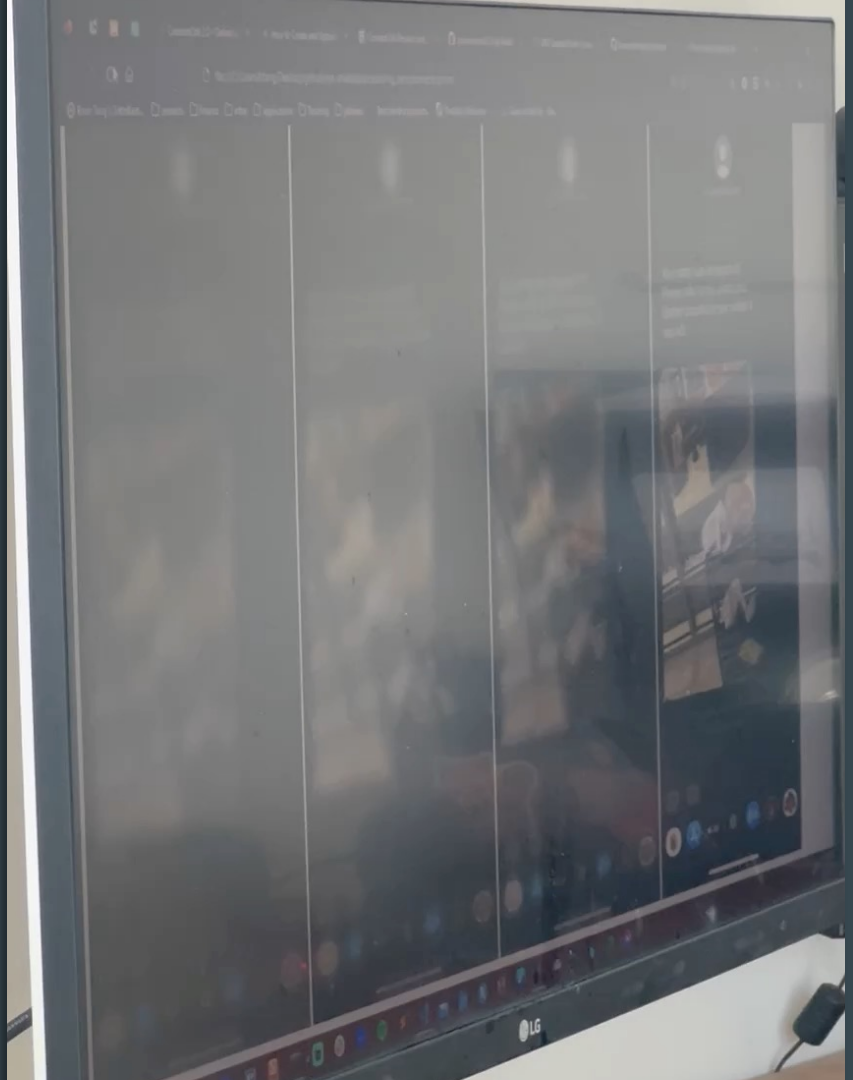
108MP
f/1.8
26mm
3× zoom

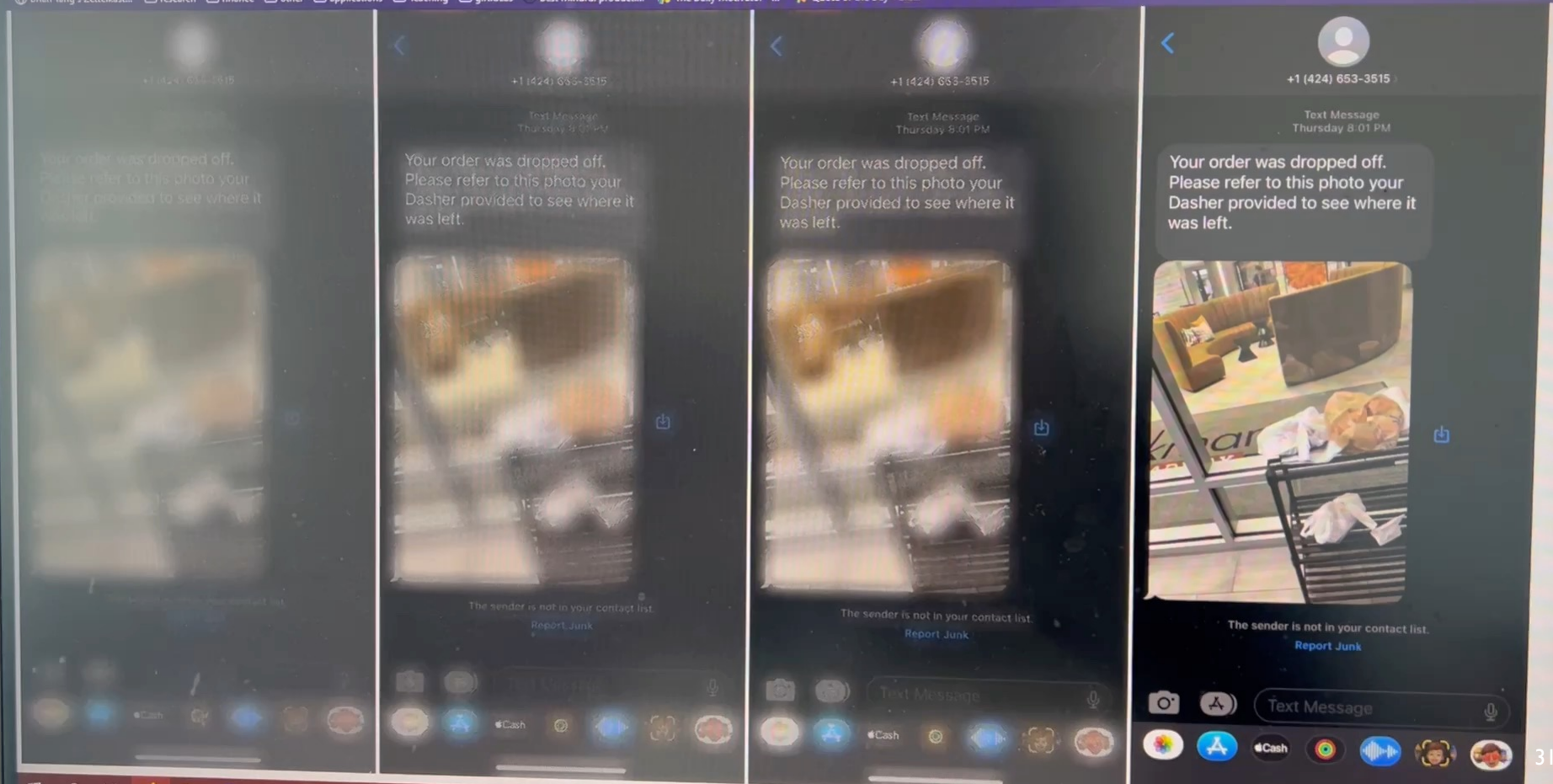




48MP
f/1.8
103mm
5× zoom

Recorded Demos




+1 (424) 653-3515
Text Message
Thursday 8:01 PM
Your order was dropped off. Please refer to this photo your Dasher provided to see where it was left.
The sender is not in your contact list.
Report Junk
Text Message
Cash

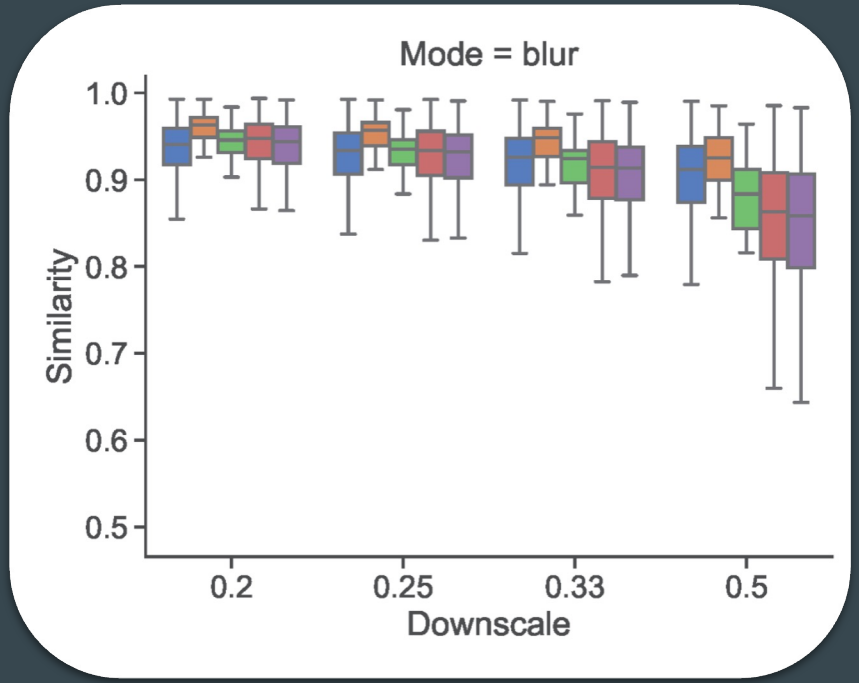
Evaluation

- Protection Efficacy
- Performance
- Usability

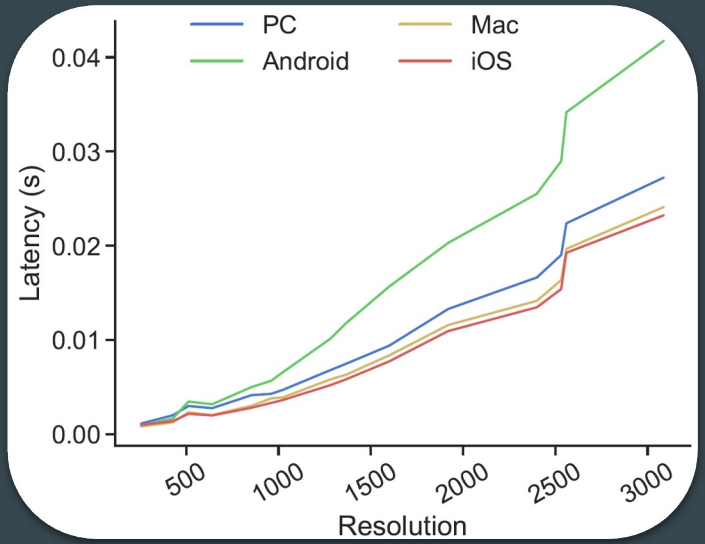
Evaluation - Efficacy (SSIM)

- SSIM (0 - low similarity, 1 - high similarity)
  - SSIM > 0.9, Eye-Shield mimics blurred images
  - The further the screen, the more Eye-Shield mimics blurred images
- Evaluated image datasets

High Resolution Images	Mobile App UIs	Video Datasets (# Frames)
900	1460	1522



Evaluation - Performance



Latency

Resolution	Android (FPS)	iOS (FPS)
1920×1080	49.25	91.39
1080×2400	39.20	74.29
1170×2532	34.52	64.95
2560×1440	29.27	51.95
1440×3088	23.95	43.05

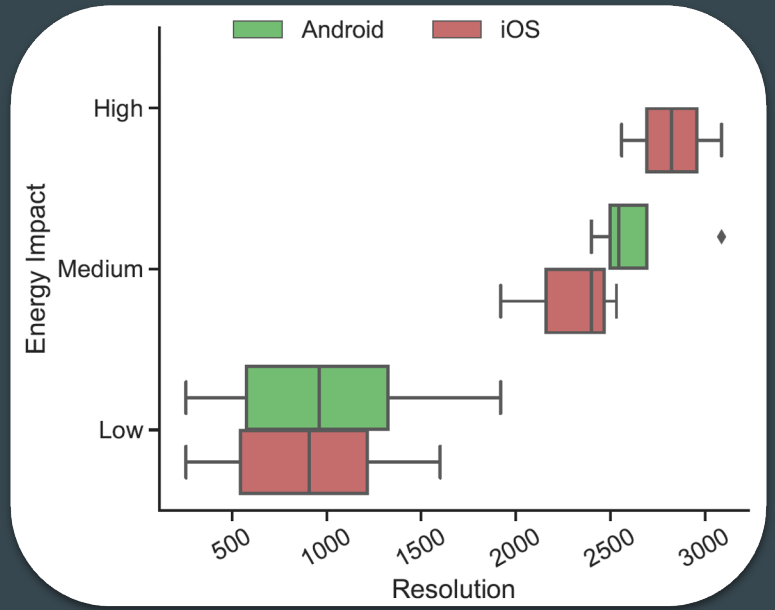
Mobile Performance Benchmarks

High performance at high resolutions

Evaluation - Performance

- Power: Low or Medium rating on most resolutions
- Memory: < 40 MB
- CPU Utilization: < 10%

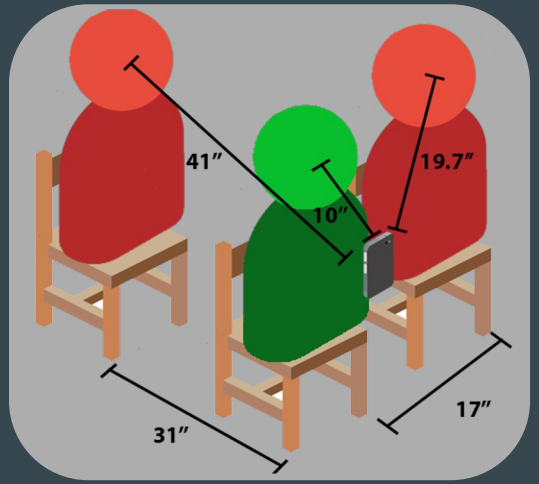
Acceptable energy and resource consumption



Mobile Battery Consumption

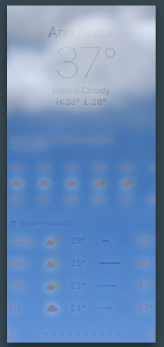
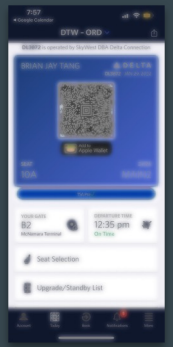
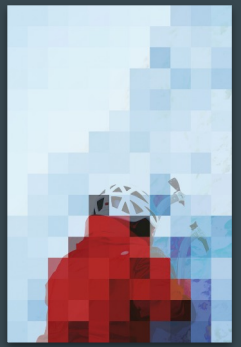
Methodology - User Study

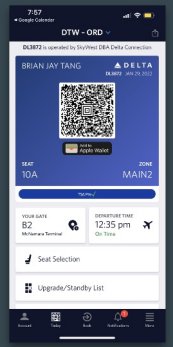
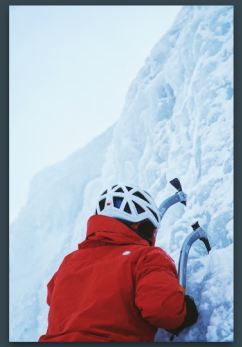
- In-Person Study (IRB Exempt)
  - 22 U.S. participants
  - Diversity in age, occupation, ethnicity, and gender
  - Brightly lit lab with device brightness at 66%
  - 6 images, 2 videos, 7 mobile app UIs, 2 screen recordings
  - Evaluation in 6 settings (in order)
    - Shoulder surfer (41”, 20” and 45°, with film + Eye-Shield)
    - Intended user 10” away (with protection)
    - Shoulder surfer without protection (41”, 20” and 45°)



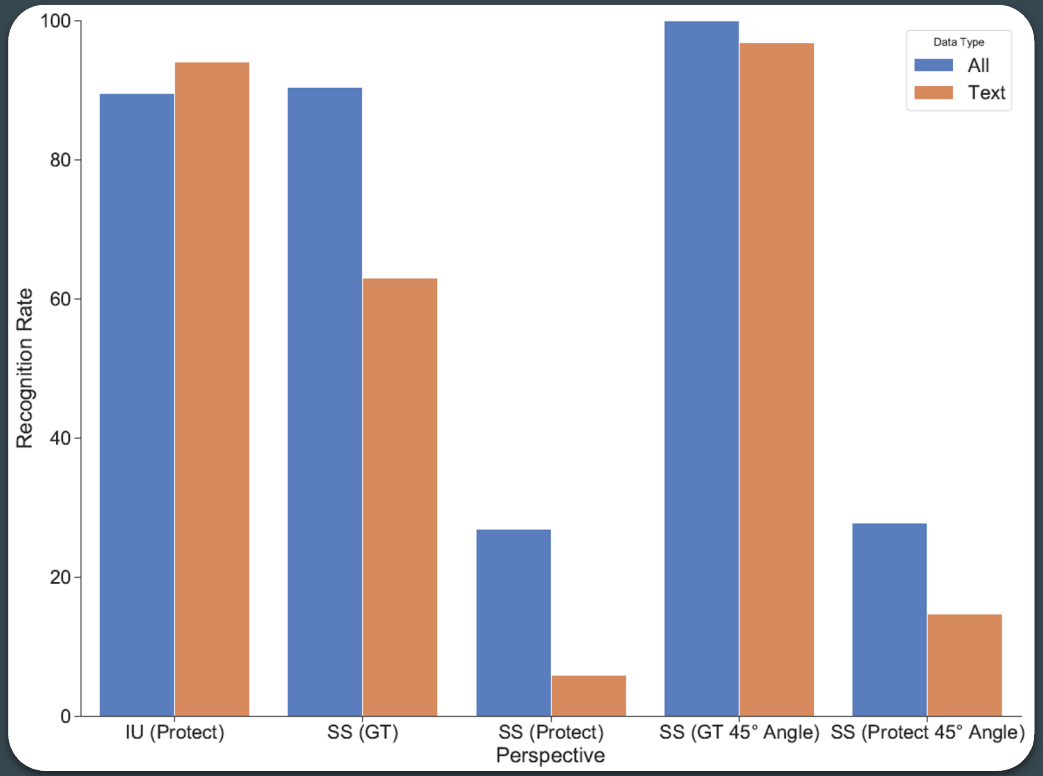
User Study - Examples

- What is the current high and low temperature?
- Can you read the first word in each sentence?
- Can you describe the displayed image?

User Study - Efficacy (In Person)

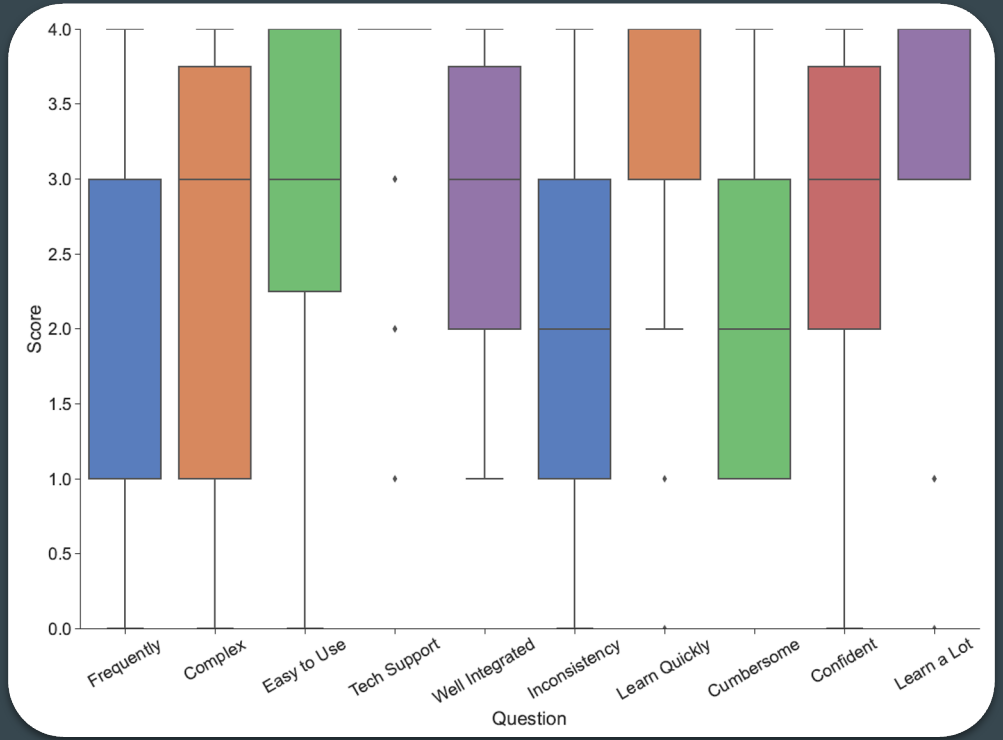


Protects information without harming intended user's reading/viewing

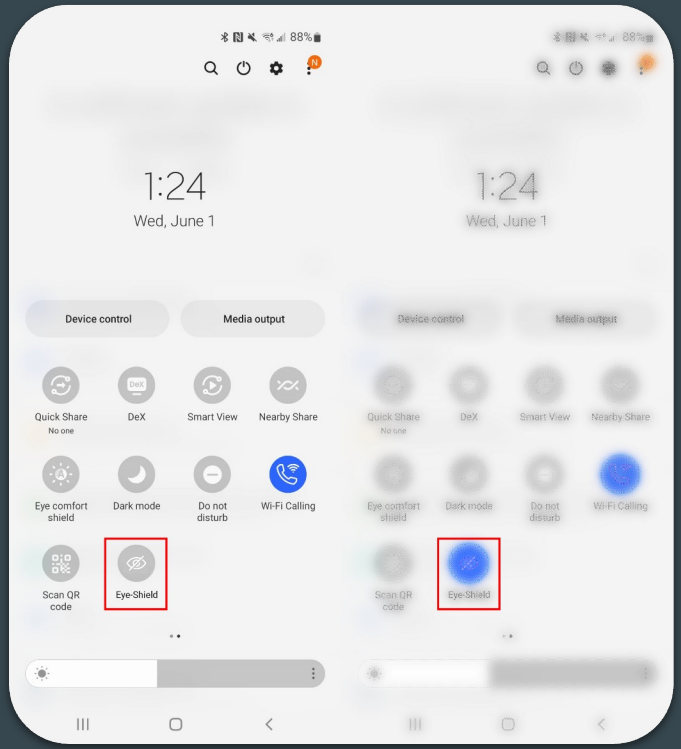
Acronym	Meaning
IU	Intended User (10")
SS	Shoulder Surfer (41" or 20"+45°)
GT	Ground Truth (Unprotected)

User Study - Usability

- SUS score 68.86
  - About average usability
  - Cutoff range = 68
- Observations
  - Sometimes referable to privacy film
  - Indicated that a toggle widget or brightness meter would be best
  - Minor eye strain after shoulder surfing for 1 hour



User Study - UI Prototypes



User Study - Privacy Films

- Privacy film only
  - Narrow protection angle
- Both privacy film and Eye-Shield
  - Better protection guarantees

Both Privacy Film

Wide Angle

Both Privacy Film

Narrow Angle

Citations and Acknowledgements

Privacy Article Screenshots:

- https://www.makeuseof.com/what-is-shoulder-surfing/
- https://www.bbc.com/news/business-65456325

Photos:

- https://www.secure-od.com/prevent-shoulder-surfing-and-theft-of-corporate-credentials/
- https://lifelock.norton.com/learn/identity-theft-resources/what-is-shoulder-surfing
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Statistics:

- https://multimedia.3m.com/mws/media/1254232O/global-visual-hacking-experiment-study-summary.pdf
- https://multimedia.3m.com/mws/media/950026O/secure-white-paper.pdf

Icons:

- Freepik and Flat Icons

Thank you to the ARO for supporting this project

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Thanks to the RTCL members and shepherds for helping me with the user study!

Conclusion

Takeaways:

- Shoulder surfing poses a significant threat to mobile security and privacy
- Eye-Shield can prevent many details of on-screen information from being leaked to shoulder surfers
- Thorough evaluations of Eye-Shield's efficacy, performance, and usability demonstrate its usefulness

Resources:

- Websites
  - https://www.bjaytang.com/
  - https://rtcl.eecs.umich.edu/rtclweb/
- Contact
  - bjaytang@umich.edu | kgshin@umich.edu

Paper & Demo