Eye Gaze Input

This week

- Understanding eye gaze input
- Using eye gaze in cool ways
- Adapting traditional UIs to eye gaze

Eye Gaze Interaction

👁️

Why study eye gaze?

- Very different input modality than we typically encounter
- In some ways, represents a **worst case scenario** for interaction
  - Usable even by severely impaired people
- Relatively easy to understand **how** to design for eye gaze input
  - But implementation can be challenging
- May be an emerging interaction mode?

Eye gaze

- How eye trackers work
- Traditional and alternative UIs
- Interaction challenges and how to overcome them
- Designing for eye gaze input

The Human Eye

- Light enters the pupil and is projected onto the retina
- Fovea is a dense group of cells representing our center vision
  - Peripheral vision much worse
- Eye muscles allow focus
- Eye gaze **saccades** rapidly back and forth, **fixates** on visually salient targets

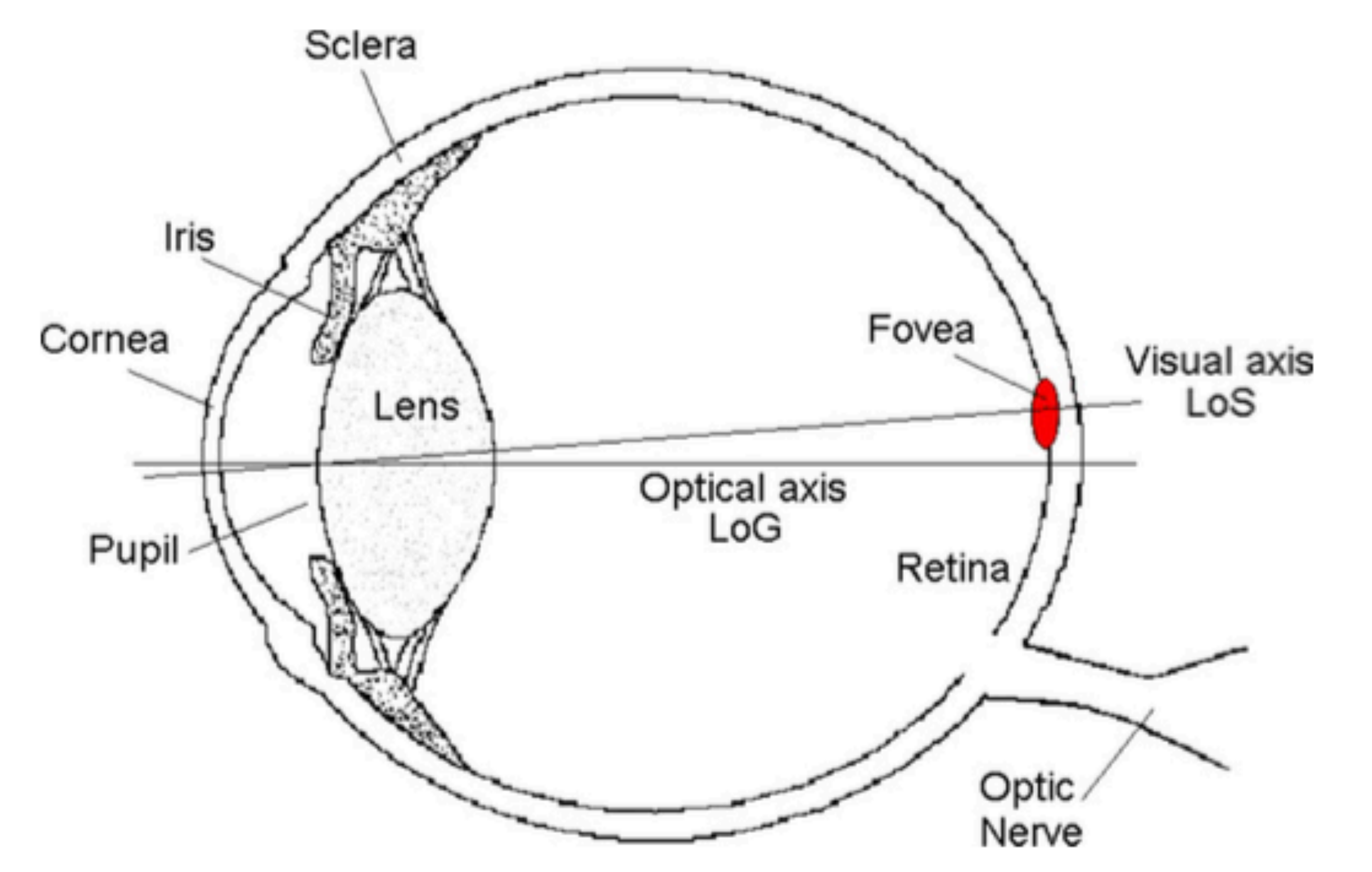


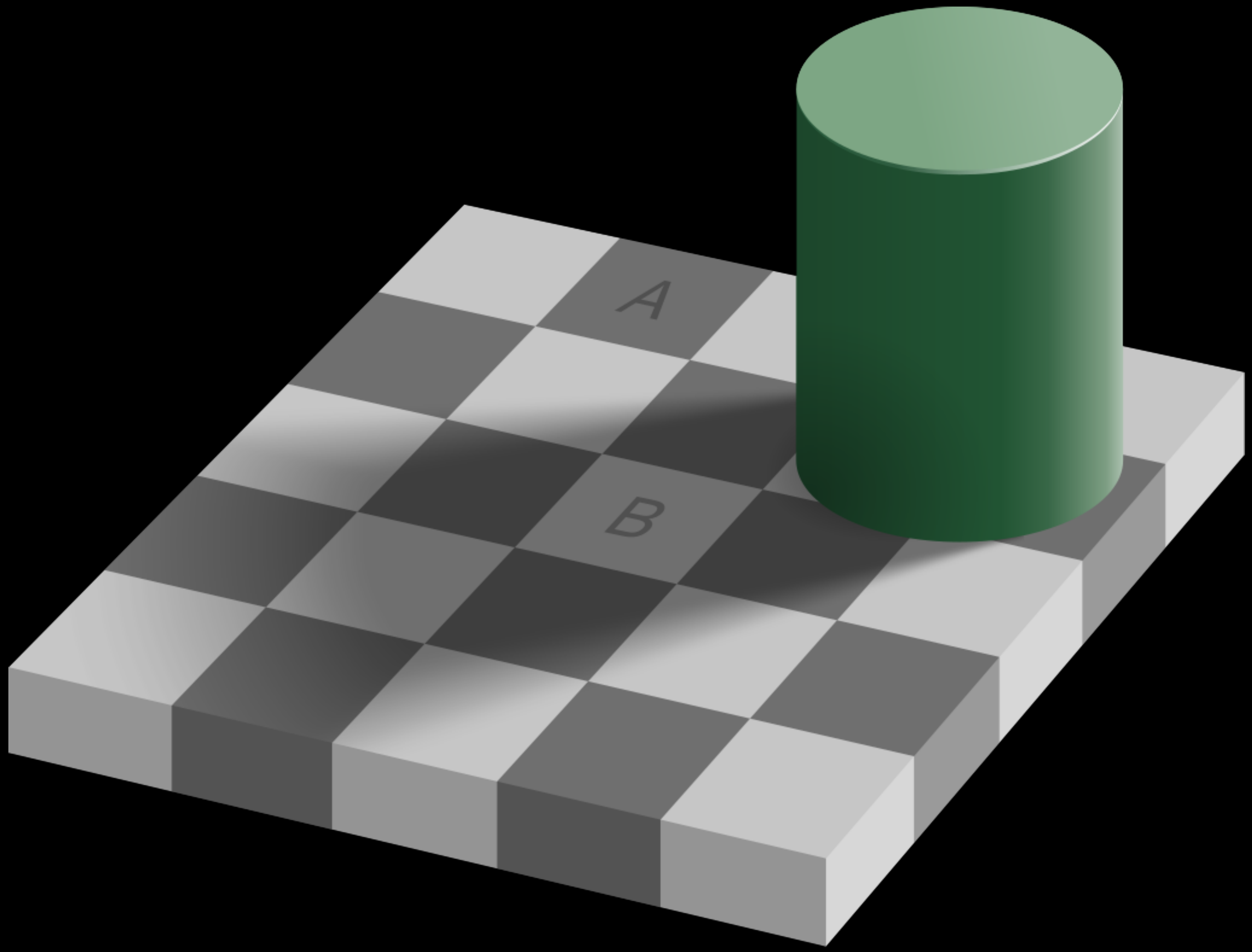
Fig. 1. Structure of the human eye.

Source: Morimoto and Mimica

Our vision vs. our experience of our vision

- Our brain is really good at tricking us about what our eyes are seeing!
- Examples:
  - Peripheral vision quality is much worse than it seems
  - Color constancy: our brain corrects for environmental factors
  - Saccades: Our eyes move around a lot!
  - Blind spots!

Optical illusions



Saccades at 600 FPS

How (most) eye trackers work

- Bounce infrared light off of the cornea
- Reflection changes as the user's gaze changes
- Requires per user calibration (3-5 minutes)
- Eye tracker hardware is essentially an infrared light array and 2D infrared cameras

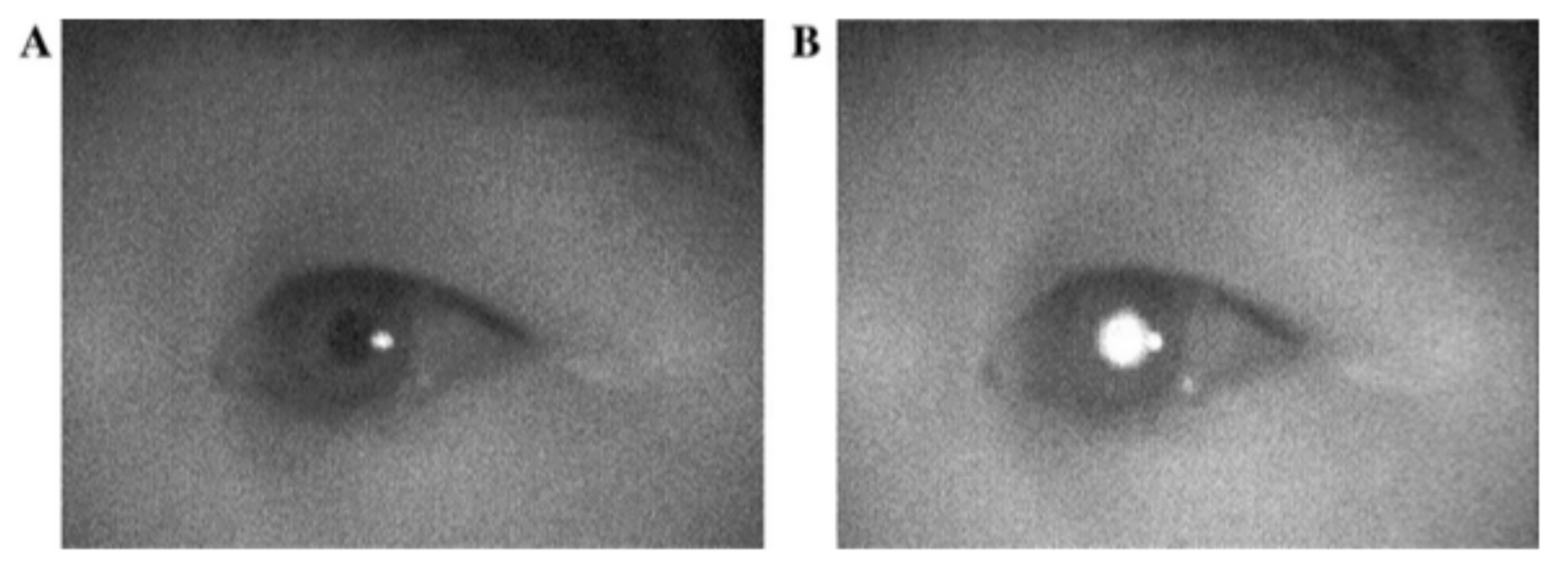
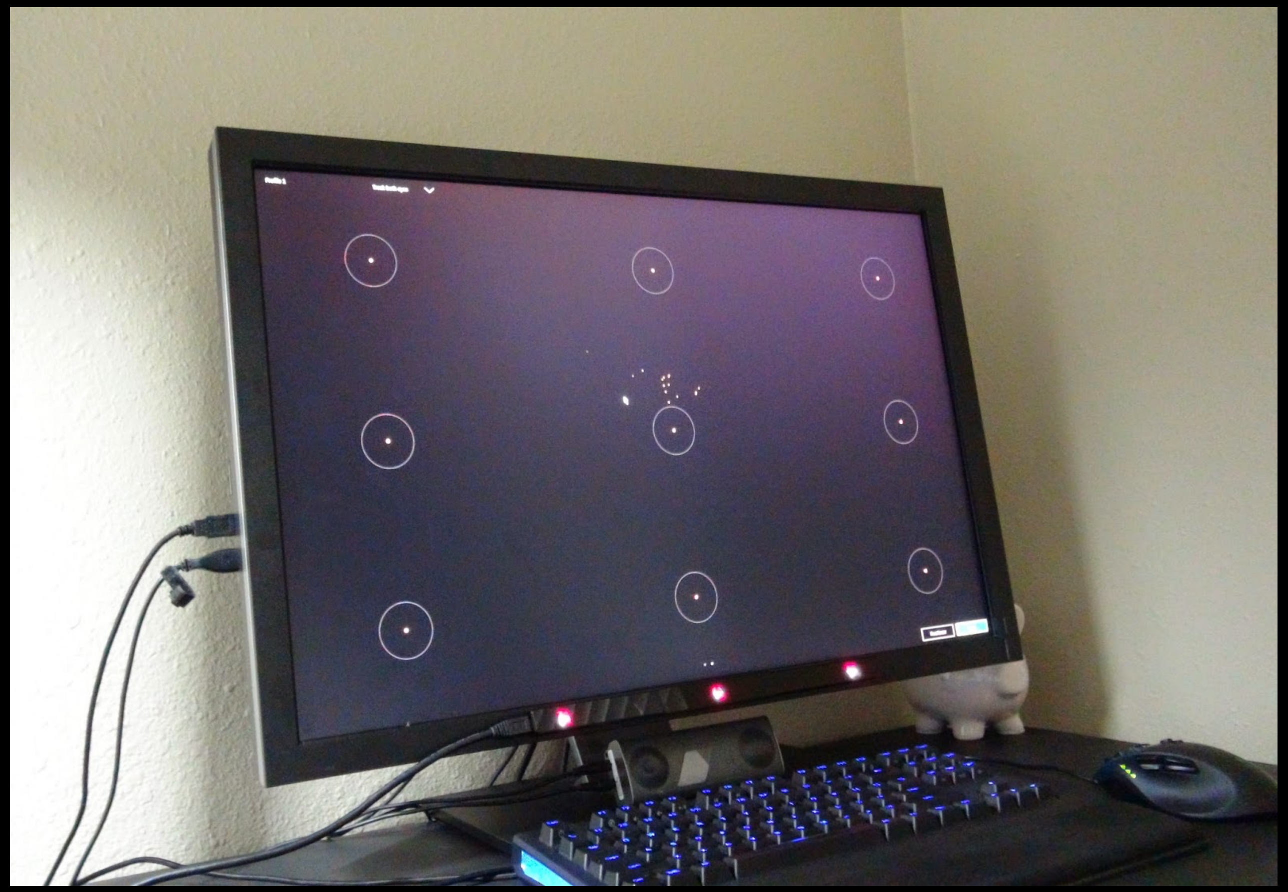


Fig. 2. Dark and bright pupil images.

Source: [Morimoto and Mimica]

Form factors



Desktop (binocular)

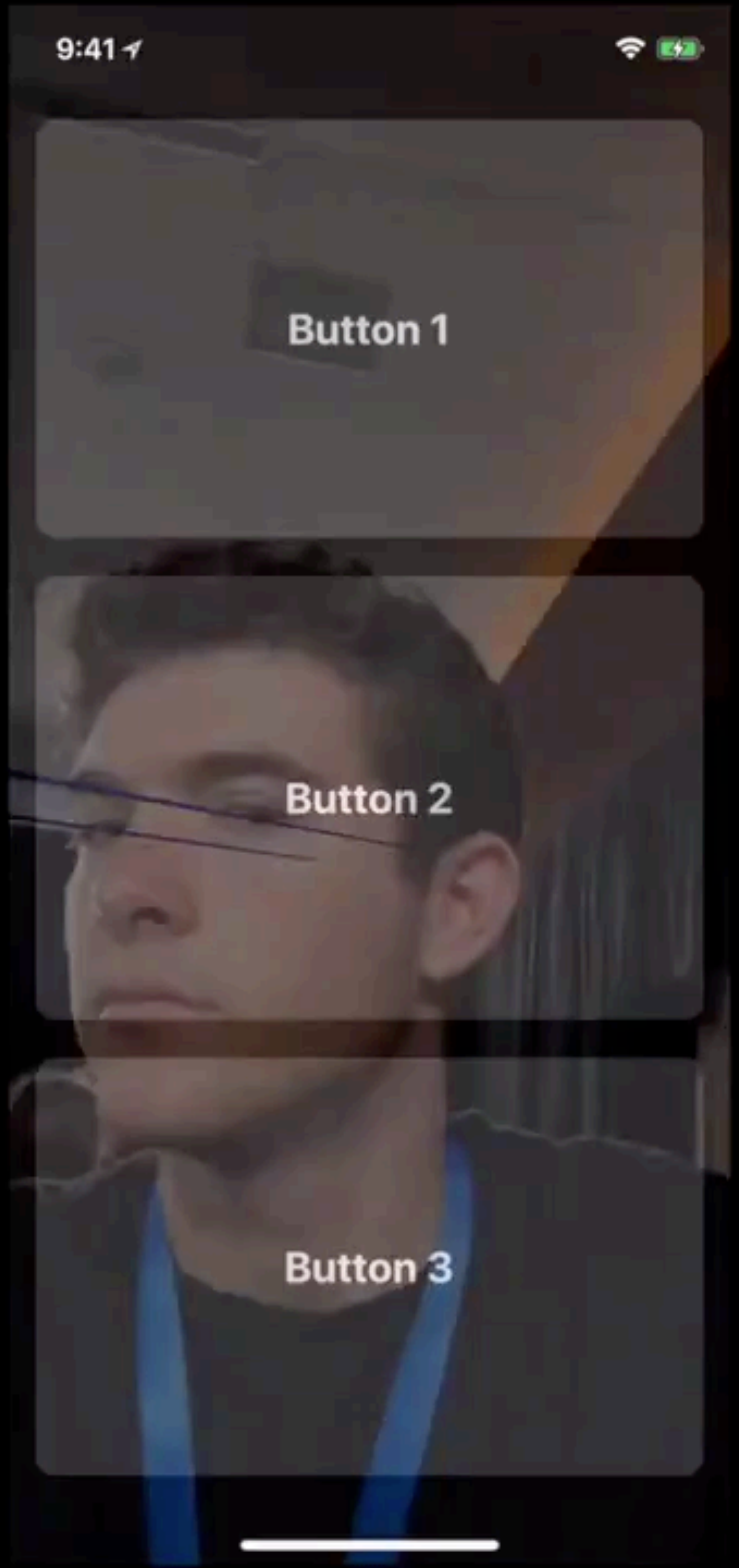
Monocular

Mobile

AR/VR

Other sensing techniques

- Depth cameras (e.g. new iPhone)
- Webcams (but not very accurate)
- Sensors in VR/AR headsets
- Use head movement (very limited)



Eyegaze: pros and cons

- Let's get some practice making sense of a new input method
- Imagine we are adapting a touch UI to a gaze-enabled UI
- How do they compare?

Eye gaze +/-

- + Fast movement
- + Simple sensing hardware
- + Subtle
- + More intuitive
- + Distance

- – Precision
- – How to select??
- – Gestures are tricky
- – Midas touch
- – Strain
- – Looking at stuff vs. interacting with stuff

How eye gaze is different

- No way to “lift” gaze - Midas touch problem and pass-through problem
- No standardized way to select targets
- Can’t easily look at the interface without interacting
- Target size much larger

Target selection

- Blinking?
  - Can be fatiguing, doesn’t work for everyone
- Dwell
- **Midas Touch** problem
  - Worse for eye gaze because looking at something does not necessarily mean you want to interact with it!
- Can also select use a switch

Dwell time

- How to design a dwell time that minimizes false positives and maximizes true positives?
- What should the value be?

Sip-and-puff

- Can suck in or blow out to provide input
- Sometimes combined with a joystick controlled by chin or mouth
- Not always compatible with breathing equipment

Why eye tracking is hard

- Must maintain specific distance (for Tobii, 18 to 45 inches)
- Must limit head movements
- Requires calibration for every user
- Sensitive to environmental factors
- **Saccades** - our eyes move even when they appear not to
- In general, not nearly as precise as a mouse or touch screen

When eye tracking fails

- Environmental factors (especially sunlight!)
- Eye trackers typically do not work outdoors
- Physiological differences (e.g., people with very dark eyes, irregular eye shape)
- User fatigue
- Positioning (especially challenging when needed for communication)
- Medications can affect focusing, dry out eyes (common with ALS)
- Less accurate at screen edges

Eye trackers vs. head mice

- Head mice provide a similar level of control to eye trackers for users whho retain head movement
- Use camera to track head movement
- Track an IR-reflective dot or use computer vision features

Paralyzed with Joy

Software-based head mice

- Camera Mouse (Windows)
- MouseTrap (Linux)
- ViaCam (Windows)
- Animouse (Windows)

Designing for eye trackers

- Target size
- Selection mode
- Target design

Designing for eye trackers

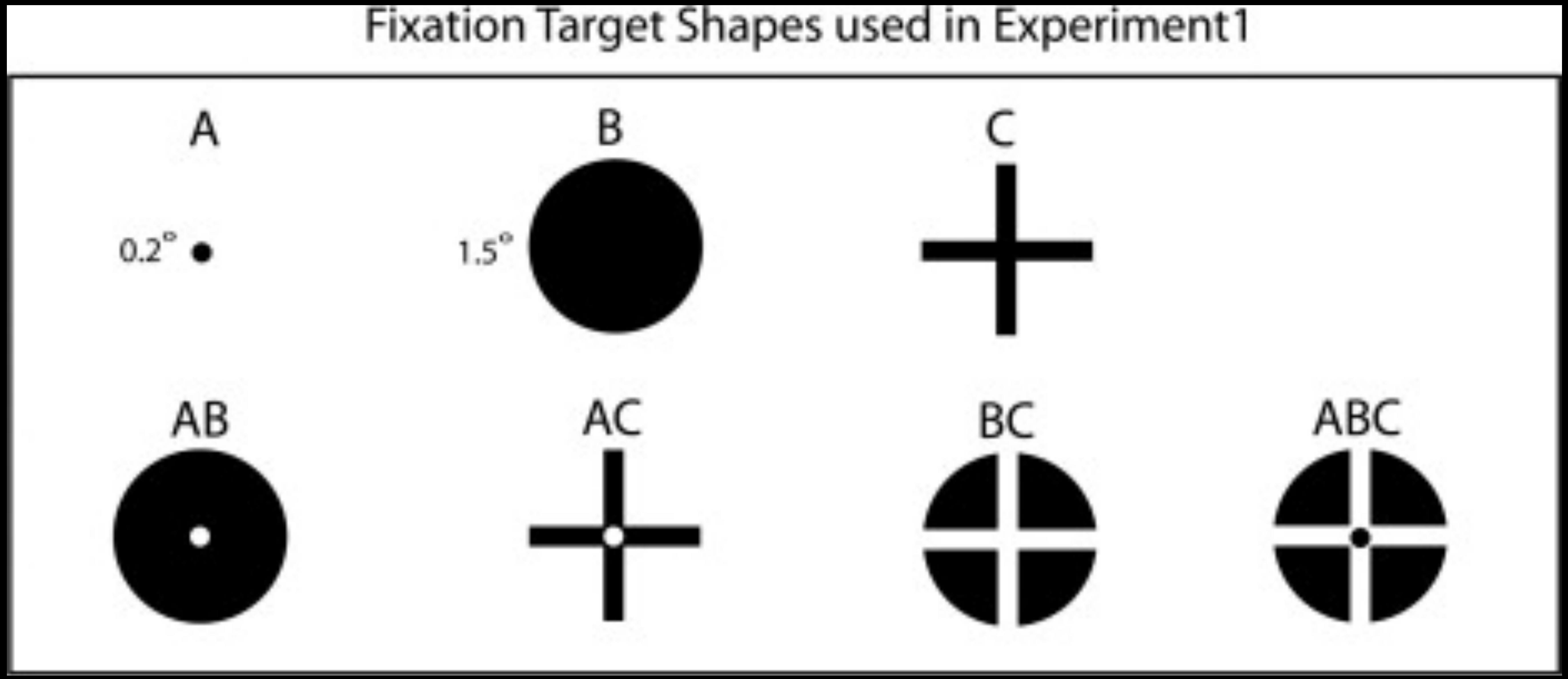
- Target size
  "Sizes can vary from 0.94×1.24 cm for users that track well, up to 5.96×6.24 cm if we want to allow robust interaction for nearly all users in our dataset." (Feit et al., CHI 2017) - 2.3 x 2.5 inches

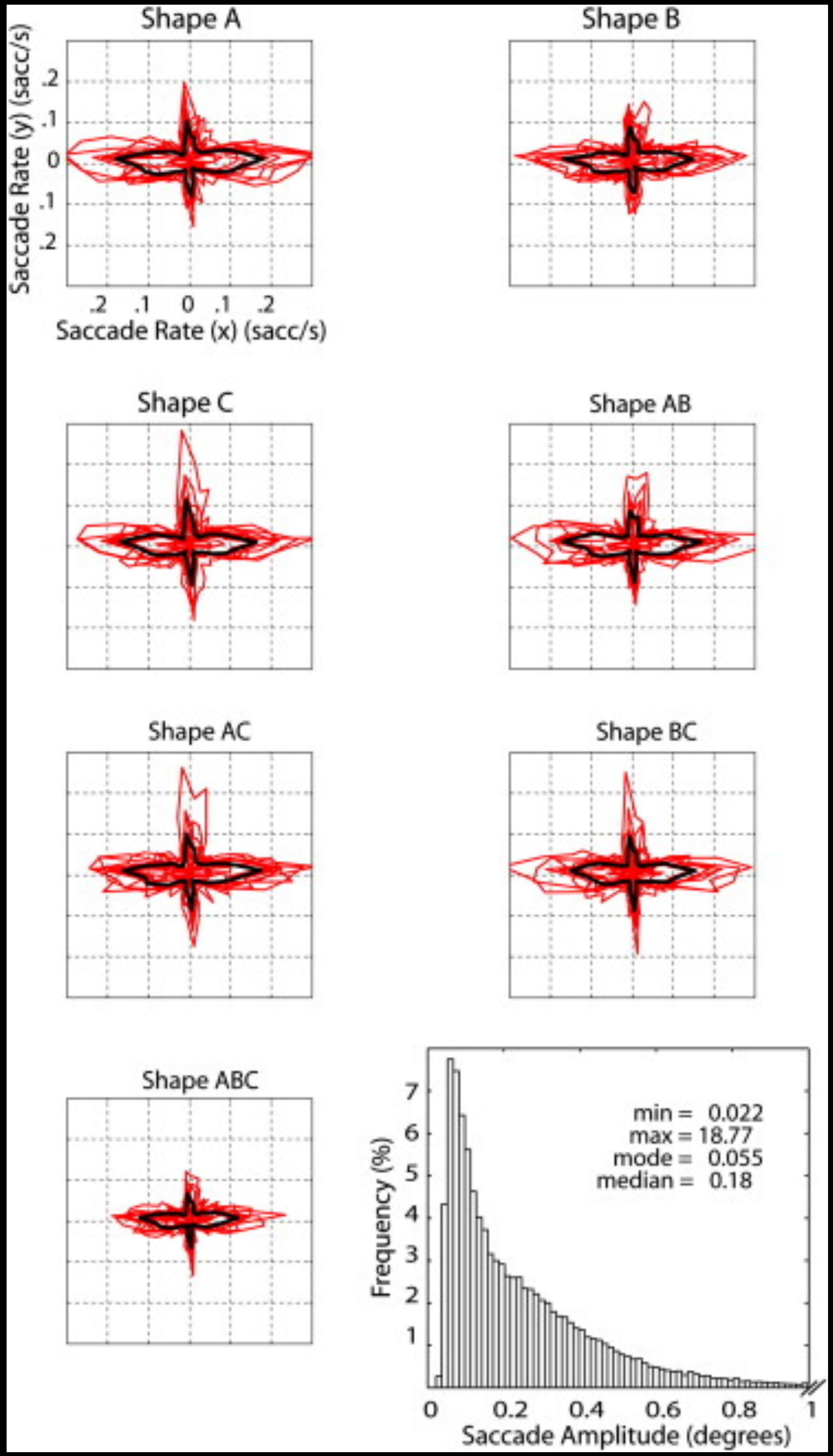
- Selection mode
  Support adjustable dwell time, switch and keyboard based selection

- Target design
  Visual screen design can distract eye gaze users; crosshair-like targets easier to select (Thaler et al., 2012) **- but test with users**

- Showing the cursor can also be distracting!

Target performance





OK, but what about anything other than clicking??

- How do we do it?
  - Double click
  - Right click
  - Swipe or mousewheel
- Let’s sketch out some ideas

Moving beyond clicks

- Regions for scrolling
- Feed forward
- Add a menu to choose action
- Right/left blink
- Crossing interface

How to support additional interactions

- Augment with “helper” apps or on-screen menus
- “Clutch” to turn off active eye gaze

Additional design guidelines

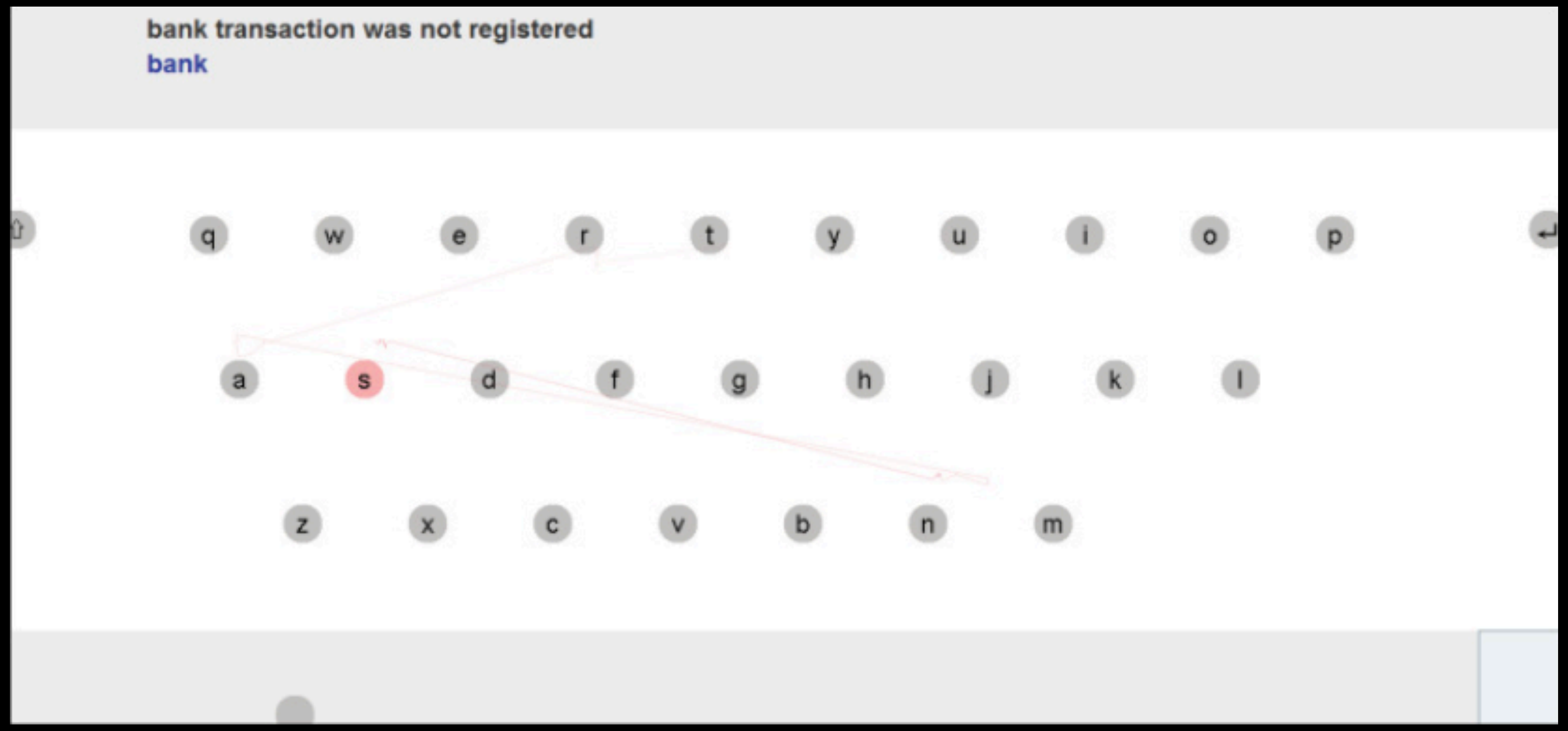
- Reduce amount of text input needed
- Predict the user's behavior when possible

Word prediction

- Word completion: complete words as they are typed
  - Uses word frequency; prior words entered
- Word prediction: suggest next word based on prior words
  - Uses a bigram (or N-gram) model; prior words or bigrams
- Other sources of prediction?
- Can also use word prediction to adjust dwell time (see Mott et al., CHI '17)

Can we go faster?

- Typical eye typing rate is 10-20 wpm ([Majaranta and Ralta]())
- Adaptive dwell, prediction have marginal benefits
- Swype doesn't seem to improve performance ([Pedrosa et al.]())



Alternative gaze-based UIs

- Use “smooth pursuit” to track eye gaze (Esteves et al, “Orbits”)

- Combine eye gaze with other input methods (e.g. Pfeuffer et al., “Gaze-Touch”)

- Use gaze to track attention/affect, rather than input

Eye gaze as input to the world

- Eye gaze can also be used to control physical objects
  - Wheelchairs, drum sets

Open challenges

- Improving the speed of input (typing maxes out at around 20wpm)
- Supporting environmental awareness and social connections while using eye gaze
- Other widgets?
- Supporting precise input
- Supporting time-sensitive input (e.g. music, gaming)

Let’s try it

- Let’s convert an existing smartphone user interface into an eye gaze-based interface
- Pick an app on your phone
- Sketch out an eye gaze-based version
- (or start working on head mouse)