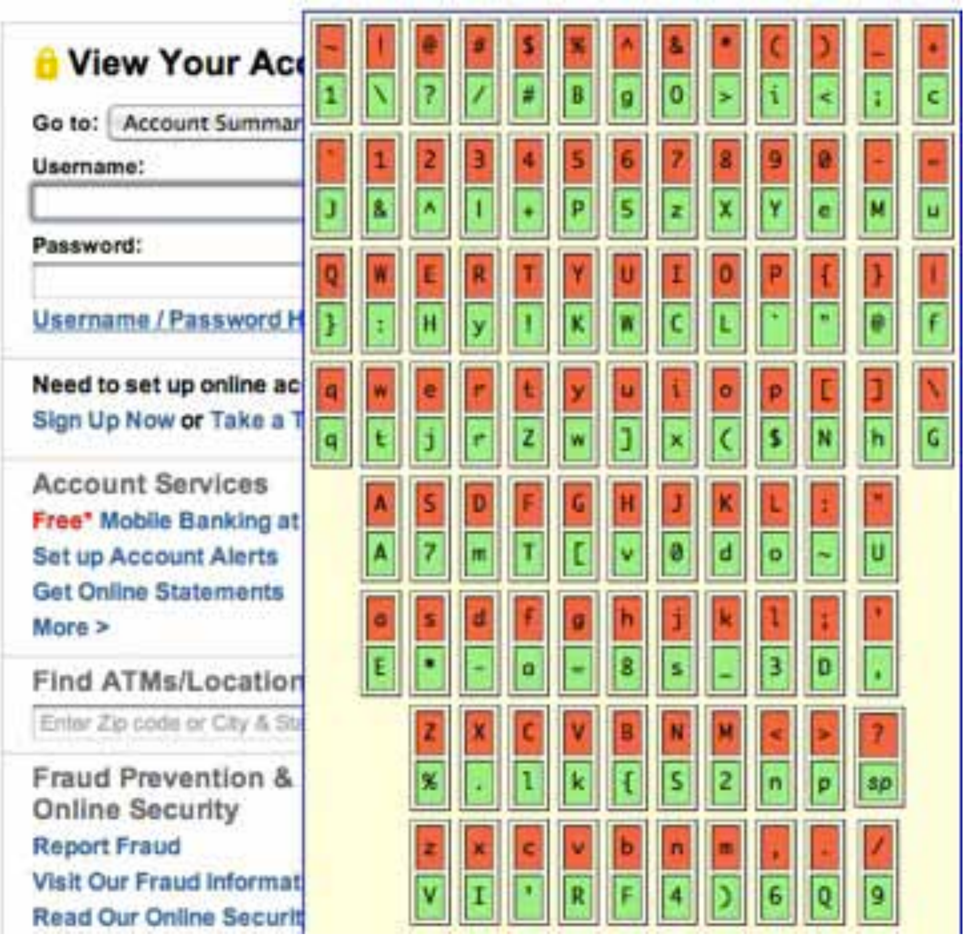
Vanquishing Voyeurs: Secure Ways to Authenticate Insecurely



View Your Acc

Go to: Account Summar

Username:

Password:

Username / Password H

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Sign Up Now or Take a T

Account Services
Free* Mobile Banking at
Set up Account Alerts
Get Online Statements
More >

Find ATMs/Location
Enter Zip code or City & St

Fraud Prevention &
Online Security
Report Fraud
Visit Our Fraud Informat
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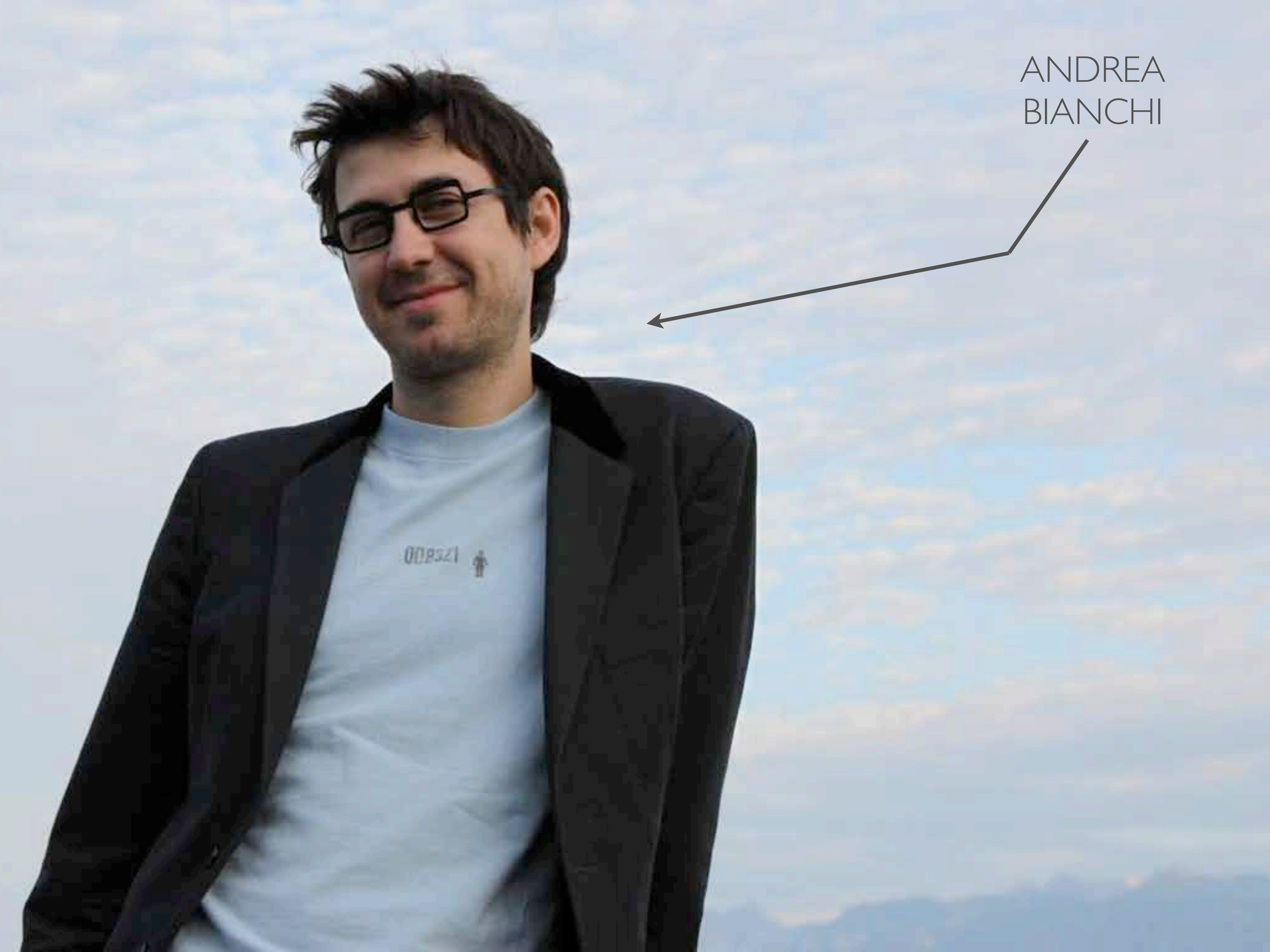
Andrea Bianchi & Zoz



ANDREA
BIANCHI

ZOZ

Overview

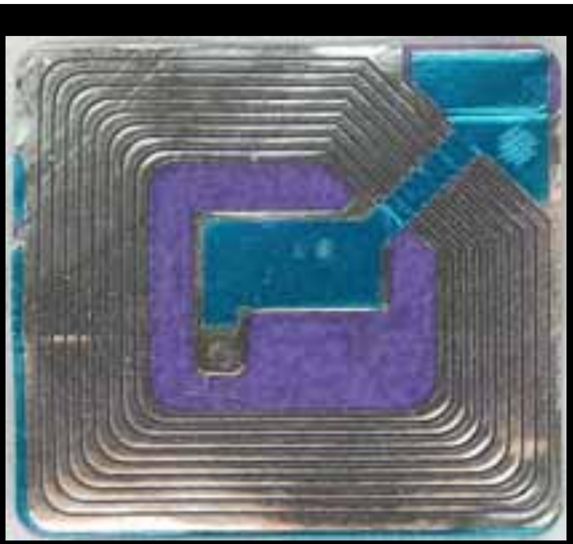
- Password/PIN Features & Observation Attacks
- Observation from Without
  - Physical Key Entry at Insecure Terminal
  - Mechanical Observation-Resistant Solutions
- Observation from Within
  - Key Protection between Insecure Input Device and Network
  - Recorder/Logger Subversion
- Rethinking Password Entry Mechanics
  - Remote Entry with Secure Transmission to Terminal
  - Utilization of Common Mobile Digital Devices

AUTHENTICATION METHODS

alphanumerical
graphical
haptic
...

PASSWORD

keys
RFID
security cards
...



fingerprints
retina scanner
voice
vein scanners
...

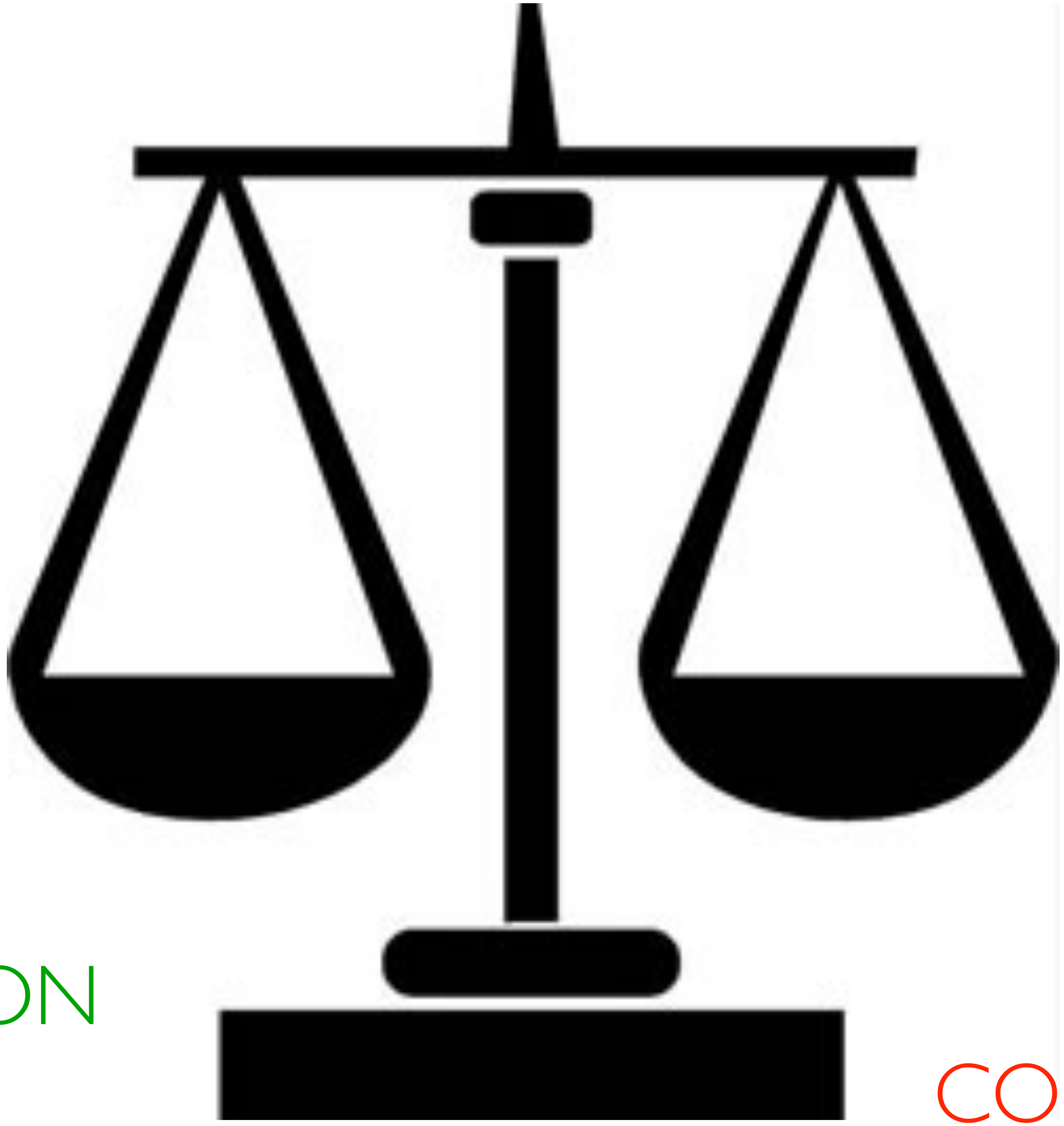
TOKEN

BIOMETRIC

NEED FOR PASSWORDS

PASSWORDS		TOKENS		BIOMETRICS	
+	-	+	-	+	-
Common **Delegation** Cheap **Invisible information**	**Observation** Memory (scaling, cognitive load)	Common **Delegation** Cheap	**Physical Property**: can be stolen, lost, copied, deteriorated	Can be easily accepted by people [Coventry 2003] **No cognitive load**	**Physical Property:** can be observed, copied, deteriorated Technology not ready yet **Philosophical** issues concerning identification **No delegation**

NEED FOR PASSWORDS



INVISIBLE
INFORMATION
+
DELEGATION

HIGH
COGNITIVE LOAD

THE PROBLEM WITH PASSWORDS

Passwords are still valuable compared to other options, and this is why they are the most common in security systems.

However their cognitive load is ultimately caused by their weakness against observation.

Passwords are subjected to observation

> **>** need to have many passwords and change them frequently
>
> > **>** high **cognitive load**

OBSERVATION ATTACKS

HUMAN INTERFACE EXTERNAL

e.g.:
- Shoulder Surfing
- Mirrors/Cameras
- Keypad Dusting

HUMAN INTERFACE INTERNAL

e.g.:
- ATM Skimmers
- Keyloggers

NETWORK

e.g.:
- Sniffing
- MITM

SECURE PRIVATE INTERFACE

ENCRYPT

WHAT ABOUT WHEN WE HAVE TO USE PUBLIC TERMINALS?

PUBLIC TERMINALS

ATMs

Airport kiosks

Door locks

Public computers

Access control

PIN ENTRY TERMINALS

What about bank **ATM** (Automatic Teller Machine) terminals?

Once upon a time...

... there was only the **human** bank teller

PIN ENTRY TERMINALS

What about bank ATM terminals?

The human bank teller

→

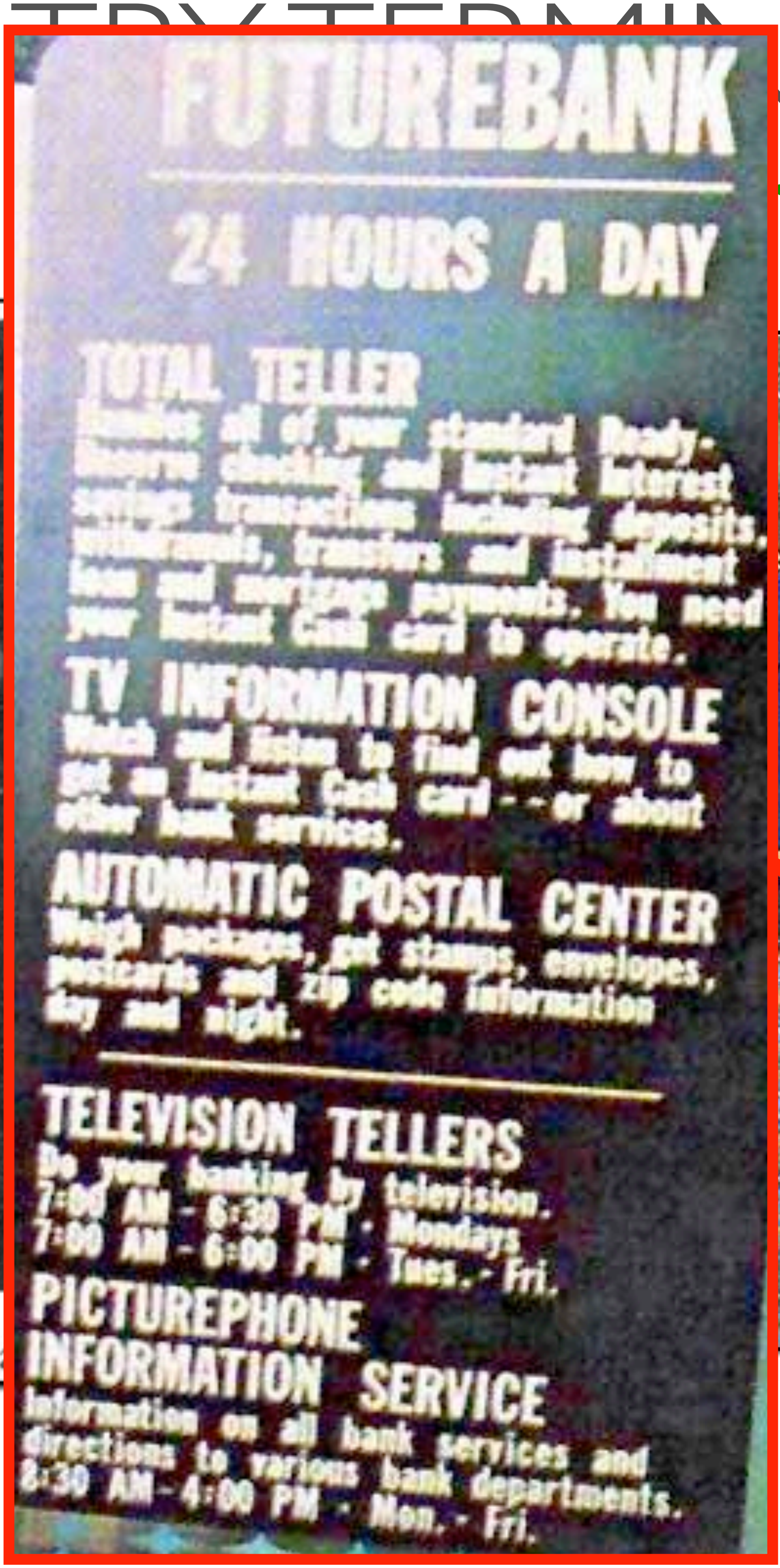
1967: The 'Barclaycash' cash dispenser
(1st cash dispenser, Barclays Bank)

PIN ENTRY TERMINALS

The terminal was

hours a day

Dianne and Leslie Swan on the



FUTUREBANK

24 HOURS A DAY

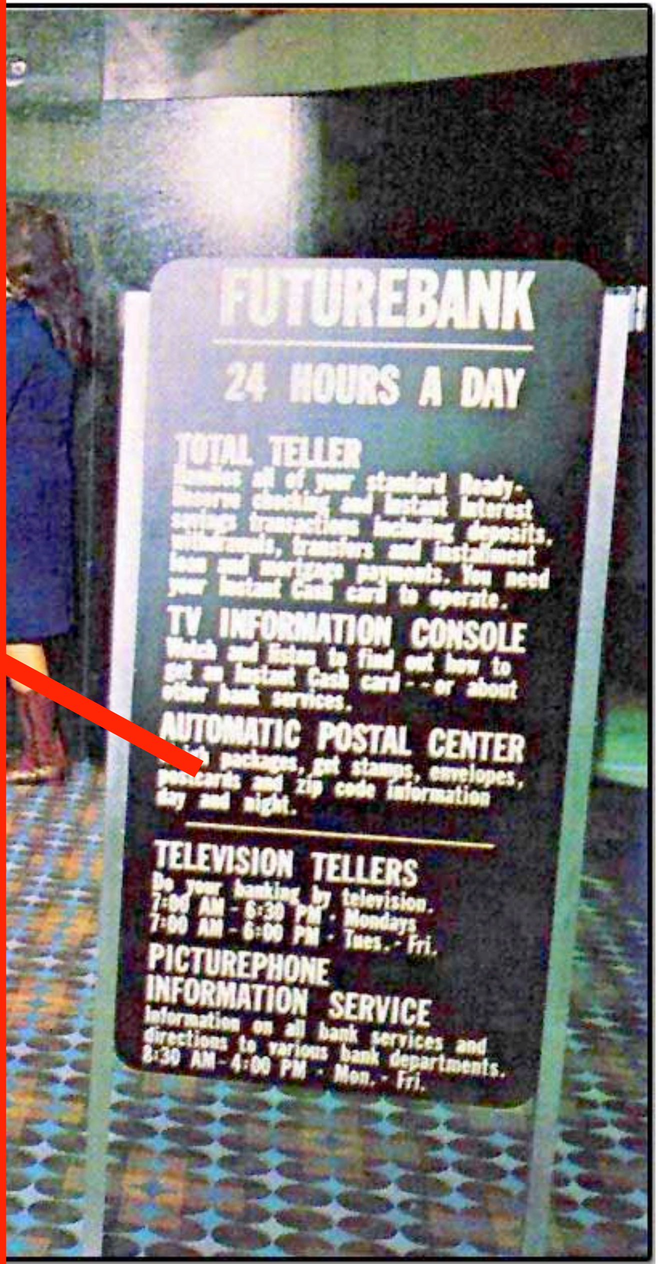
TOTAL TELLER
Handles all of your standard Ready-Reserve checking and Instant Interest savings transactions including deposits, withdrawals, transfers and installment loan and mortgage payments. You need your Instant Cash card to operate.

TV INFORMATION CONSOLE
Watch and listen to find out how to get an Instant Cash card--or about other bank services.

AUTOMATIC POSTAL CENTER
Weigh packages, get stamps, envelopes, postcards and zip code information day and night.

TELEVISION TELLERS
Do your banking by television.
7:00 AM - 6:30 PM - Mondays
7:00 AM - 6:00 PM - Tues.- Fri.

PICTUREPHONE INFORMATION SERVICE
Information on all bank services and directions to various bank departments.
8:30 AM - 4:00 PM - Mon.- Fri.



Wells Fargo Archives

PIN ENTRY TERMINALS

The terminal was public to grant access **24 hours a day and even remotely!**

Key features of the bank of the future are the Total Teller, remote television tellers, a Picturephone and a self-service postal unit.

Wells Fargo Archives

The future tellers (1973) and PAT (2010)

INTERACTION HISTORY

Interaction history

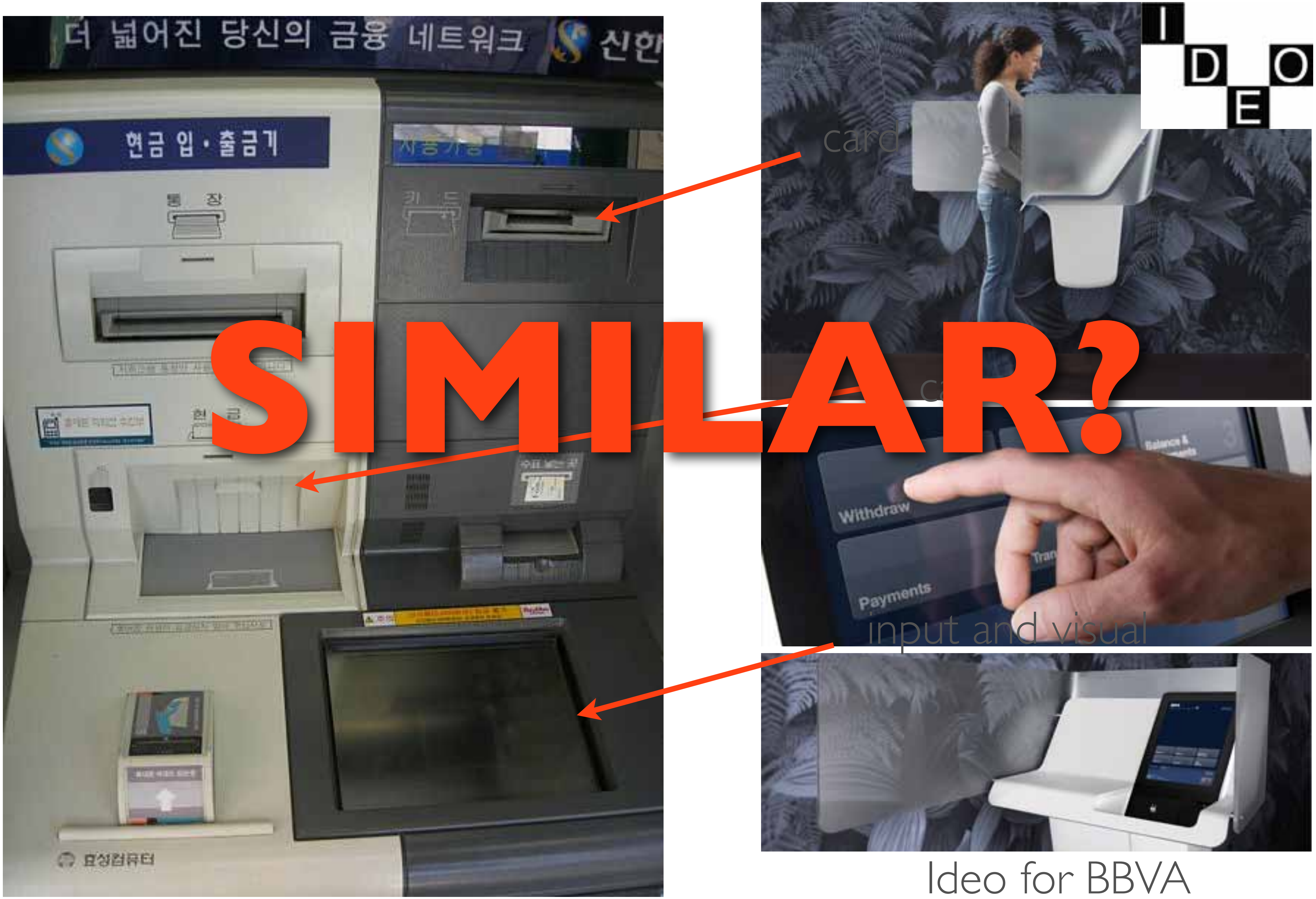
In the past **40** years, the ATM terminals substantially **did not change.**
The interaction with the terminals did not change as well.

Observation is still one of the most common **attacks**!

conexus ATM
CASH & DEPOSIT
5551 - Wincor ProCash 2250
The Golden 1
4002 Surround
COMMUNITY
8601 - Tranax MB5000
BMO Bank of Montreal
7310 Custom Surround
Better Banks
7310 Drive-up Surround
THE NATIONAL BANK
5576 Canopy
1st First Bank
9382 Surround
F&M BANK
9315 Double Walk-up Surr
SCHOOLS
schools.org
9386 - Diebold 1072ix
TFCU 24 HOUR ATM
Be nice to your money
FINANCIAL SERVICES
5576 Canopy, 3830 Island
REGAL EXPRESS
7200 - Ticketing
conexus ATM
conexus
5551 - Wincor ProCash 2250
COMPANION SYSTEMS DESIGN • MANUFACTURING

SIMILAR?

SIMILAR INTERFACES



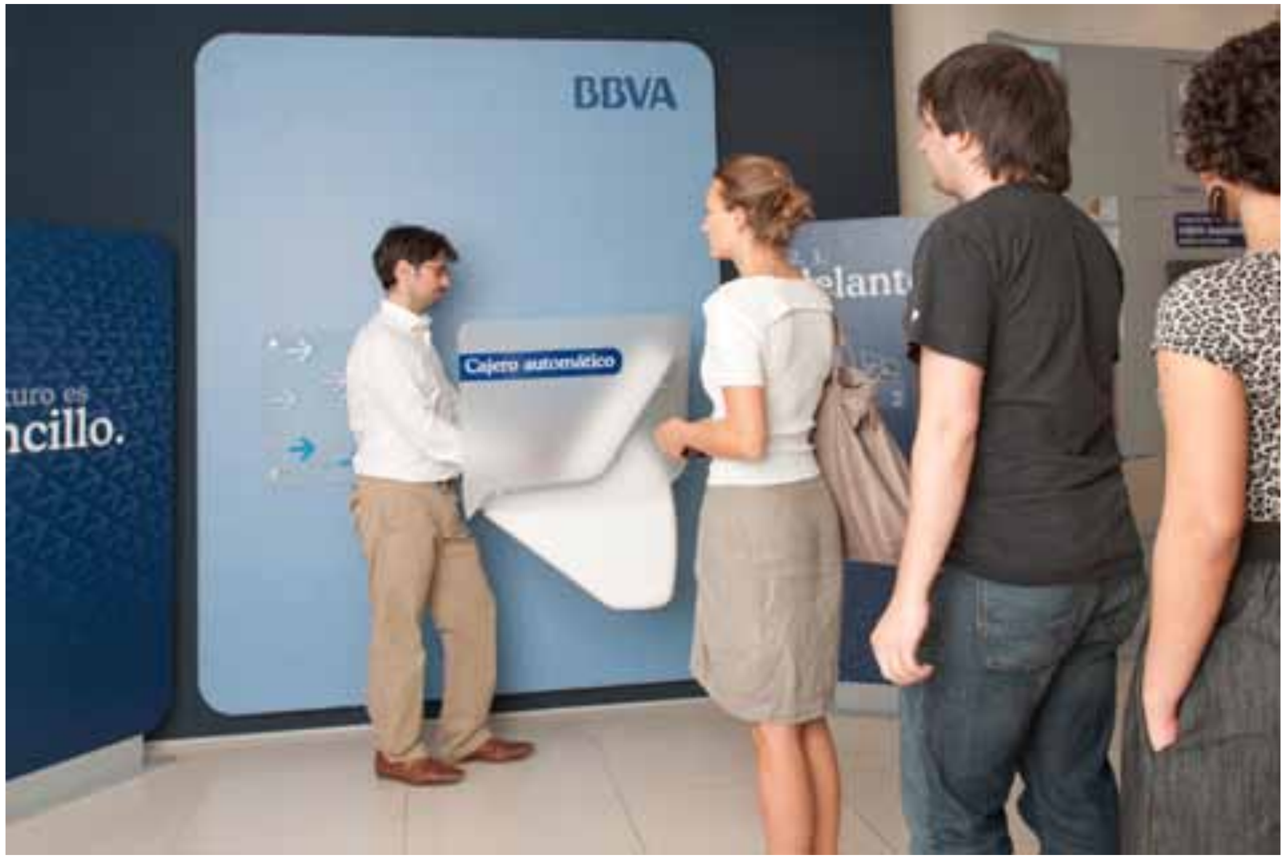
card

input and visual

SIMILAR?

Ideo for BBVA

THE INTERACTION



Ideo for BBVA

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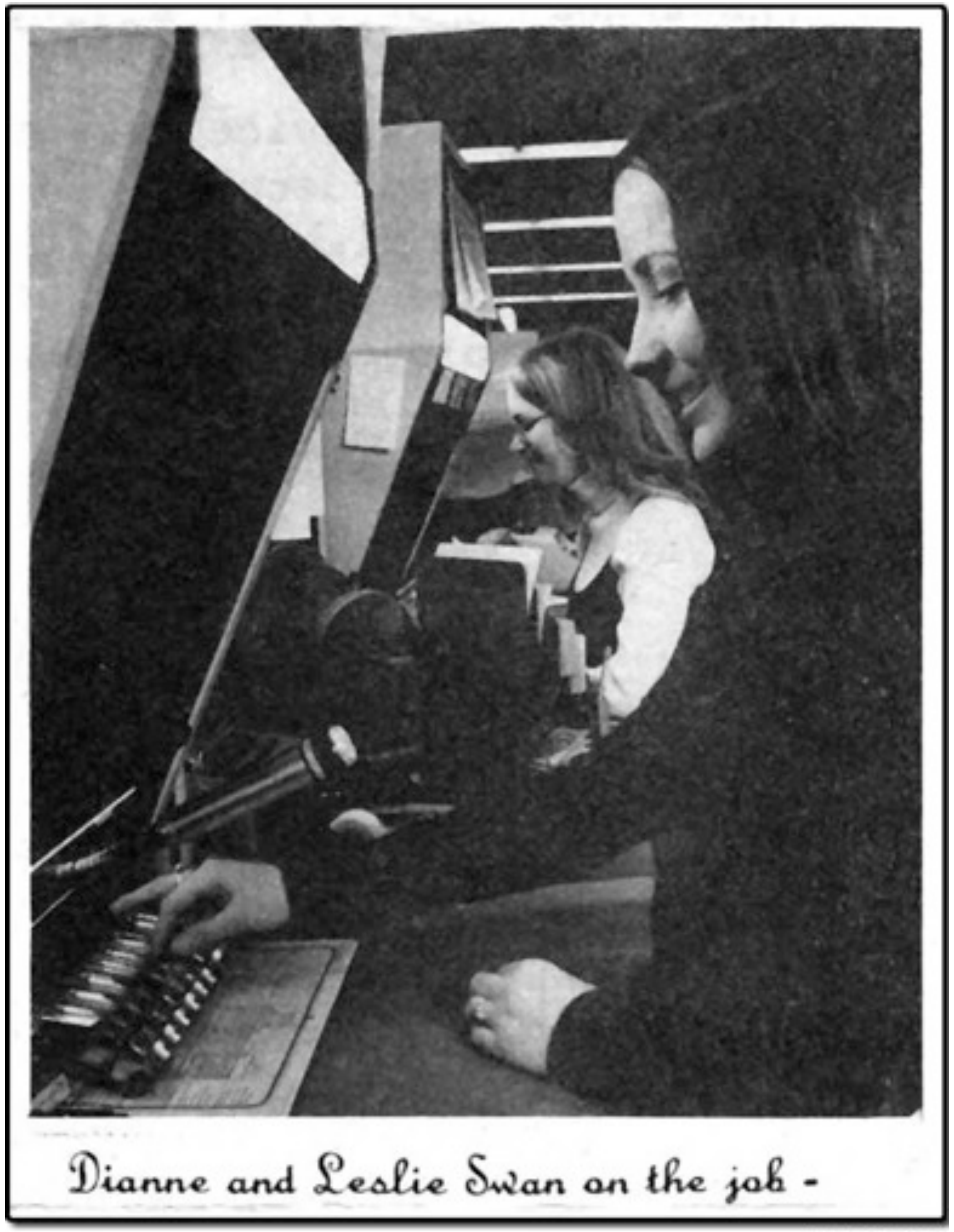


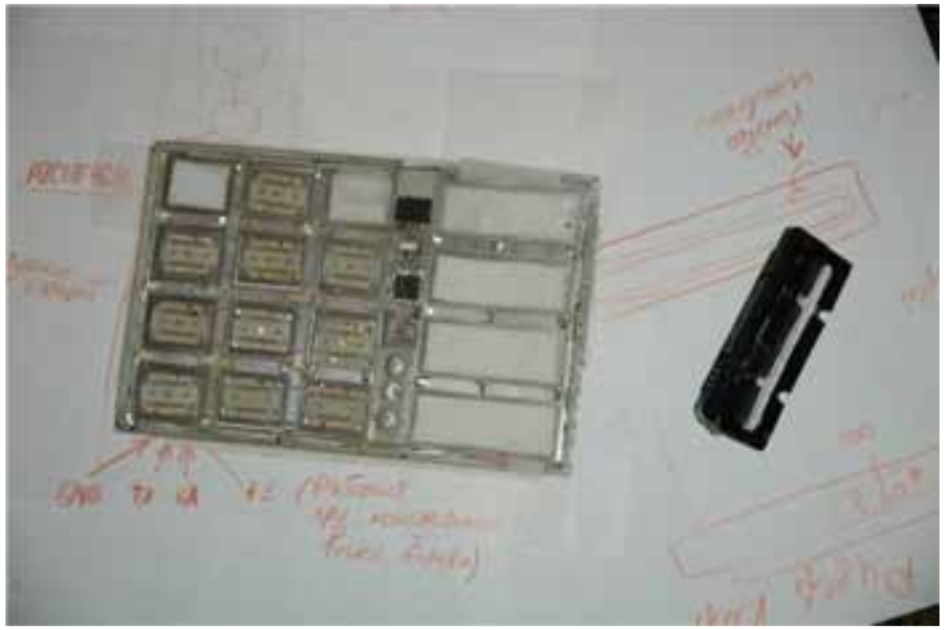
Dianne and Leslie Swan on the job -

Wells Fargo Archives

ATM in 1973

THE INTERACTION

(SECURITY PERSPECTIVE)

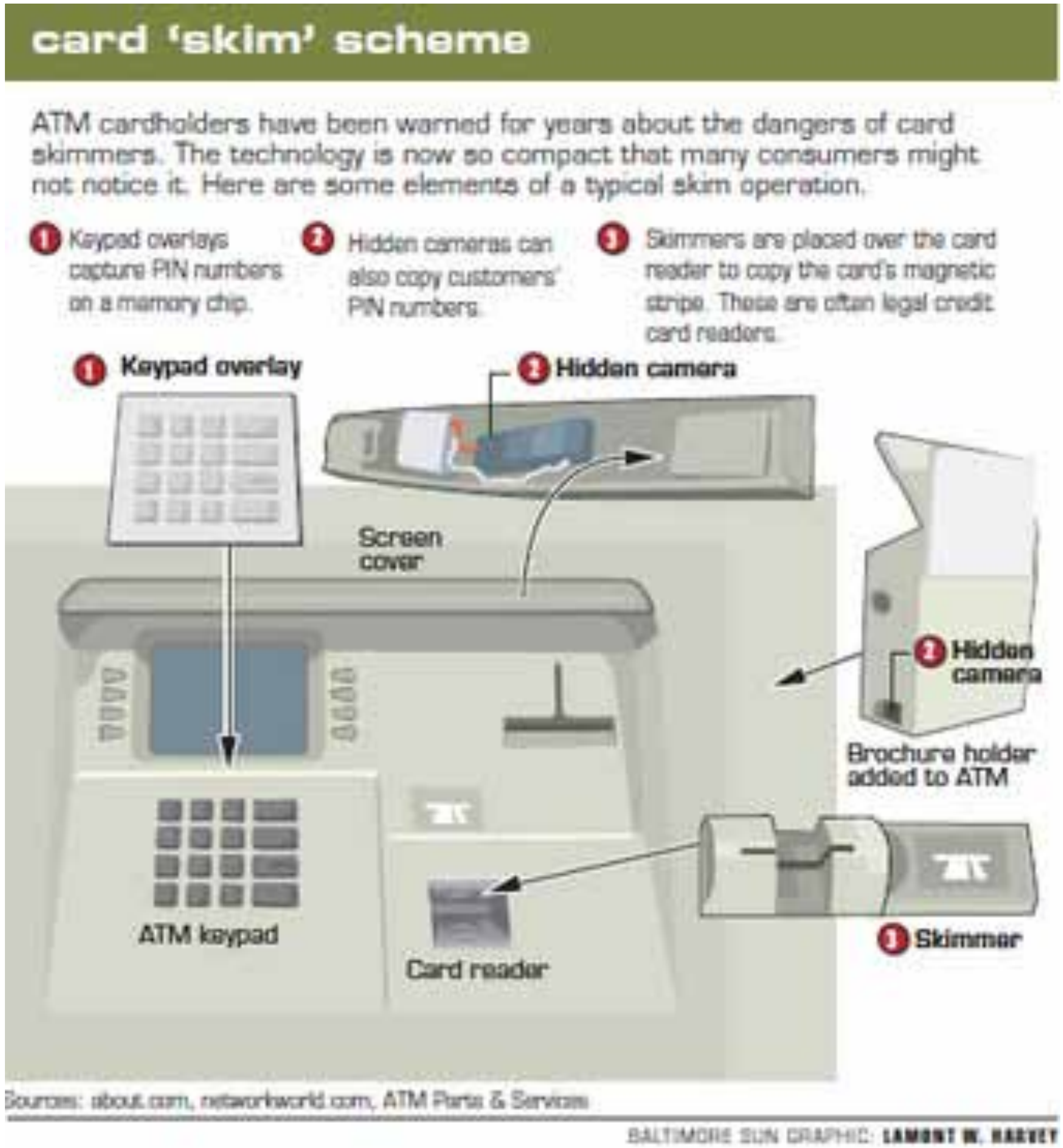


The interaction is **physically situated**

hence easily attackable (i.e. shoulder surfing and camera attack)

PUBLIC THREAT

1. Public terminals **dangerous** (DeLuca 2010 and Gizmodo)



card 'skim' scheme

ATM cardholders have been warned for years about the dangers of card skimmers. The technology is now so compact that many consumers might not notice it. Here are some elements of a typical skim operation.

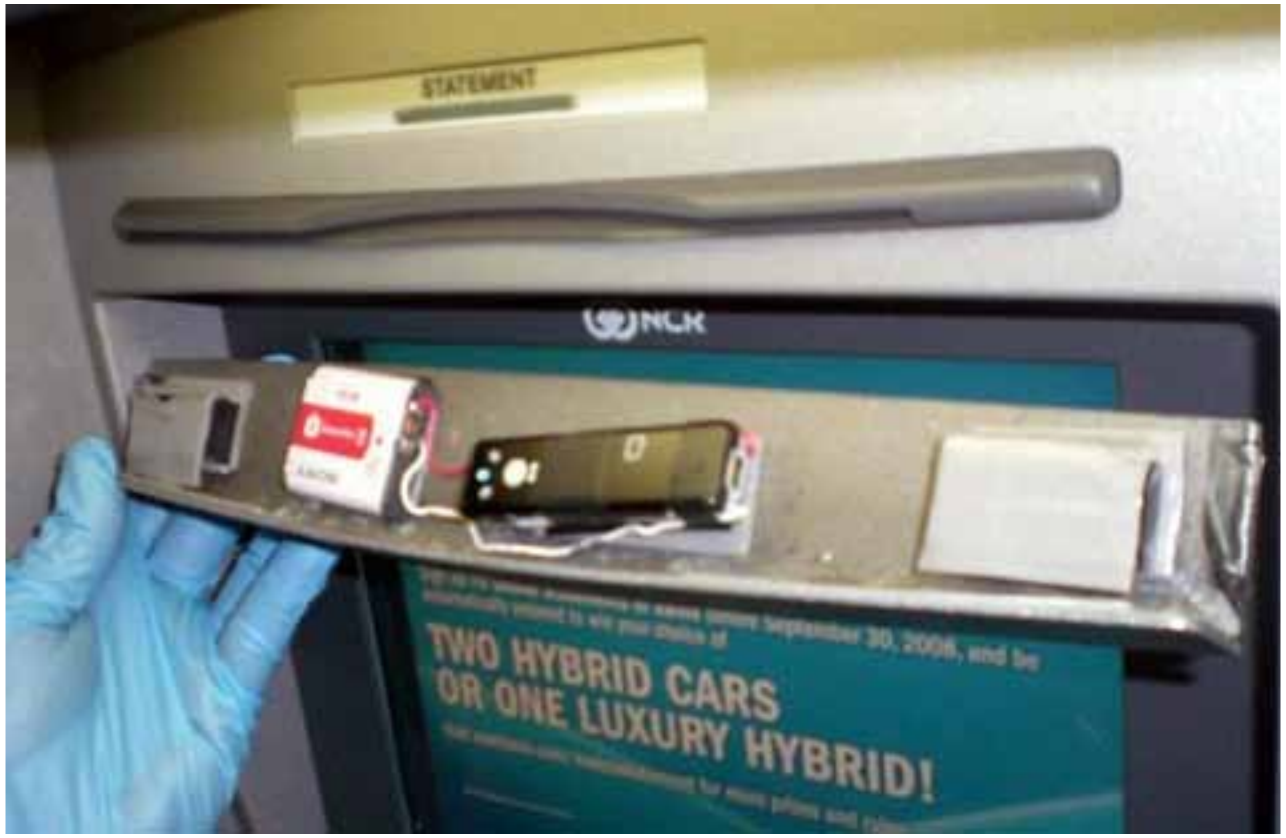
1 Keypad overlays capture PIN numbers on a memory chip.

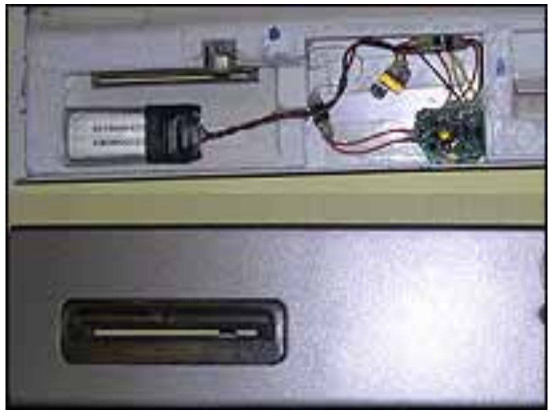
2 Hidden cameras can also copy customers' PIN numbers.

3 Skimmers are placed over the card reader to copy the card's magnetic stripe. These are often legal credit card readers.

Sources: about.com, networkworld.com, ATM Parts & Services

BALTIMORE SUN GRAPHIC: LAMONT W. HARVEY

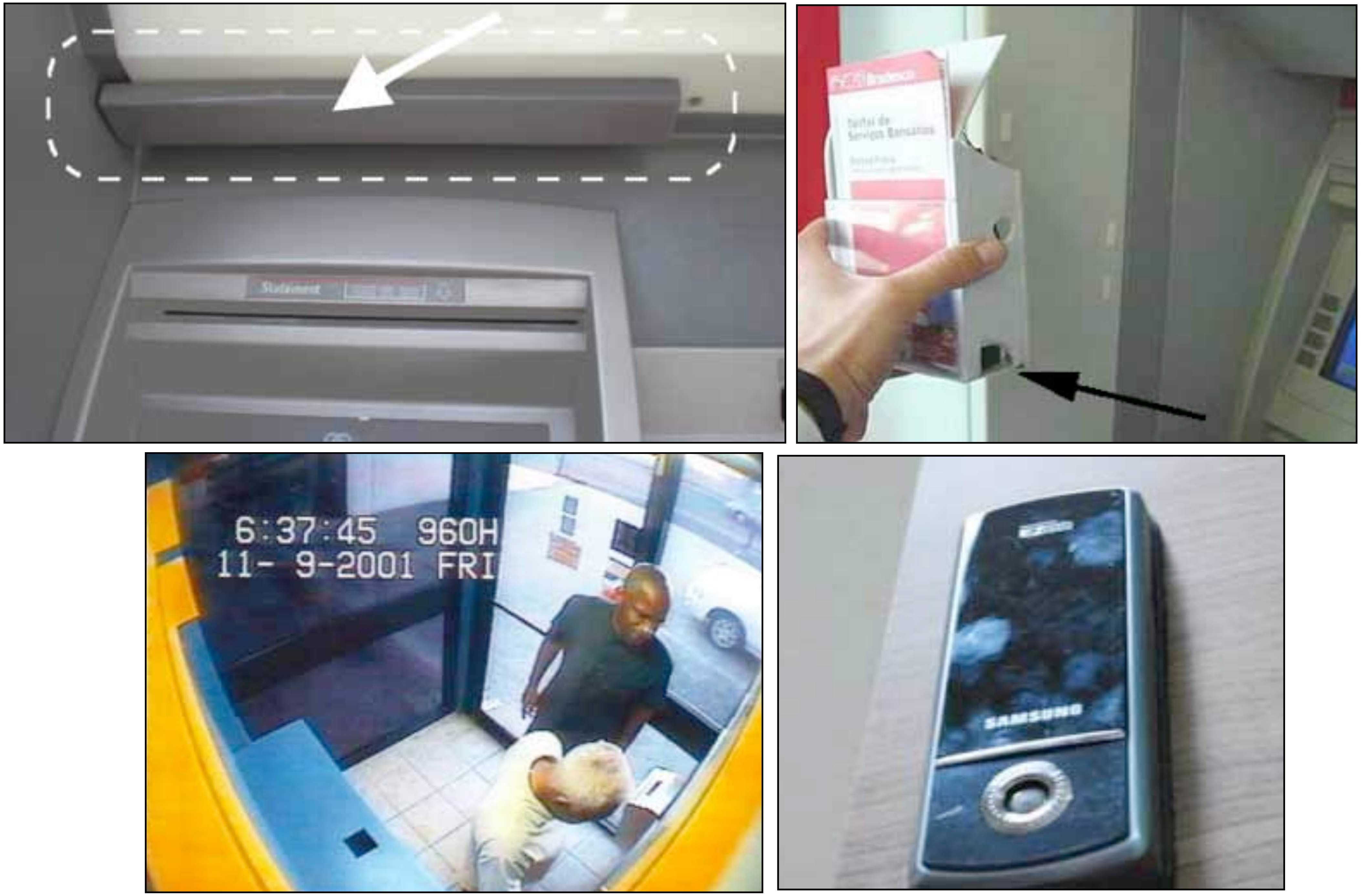




Skimming a terminal

PUBLIC THREAT

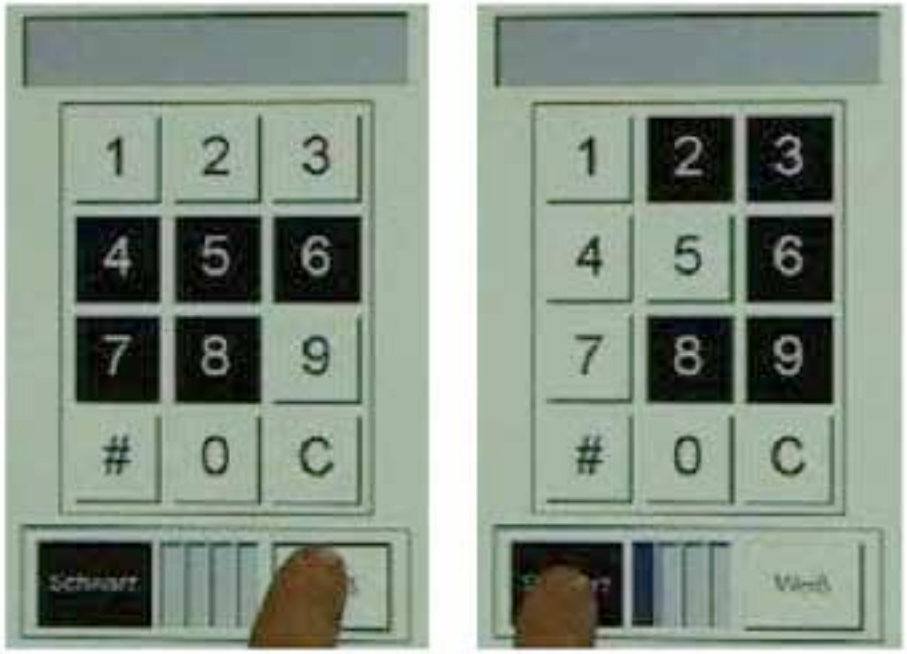
1. Public terminals **dangerous**



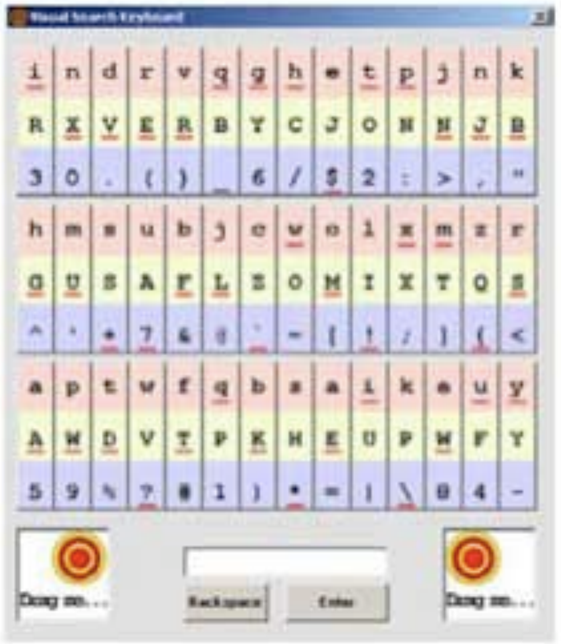
Camera, Observation, Tamper

PINS IN PREVIOUS WORK

Different people want different password schemes or input methods

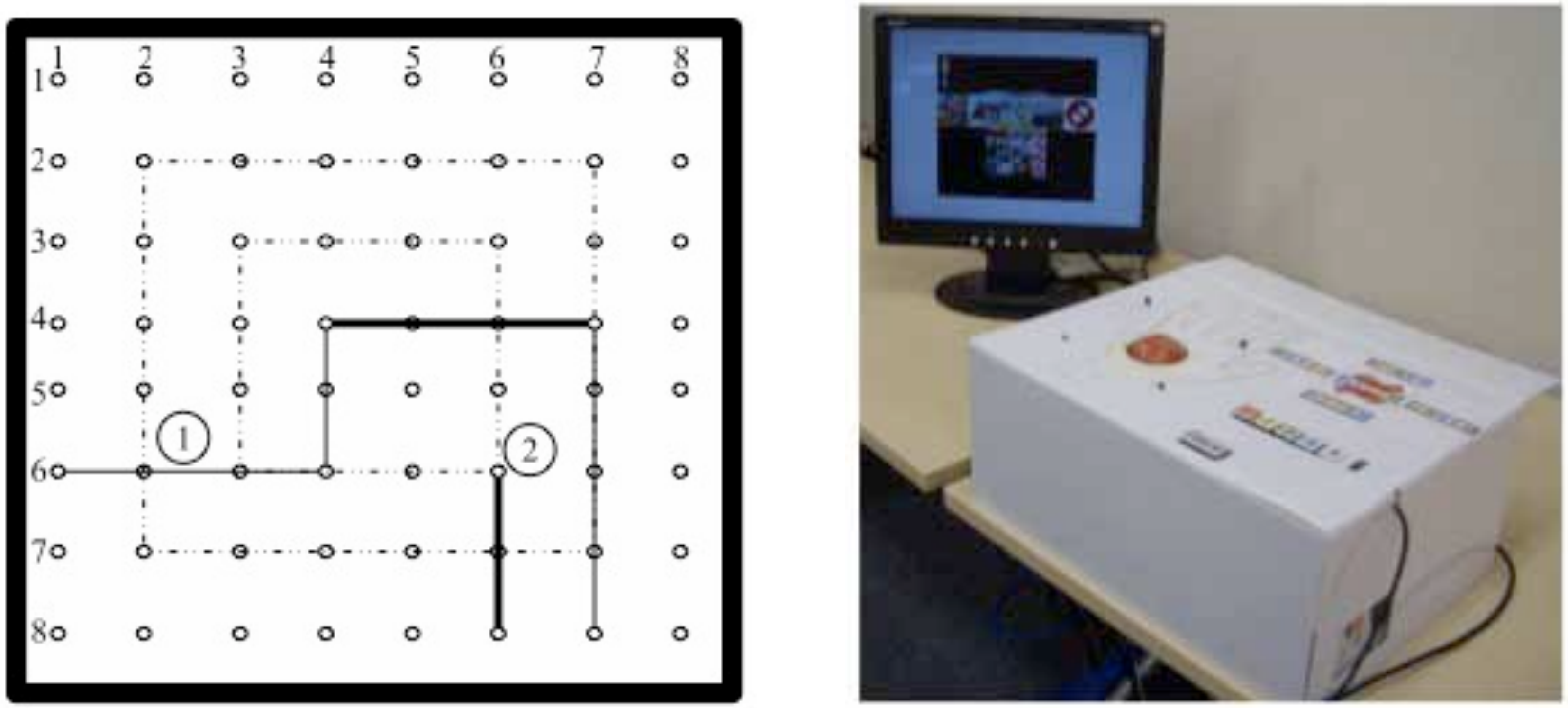


PIN Entry by trapdoor game (**Roth et al.**)



Spy-resistant Keyboard (**Tan et al.**)

Gaze-Based Password (**Kumar et al.**)



Haptic Passwords by Malek and Sasamoto

PINS IN THE REAL WORLD

Despite all these new methods we still rely on keypads!

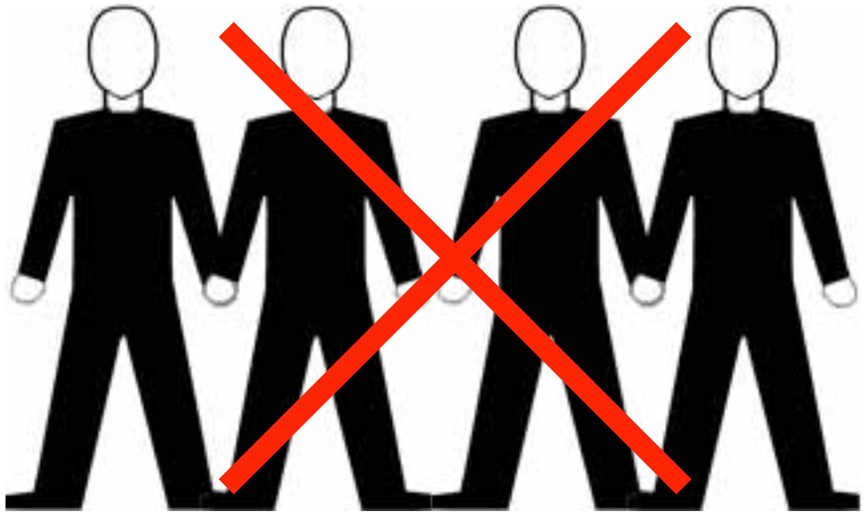
BASIC CONSIDERATIONS

We need to access public terminals, **but** it does not mean that

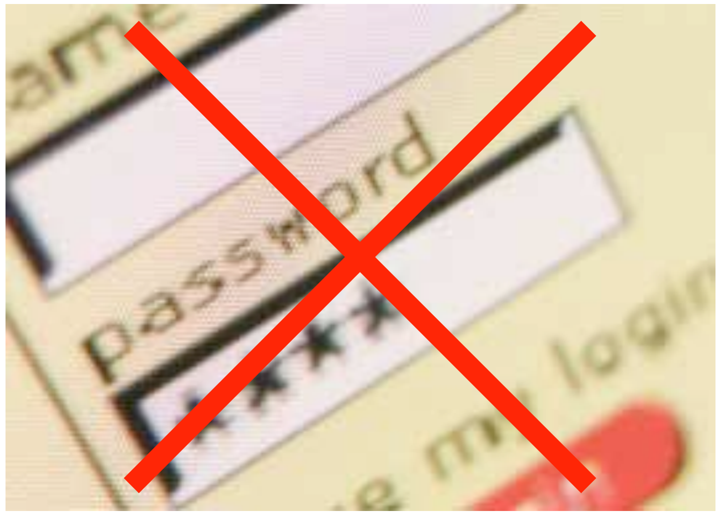
the interaction **must be the same for all of us**

the interaction **must be limited to the default interface**

and the interaction **must be done at the terminal**



DIFFERENT PASSWORDS FOR DIFFERENT PEOPLE AND DIFFERENT SITUATIONS



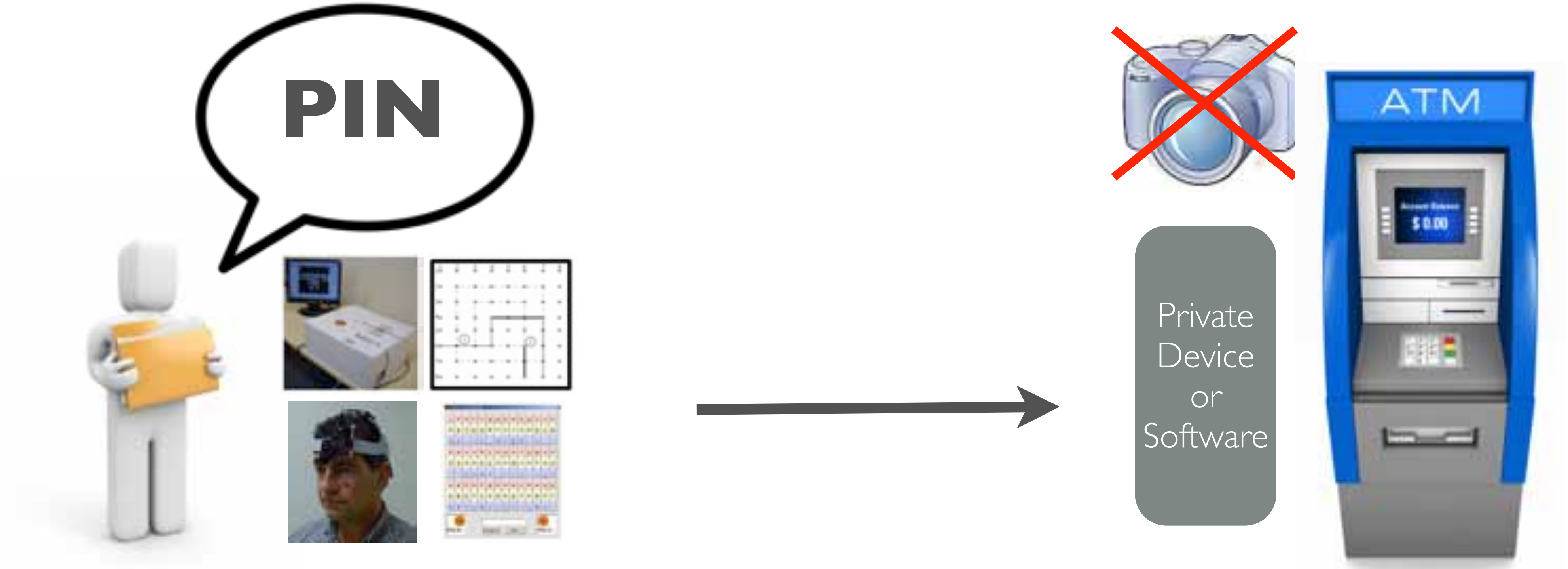
ONLINE INTERFACE SECURITY IS ONLY A MINIMUM STANDARD

INTERACTING AT THE TERMINAL IS DANGEROUS

STRATEGY SHIFT

Before

After



Private Device or Software

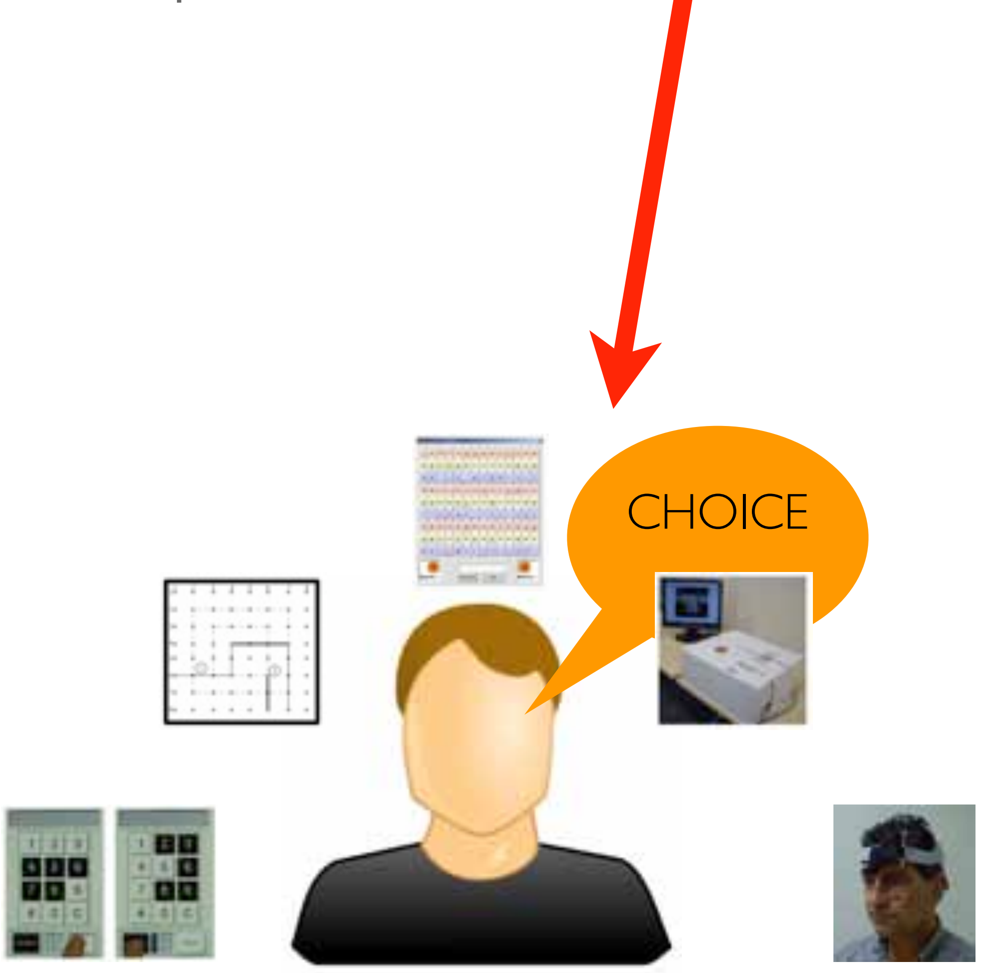
CHOICE

MEDIATED INPUT

STRATEGY SHIFT

An alternative strategy is to ***decouple*** interaction in two parts:

we separate the **input** method for a PIN from the **communication** of the password to a terminal.

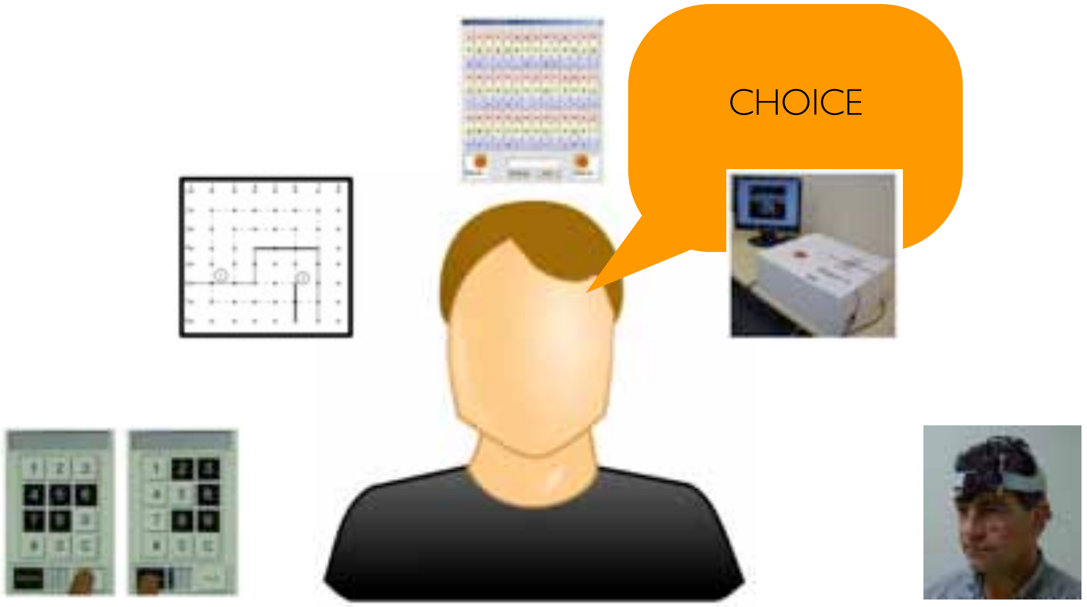


CHOICE

MEDIATED INPUT

PART I

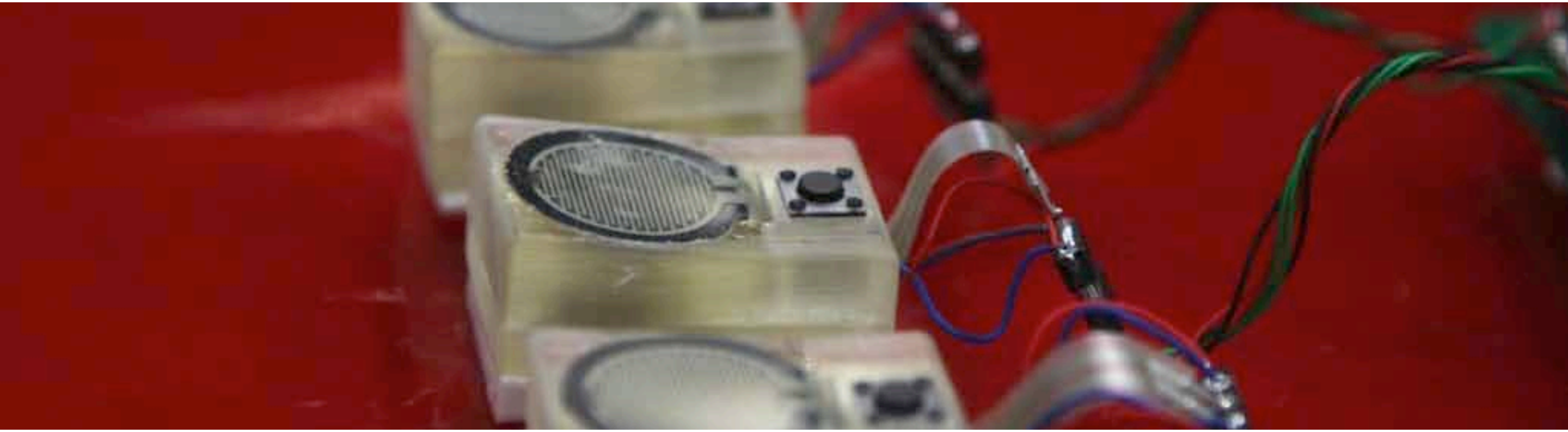
THE ENEMY WITHOUT: PROTECTED PHYSICAL KEY ENTRY METHODS FOR UNTRUSTED ENVIRONMENTS



CHOICE

The Secure Haptic Keypad

A Tactile Password System



Bianchi, A., Oakley, I., Kwon, D.S., The Secure Haptic Keypad: Design and Evaluation of a Tactile Password System.
In CHI 2010, ACM, New York, NY, pp. 1089-1092.

The Problem: Observation Attack

Authentication in public spaces is common

ATMs, entry door systems, quick flight check-in kiosks, etc...

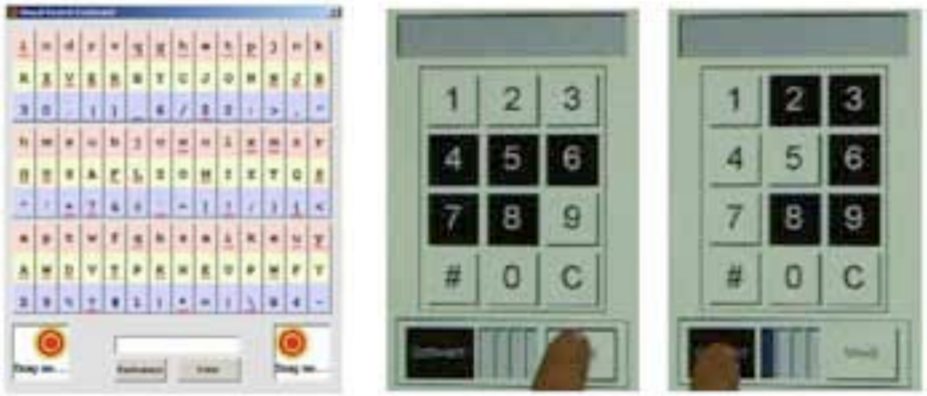
Stolen PINs pose a significant risk to many systems

U.S. estimated yearly bank fraud amount s $60M

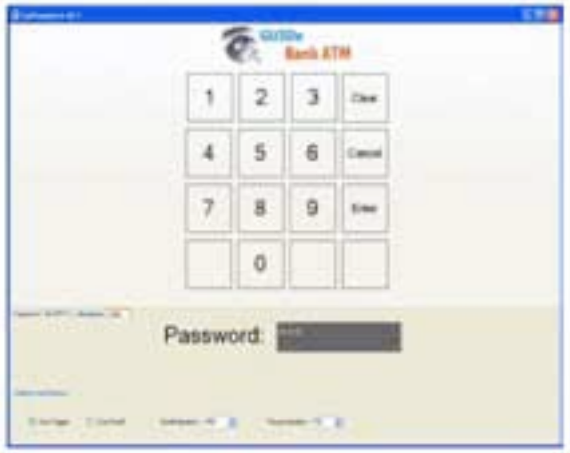
➡ Observation attack: “Shoulder-surfing” or “Camera-attack”

Related Work

1. Visual Obfuscation



2. Eye Tracking

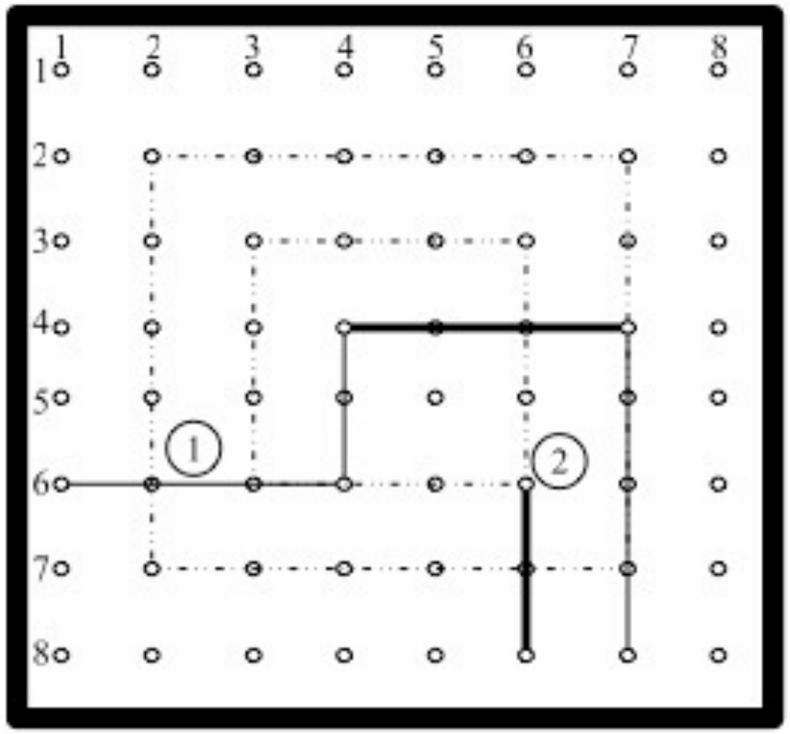


3. Personal Interfaces

4: Haptic Obfuscation

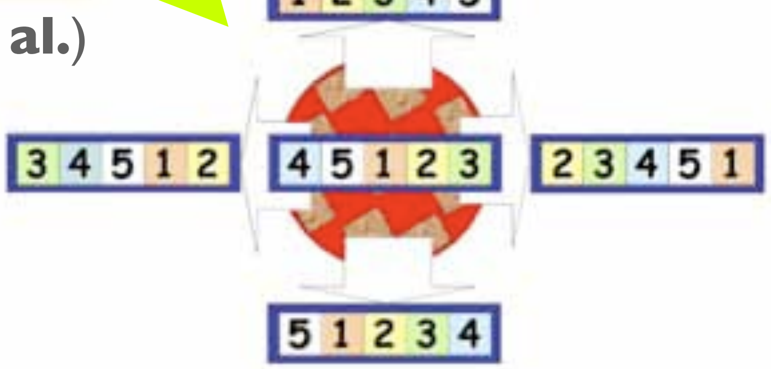
Multimodal systems: password information (i.e. textual and graphical passwords) can be obfuscated using haptics, as an invisible channel.

Relies on a cognitive transformation/mapping.



Haptic-based Graphical Password (**Malek et al.**)

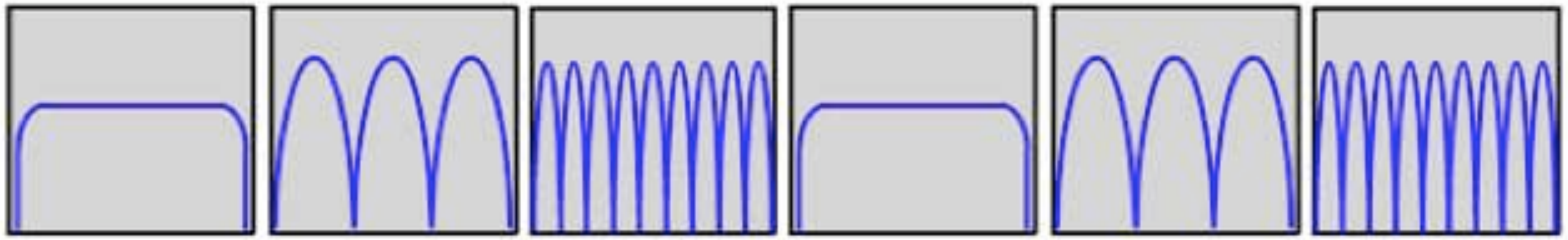
Undercover (**Sasamoto et al.**)



The idea: Haptic Password

System

Haptic password

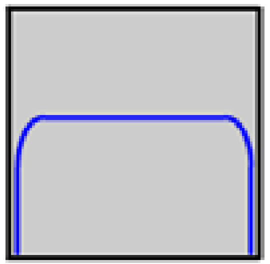


A sequence of **tactile cues** (tactons), inherently **invisible** to everyone.

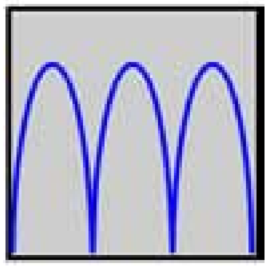
Password Model

Passwords in the system take the form of a sequence of tactile feedback in the forms of vibrations (from a set of 3 possibilities)

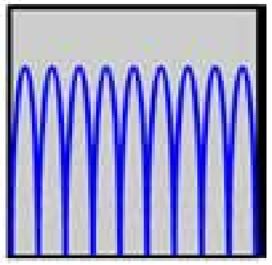
Our 3 Tactons



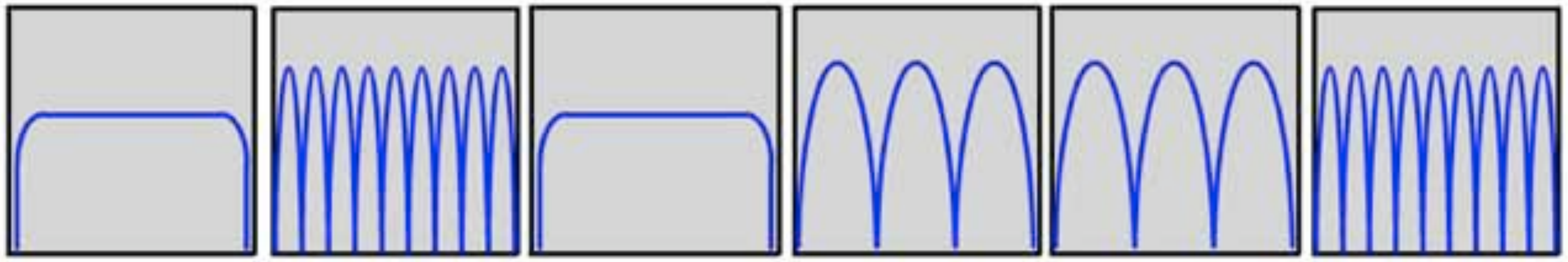
Continuous



1 Hz

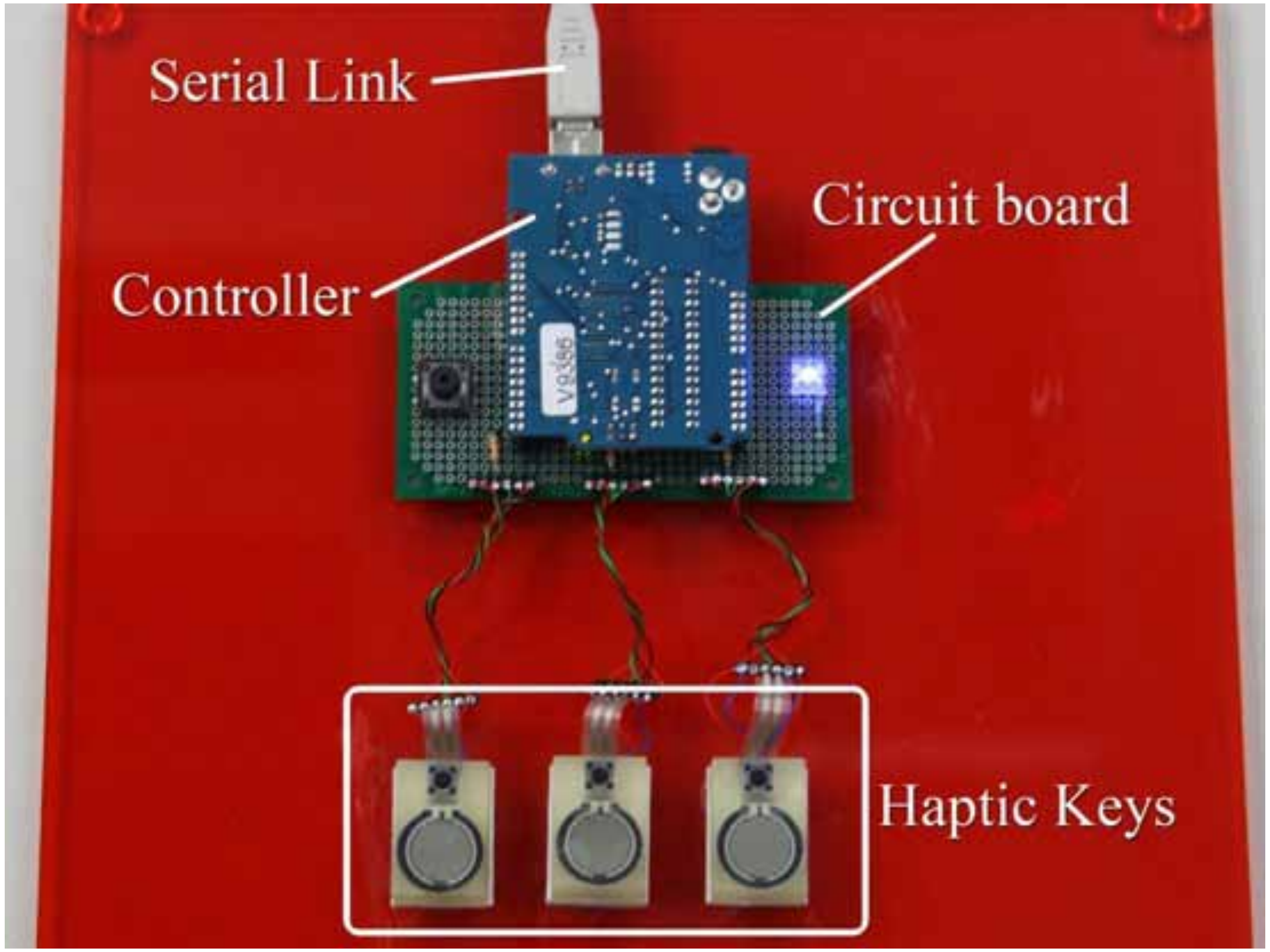


2 Hz



Example of Haptic Password **made of 3 tactons**

Haptic Keypad Overview



Keypad constructed of three physically independent buttons each capable of (1)sensing finger input and (2)rendering vibrotactile cues in the form of tactons and (3)accepting input selection.

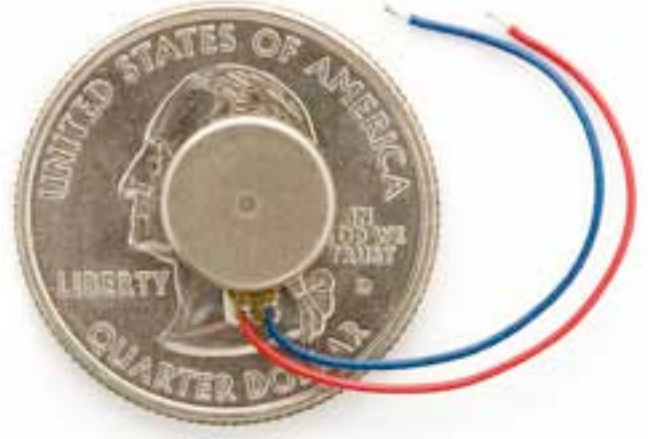
Haptic Keys

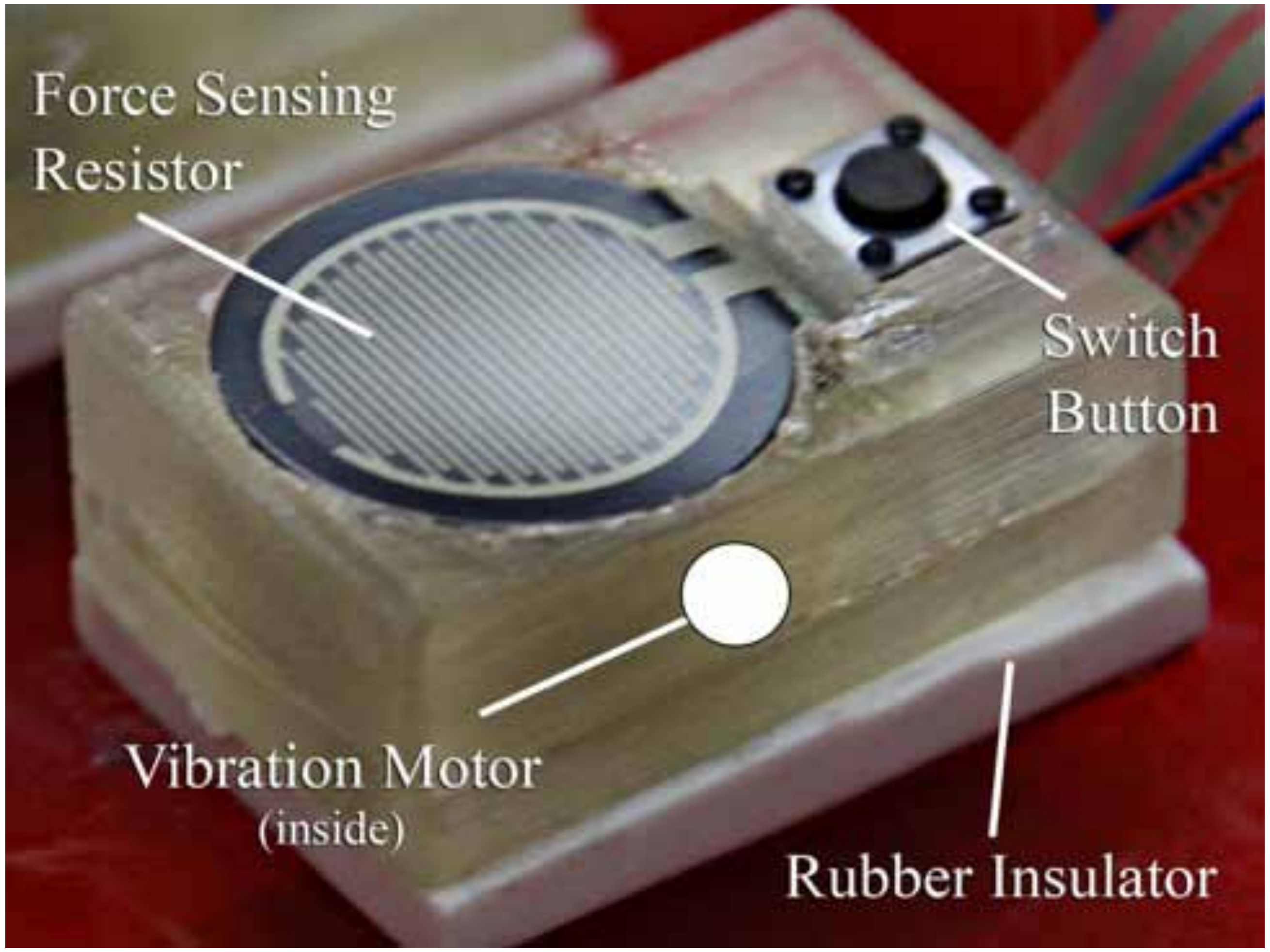
Three *identical* hardware:

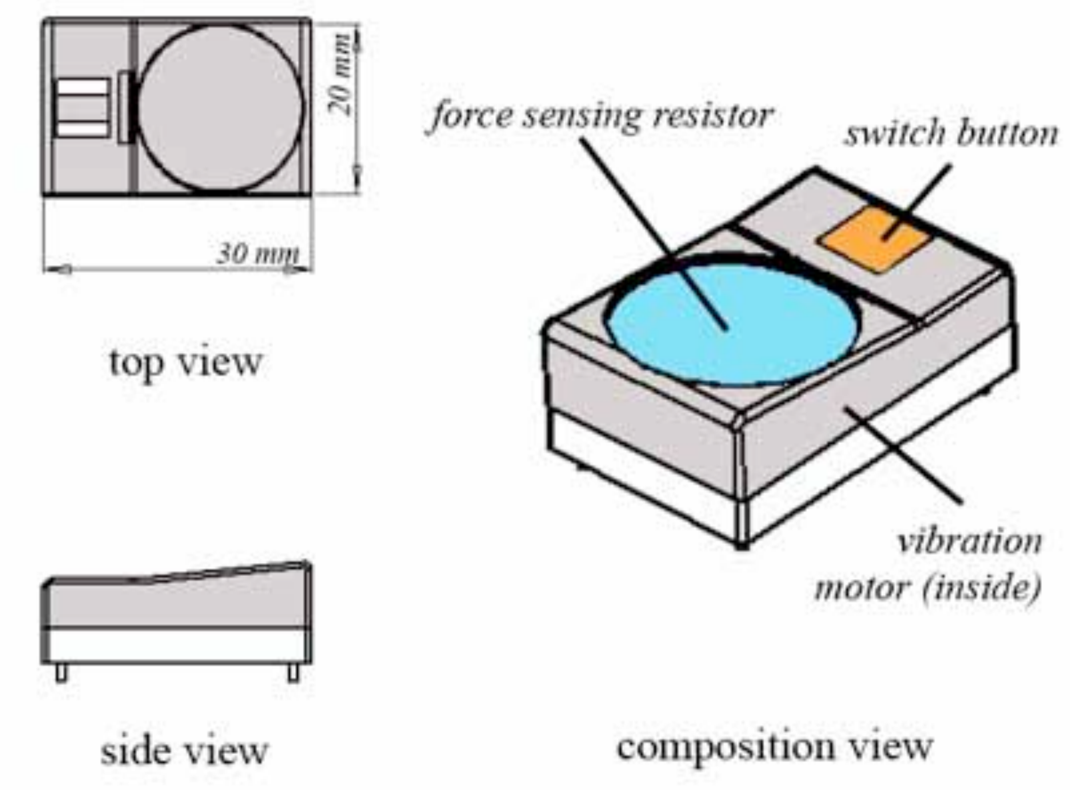
(1) force sensing resistor (FSR) adjust the strength of the vibrotactile output

(2) linear coil vibrotactile actuators within the casing

(3) physical switches for key selection

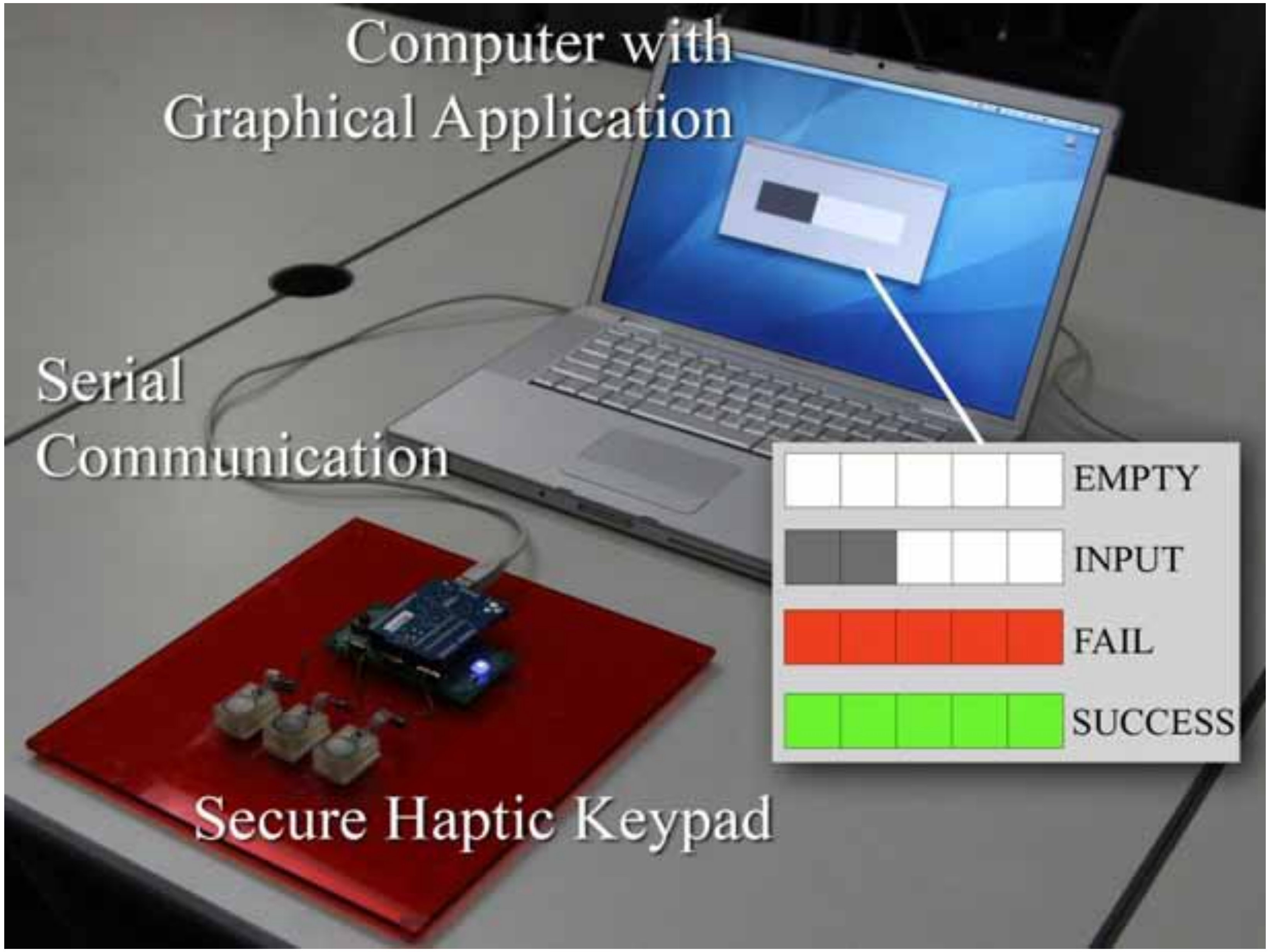






The Password Software

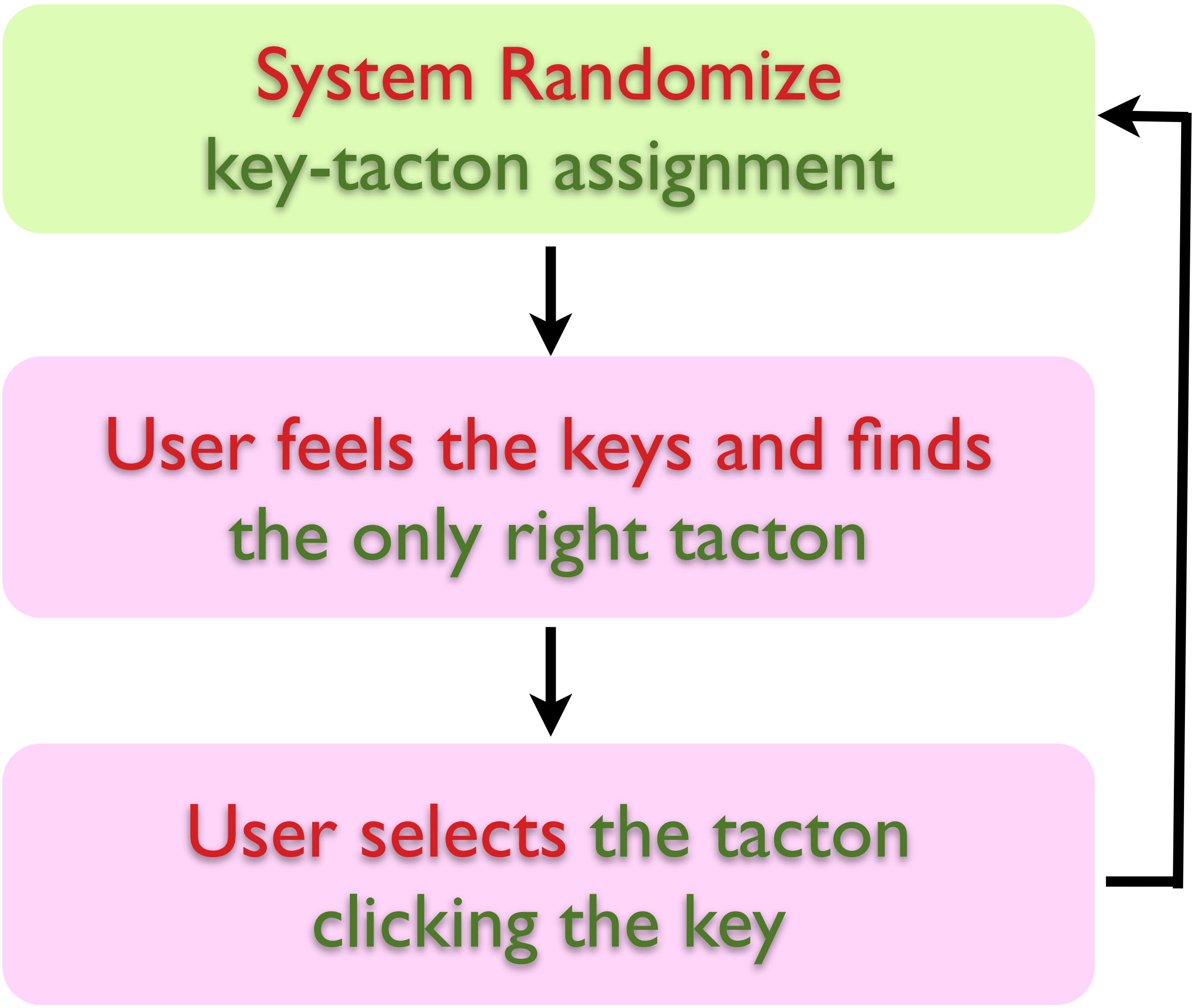
1. AVR micro-controller handles sensing, rendering and input.
2. The Haptic Keypad is connected to a computer via serial port.
3. Minimal GUI represents only completion progress



Interaction Model

Rules:

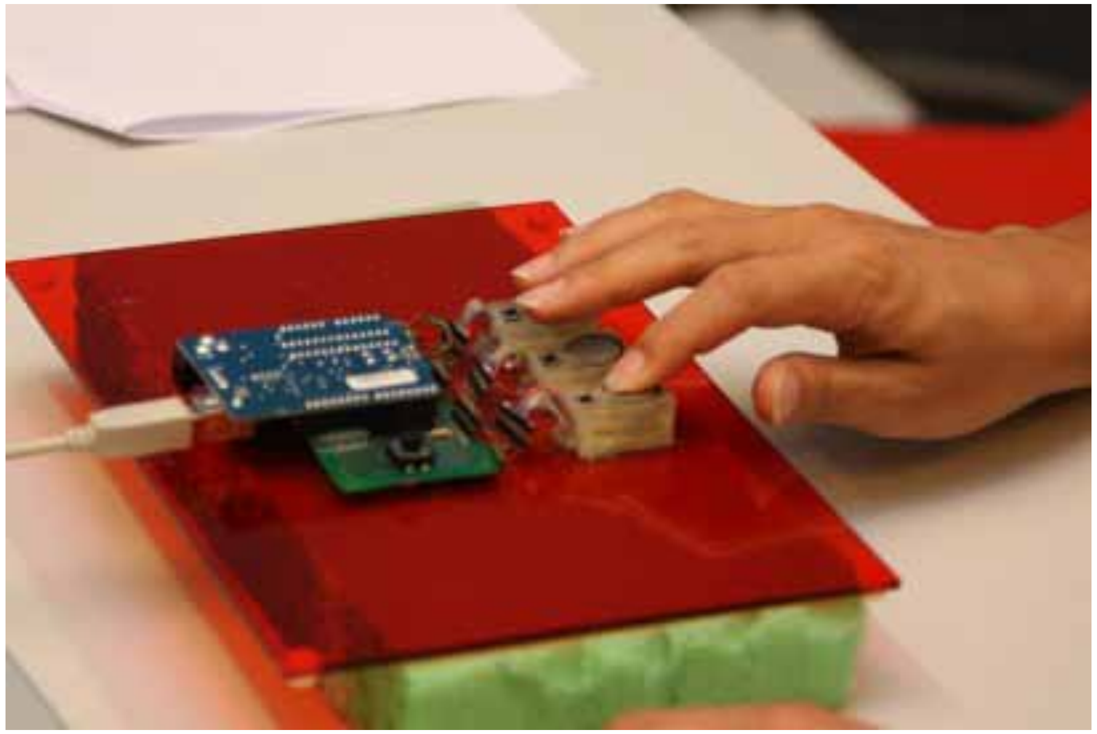
- 3 tactons are assigned to 3 keys (1<->1 correspondence)
- Tactons are randomized on keys after each entry.

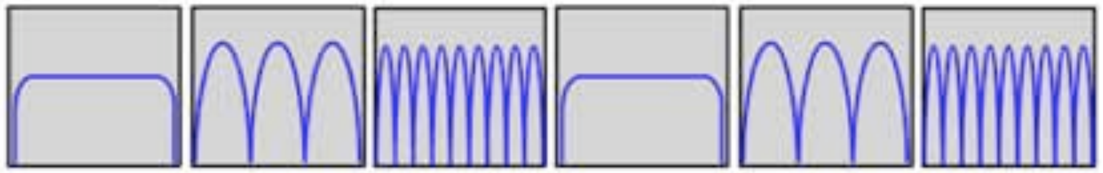


System Randomize key-tacton assignment

User feels the keys and finds the only right tacton

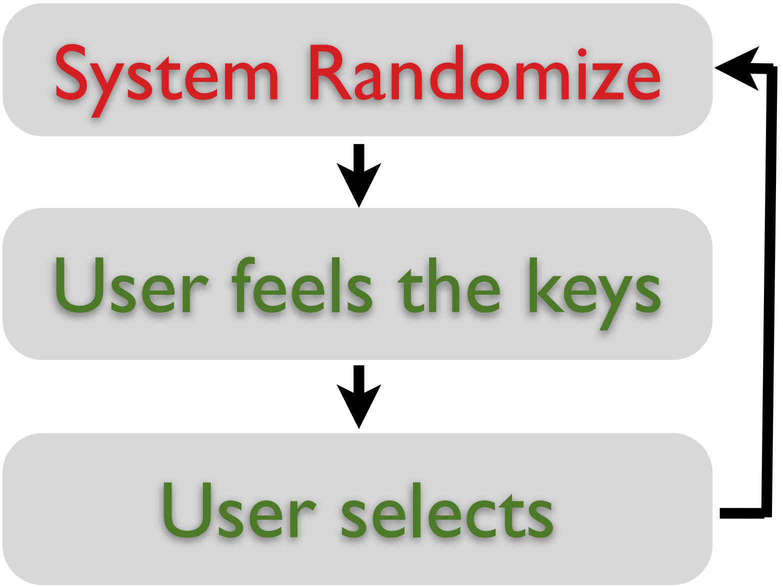
User selects the tacton clicking the key





Match **input** with **password**

Example of Interaction

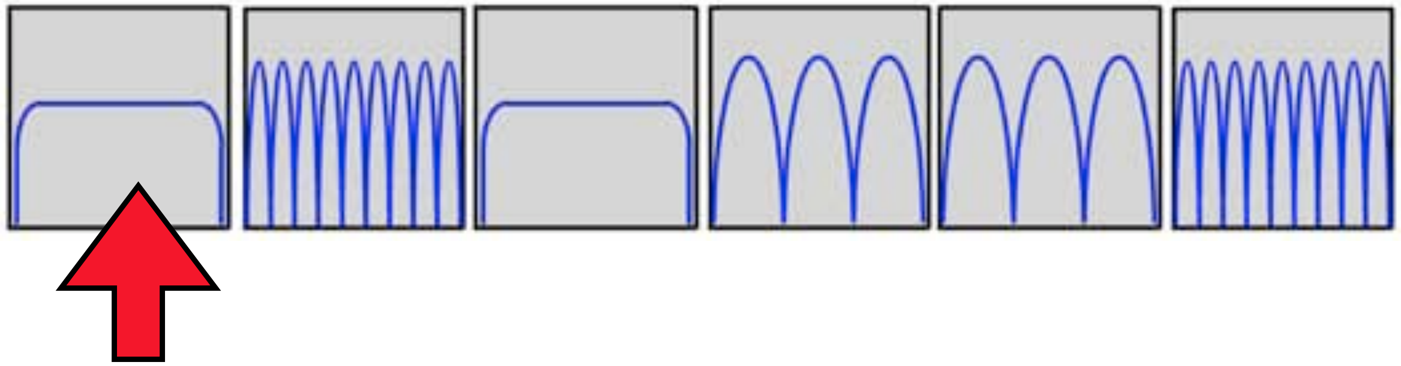


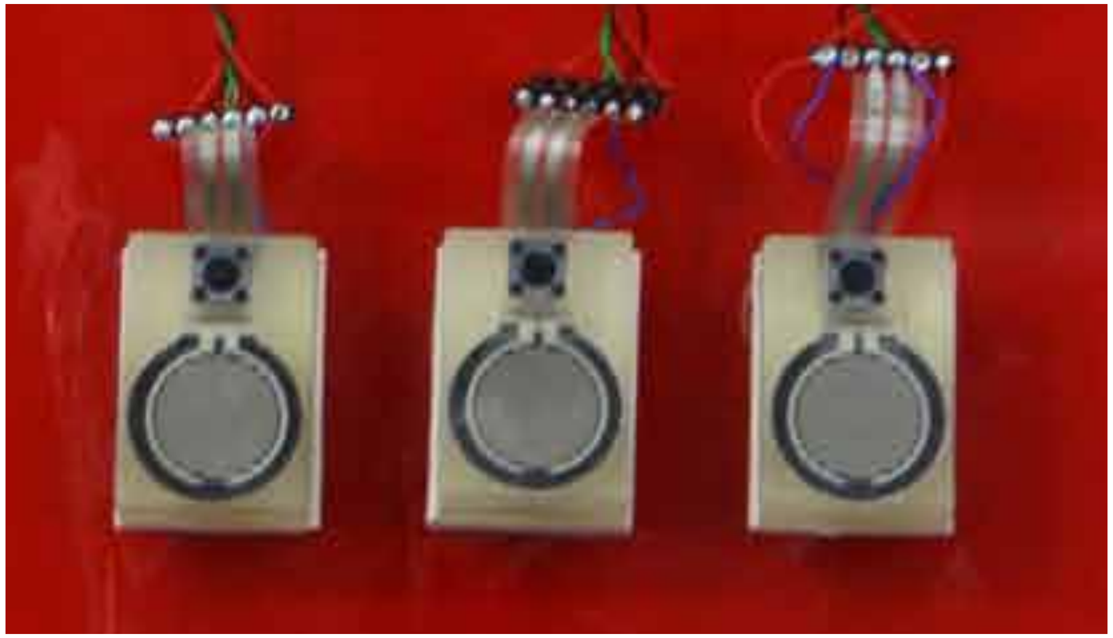
System Randomize

User feels the keys

User selects

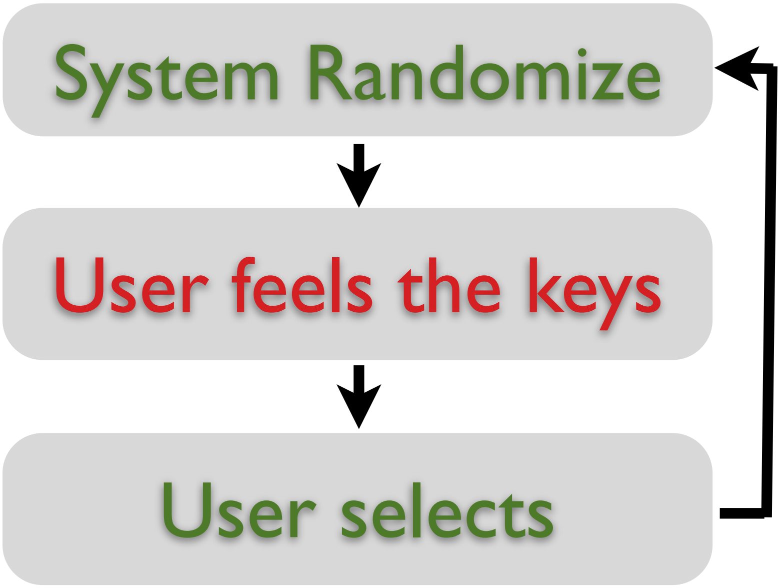
Password To match





With no interaction keys are silent

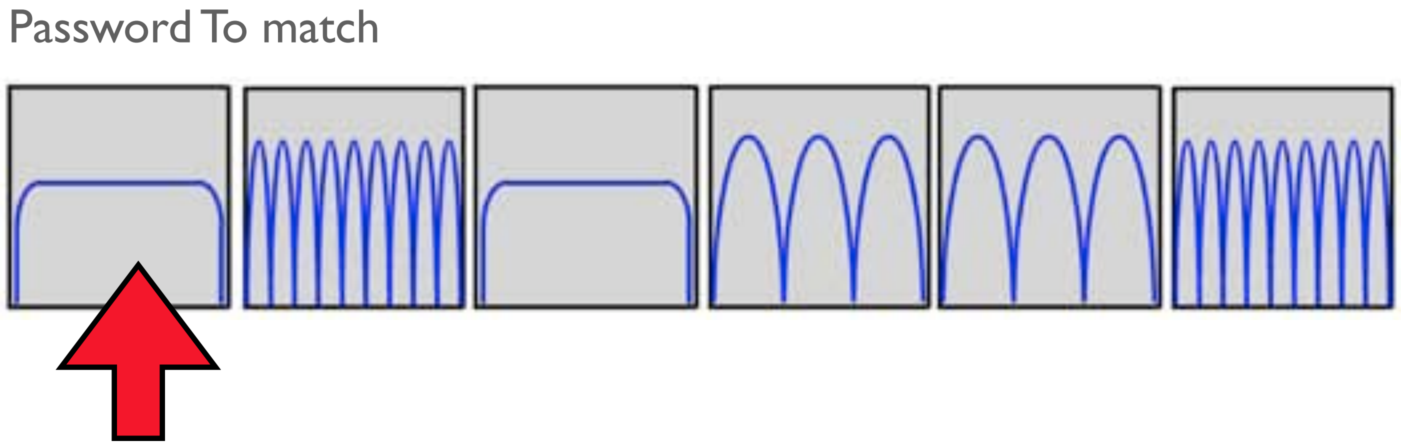
Example of Interaction

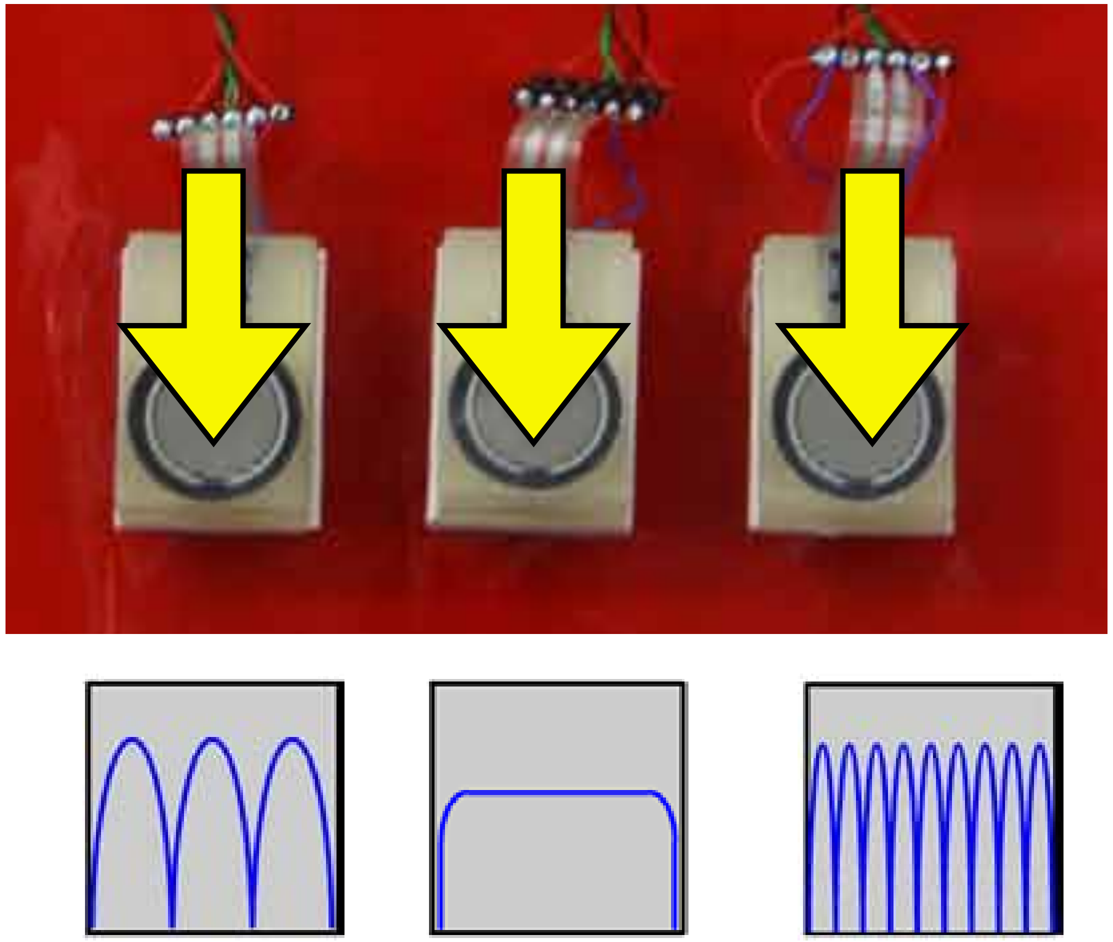


System Randomize

User feels the keys

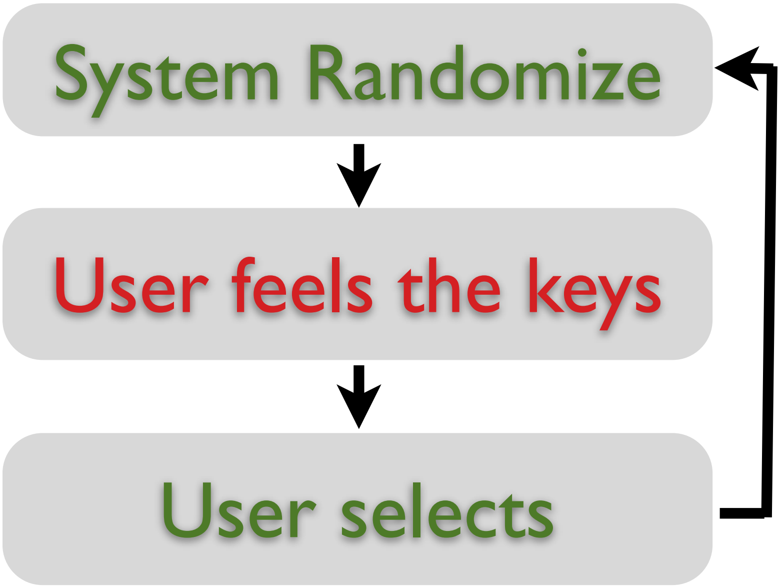
User selects





Press the FSRs to “feel” the tactons

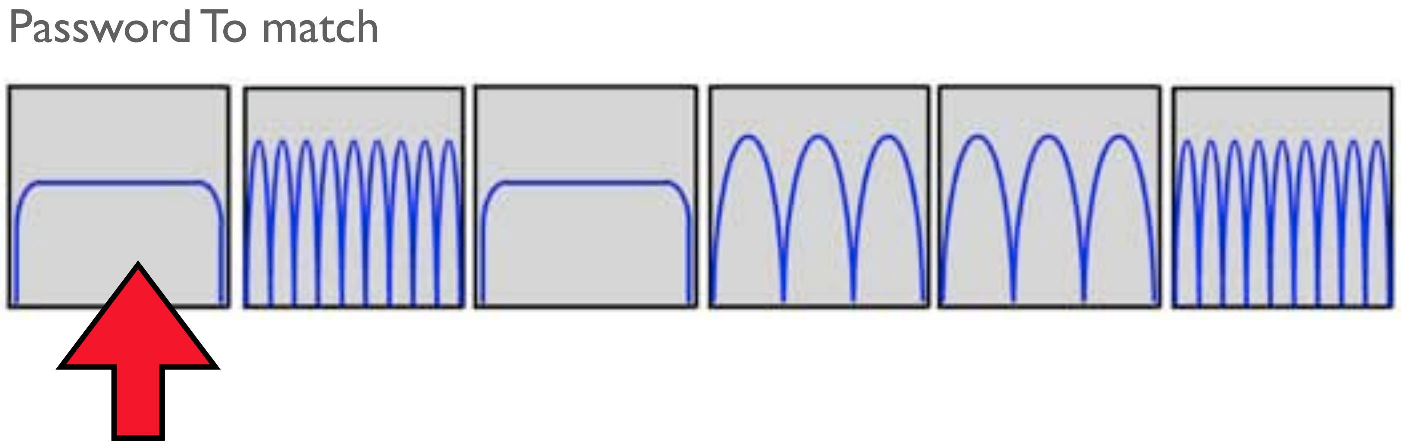
Example of Interaction

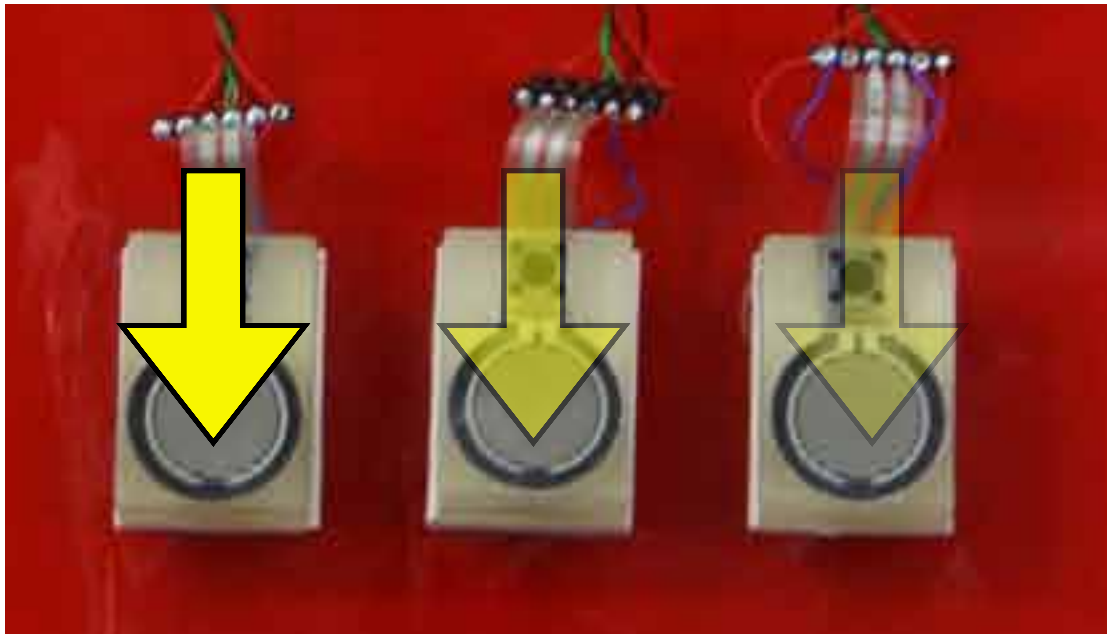


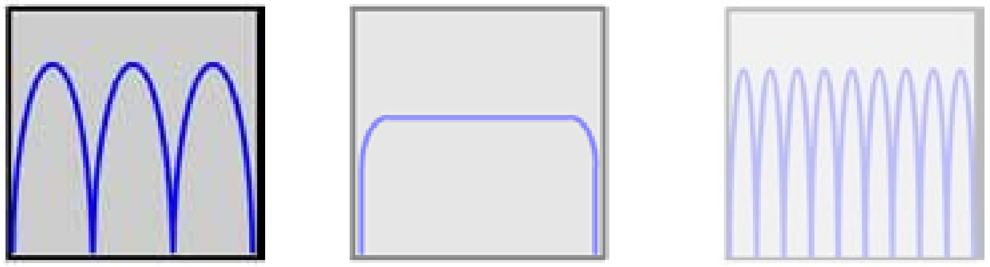
System Randomize

User feels the keys

User selects

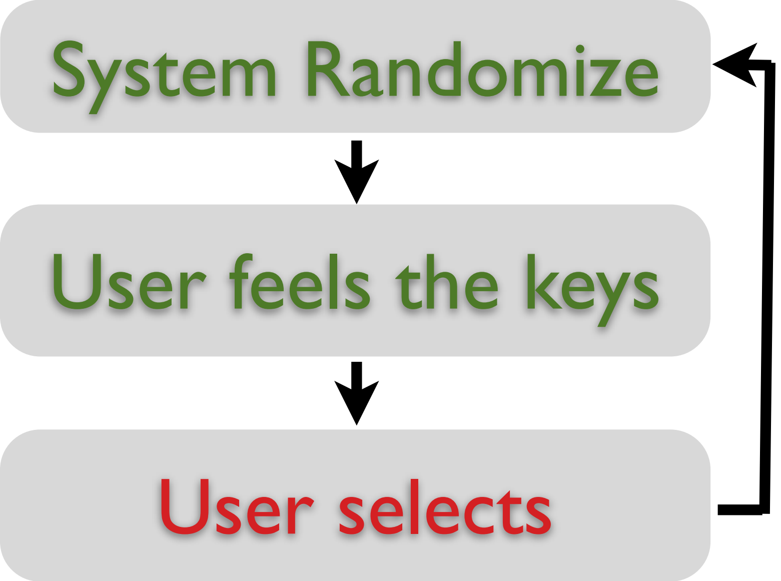






The “strength” of the tacton depends of the pressure applied

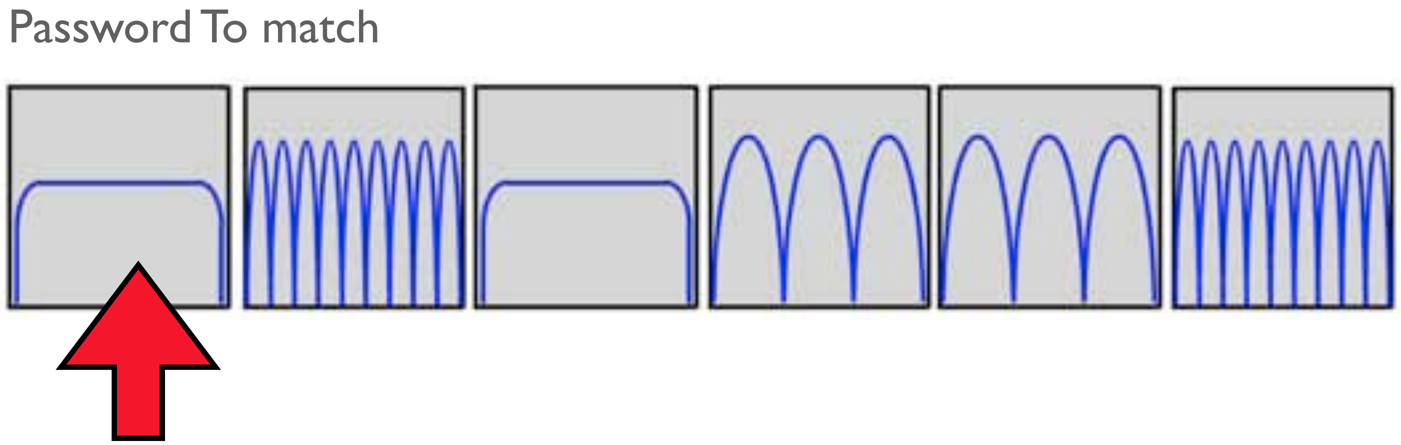
Example of Interaction

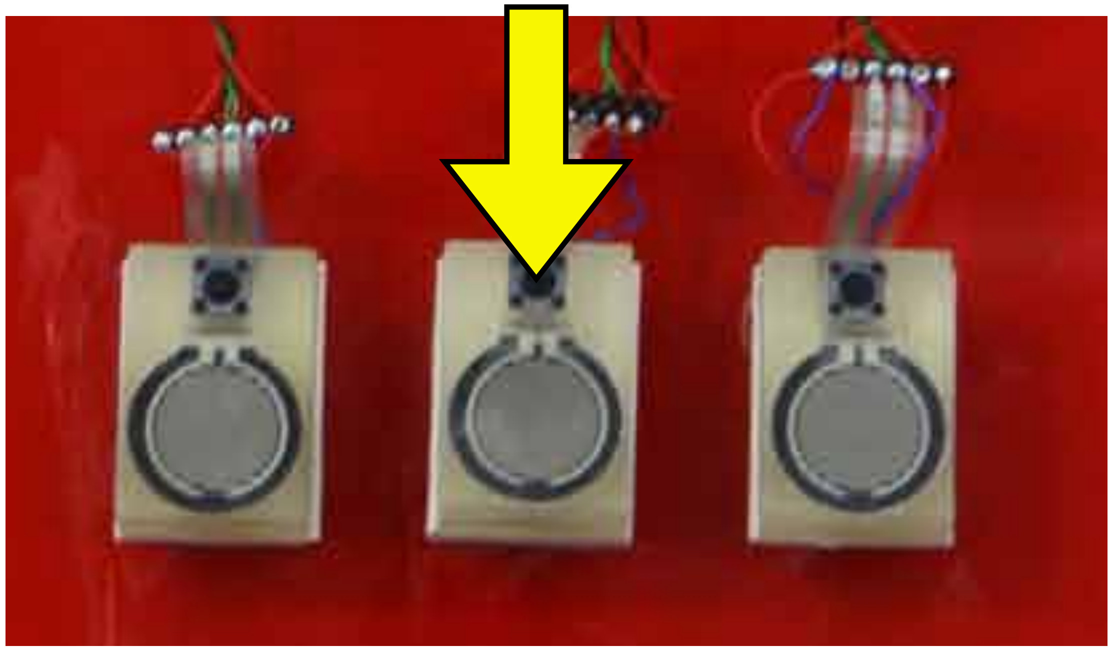


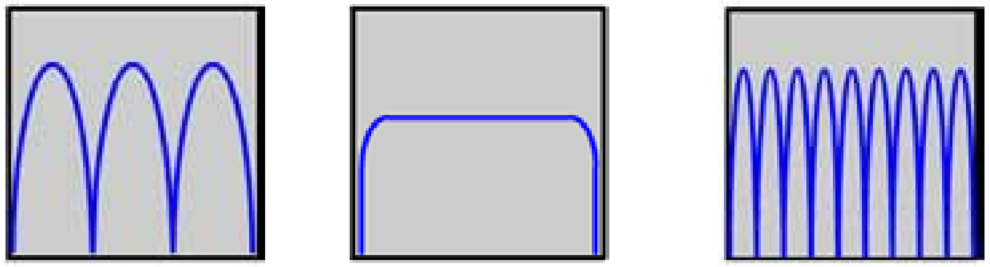
System Randomize

User feels the keys

User selects

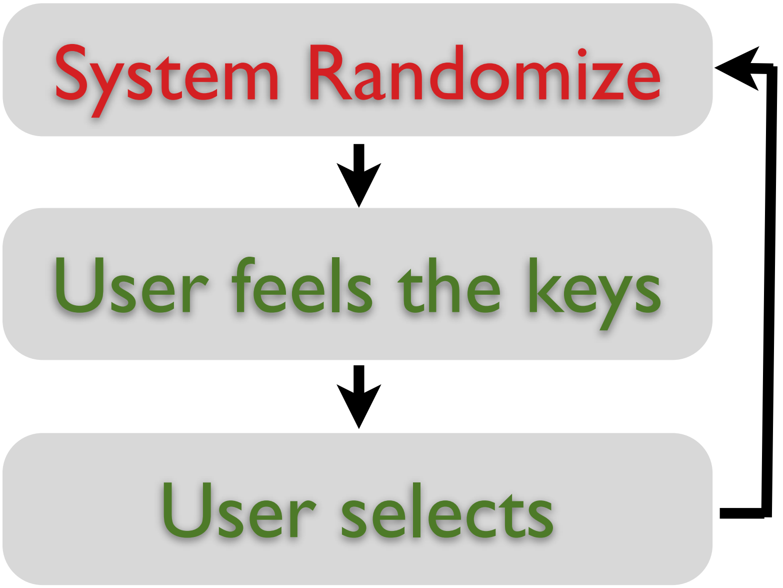






Click the button to apply selection

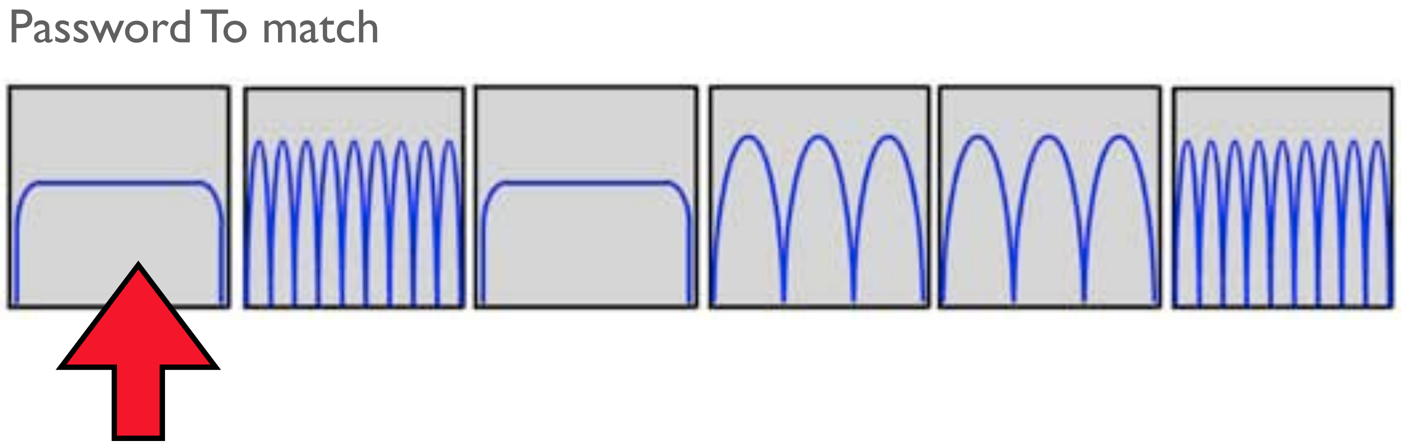
Example of Interaction

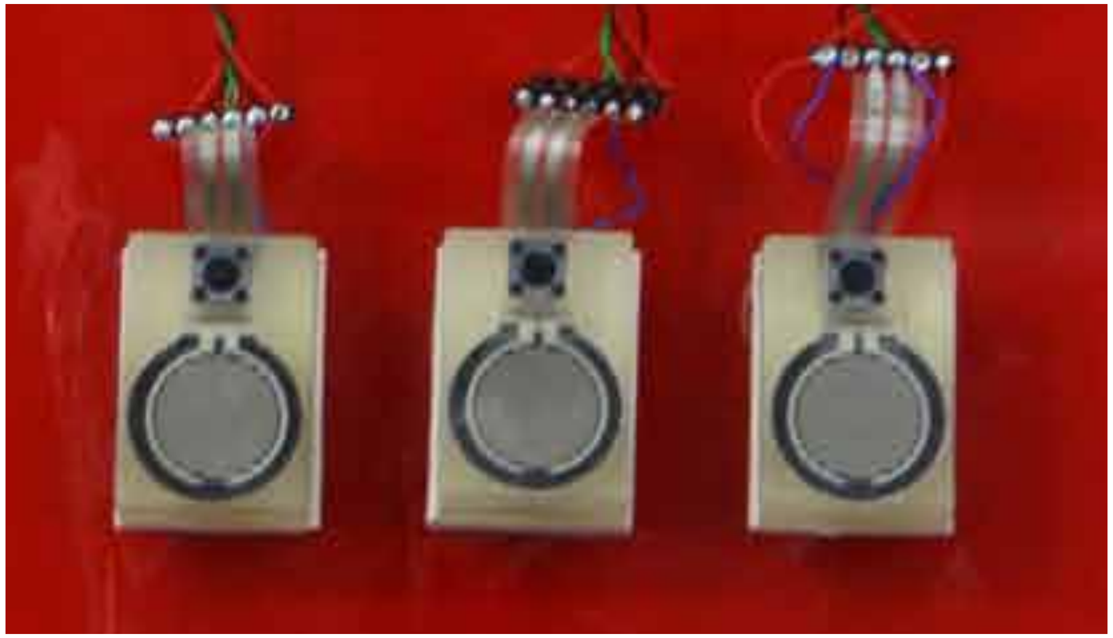


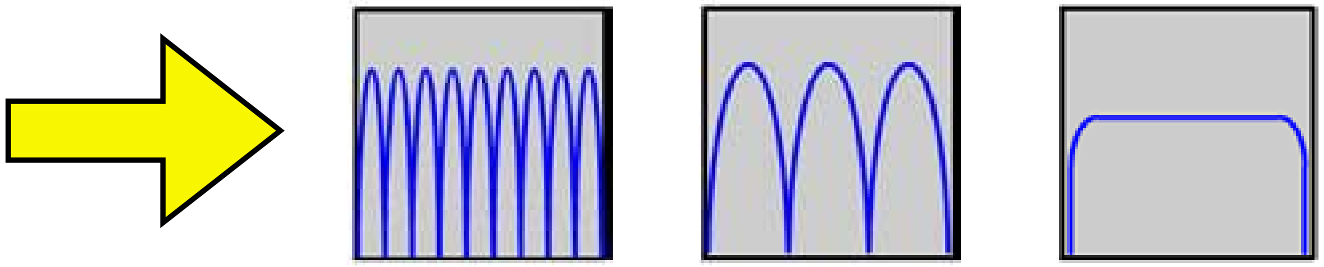
System Randomize

User feels the keys

User selects

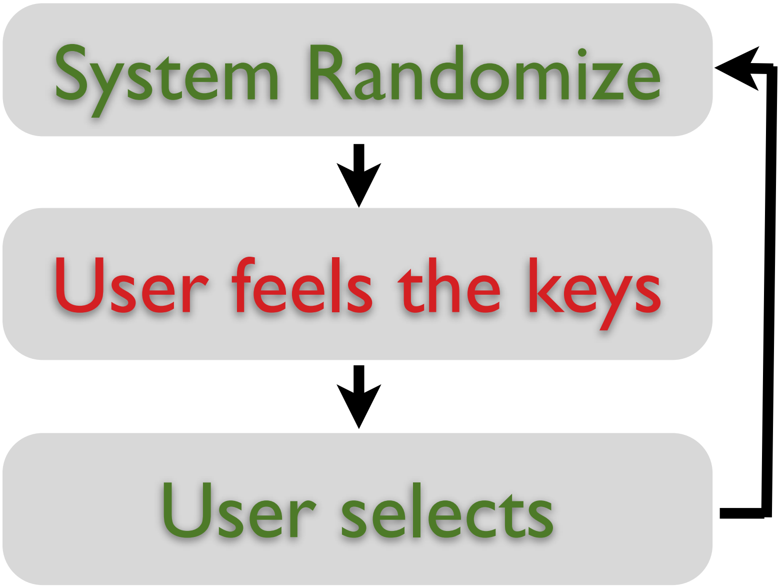


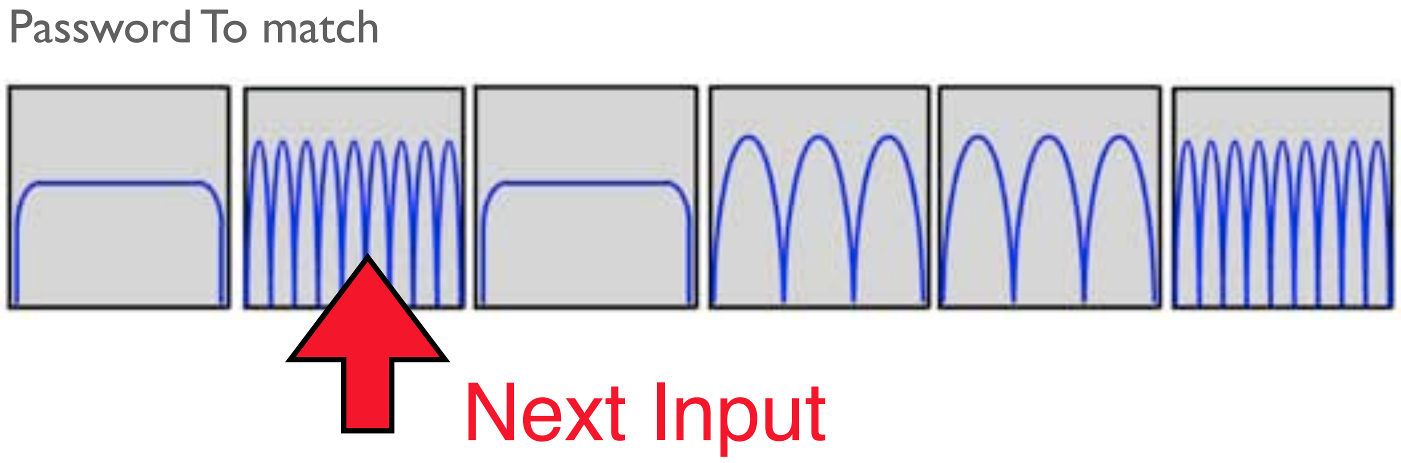


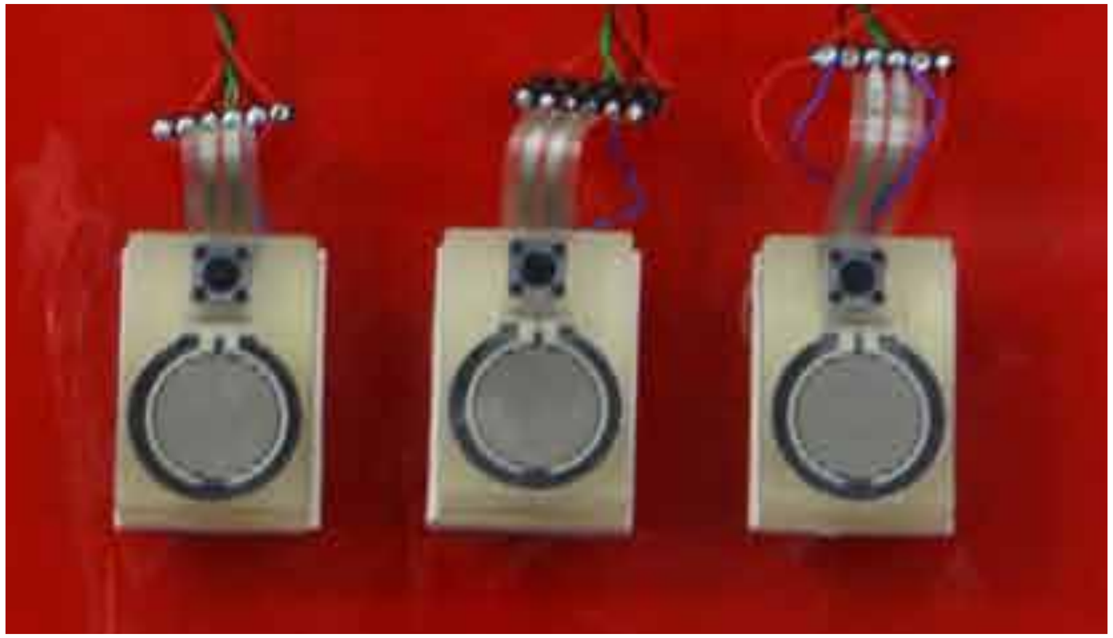


The tactons are randomly re-assigned to the keys

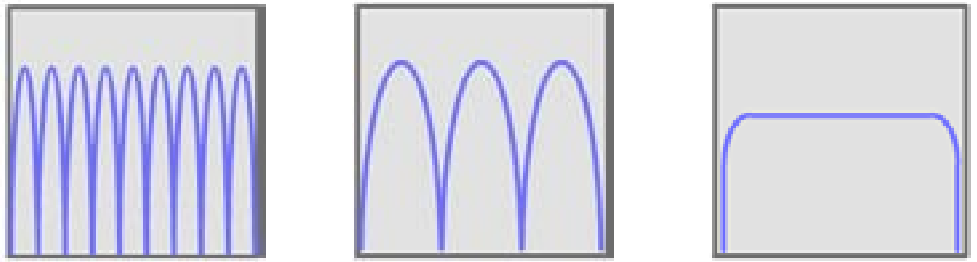
Example of Interaction





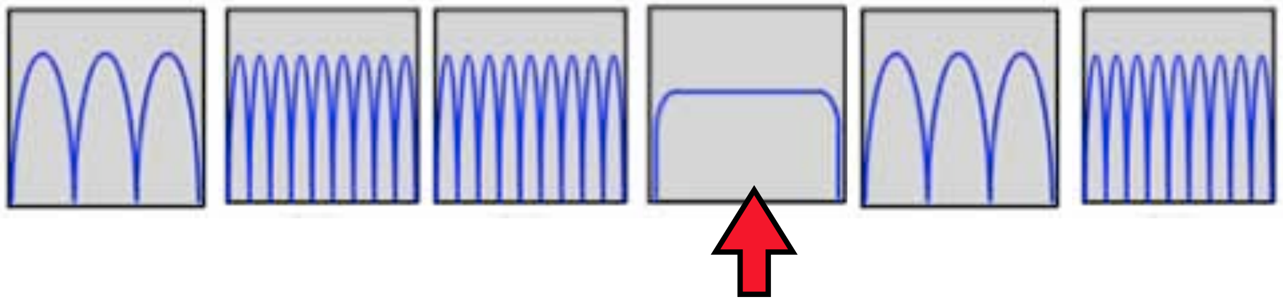


Keep going on until done.

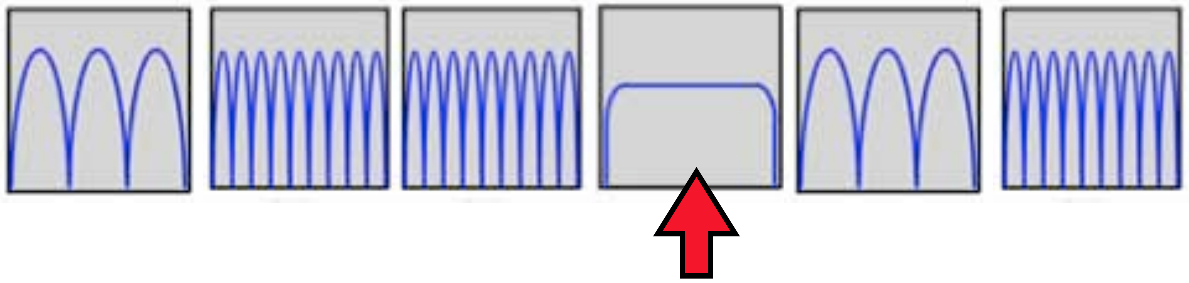


Example of Interaction

Password to Match

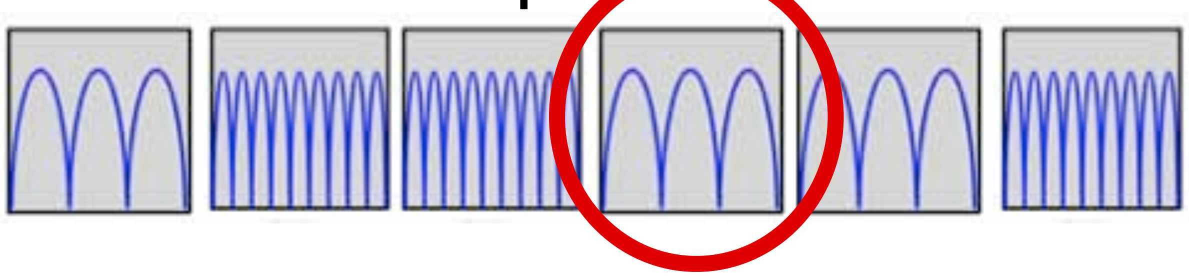


Case 1: User Input



AUTHENTICATION SUCCESSFUL

Case 2: User Input



AUTHENTICATION NOT SUCCESSFUL

Security Objective

p(brute-force attack) = p(observation attack)

resilience to observation and brute-force attacks.

$$p(attack) = \left(\frac{1}{3}\right)^{pin}$$

Security Standard:

4 digit numerical password

p(attack)= 1/10000

Evaluation: 2 studies

To gauge our interface we conducted 2 experiments

Pilot Study

Test tactons recognition rate

Evaluate if tactons are perceptually distinct

User Study

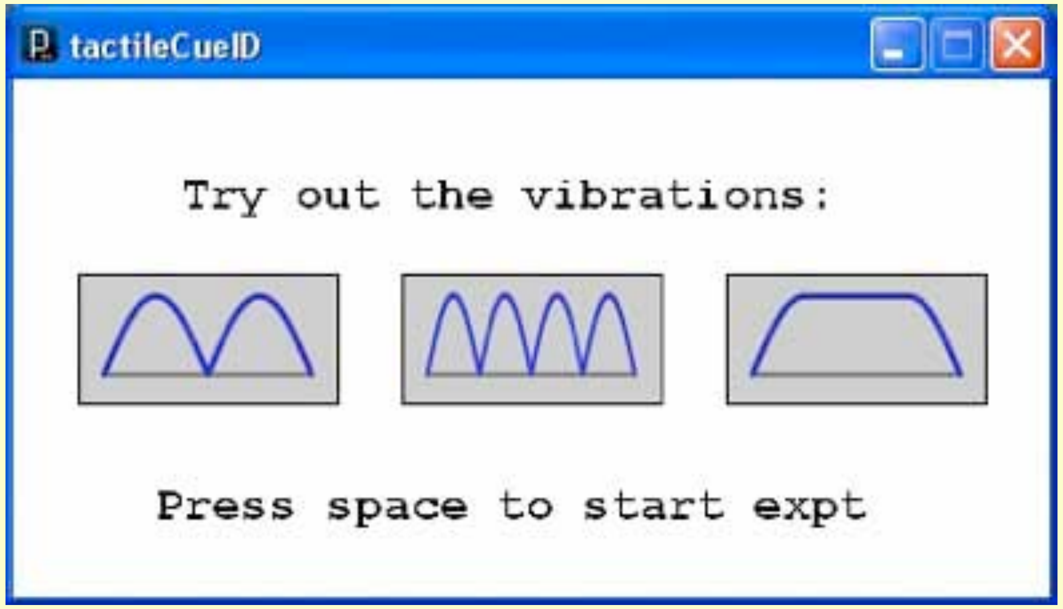
Evaluation of 3 software interfaces with the same hardware (Haptic Keypad)

Compare extreme authentication schemes to obtain some insight.

Experiments Design

Pilot Study

- Tacton recognition rates and times
- 4 participants
- Simplified version of the hardware
- 15 practice trial + 60 test trials (20 of each cue)



Try out the vibrations:

Press space to start expt

Experiments Design

Pilot Study

- Tacton recognition rates and times
- 4 participants
- Simplified version of the hardware
- 15 practice trial + 60 test trials (20 of each cue)

- **Result 1**: no errors.
- **Result 2**: average selection time was 2.5s (SD 0.57s)

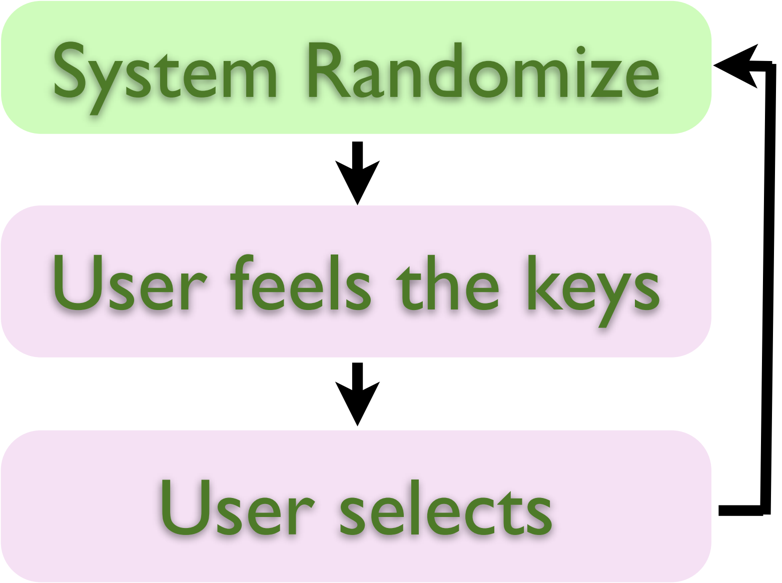
User Study

- 3 experimental conditions (3 software prototypes)
- 12 participants volunteered (mean age 29y)

- Fully balanced repeated measures. Given random passwords.
- 10 trials x 12 subjects x 3 conditions = 360 PIN entry (2520 selection events)

3 Conditions, 3 Software Prototypes

Evaluation



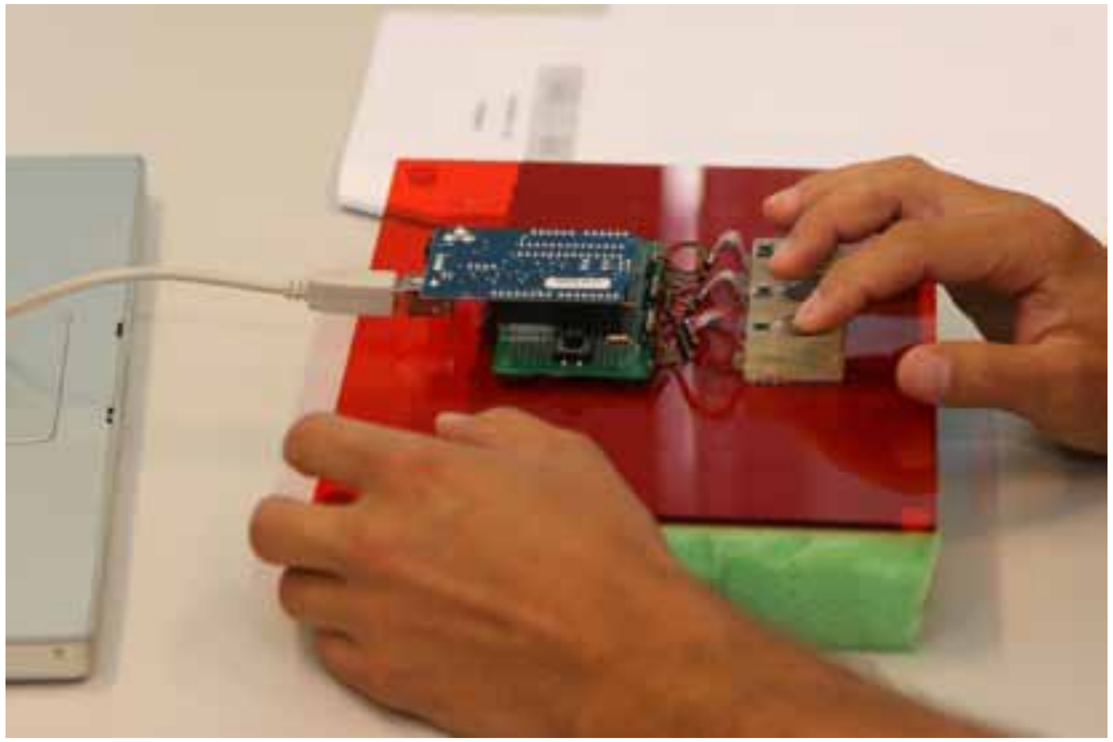
System Randomize

User feels the keys

User selects

Normal Mode

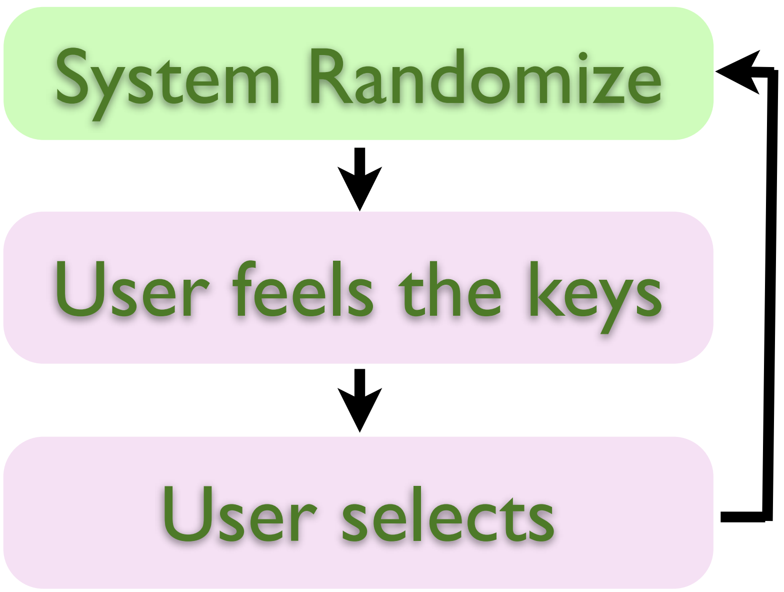
PIN	TACTONS	P(attack)	Safe?
6	3	1 / 729	NO
9	3	1 / 19863	YES



Trade off

"password length-performance"

3 Conditions, 3 Software Prototypes



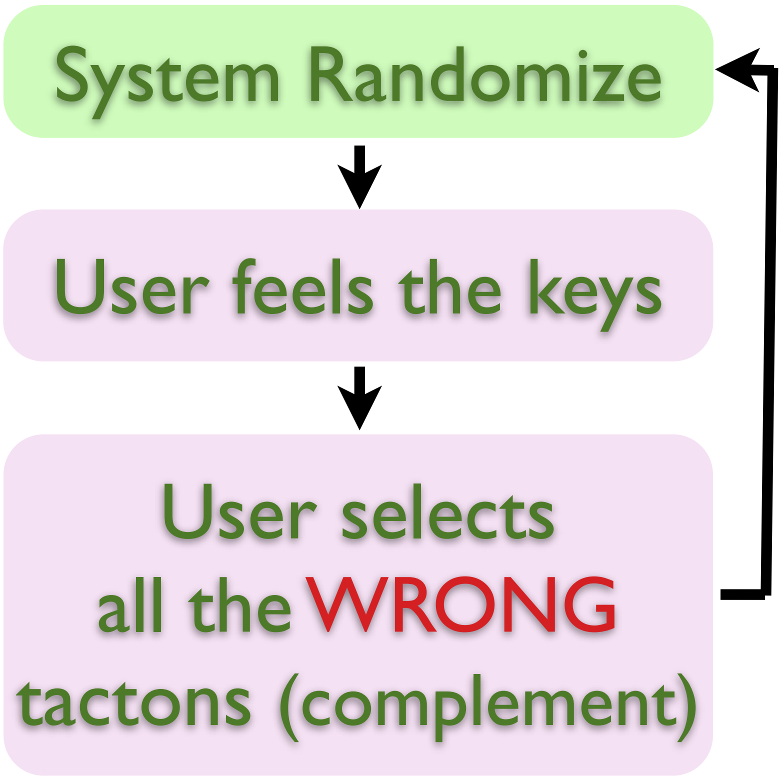
System Randomize

User feels the keys

User selects

OR

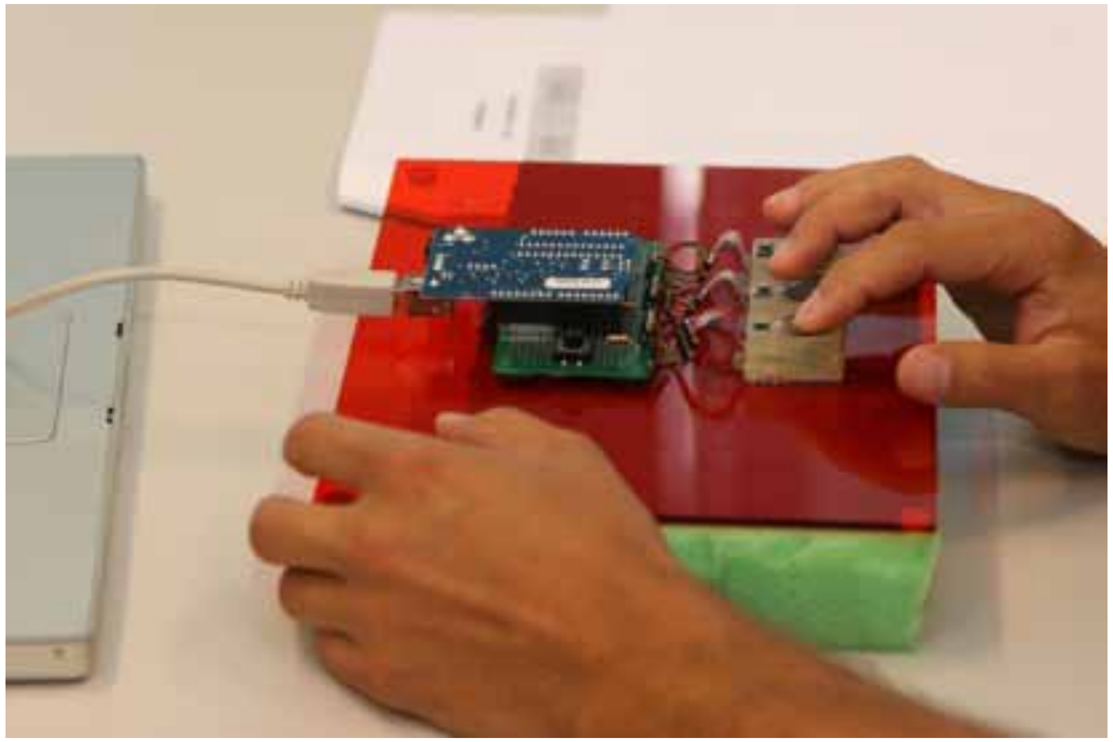
weighted 55% of cases



System Randomize

User feels the keys

User selects all the WRONG tactons (complement)



Hybrid Mode

PIN	TACTONS	P(attack)	Safe?
6	3	1 / 11941	Only to Observation

Trade off

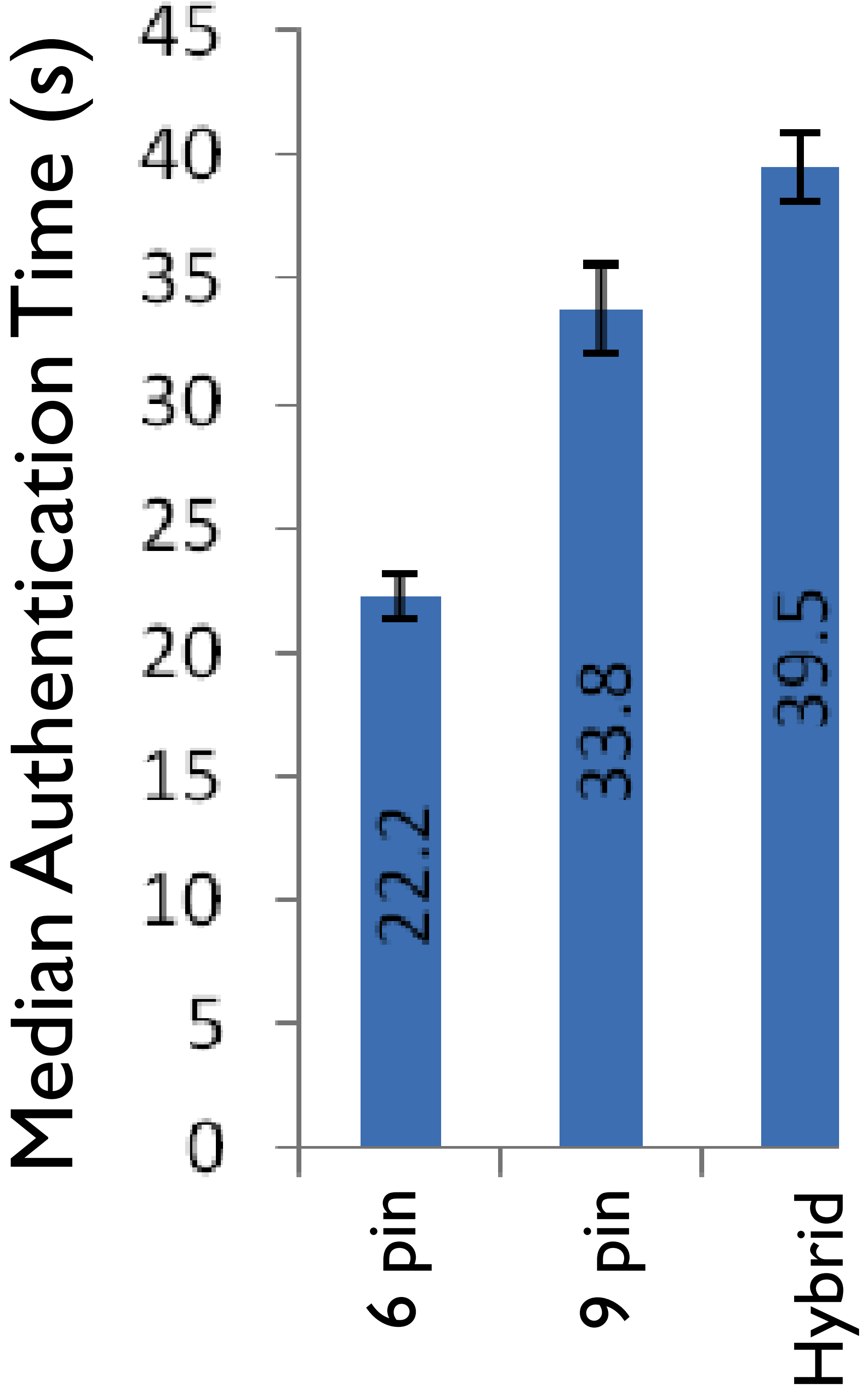
“complexity-performance”

1. Experiment Results: Authentication Time

Median task completion time

Medians were used to minimize the effect of outliers.

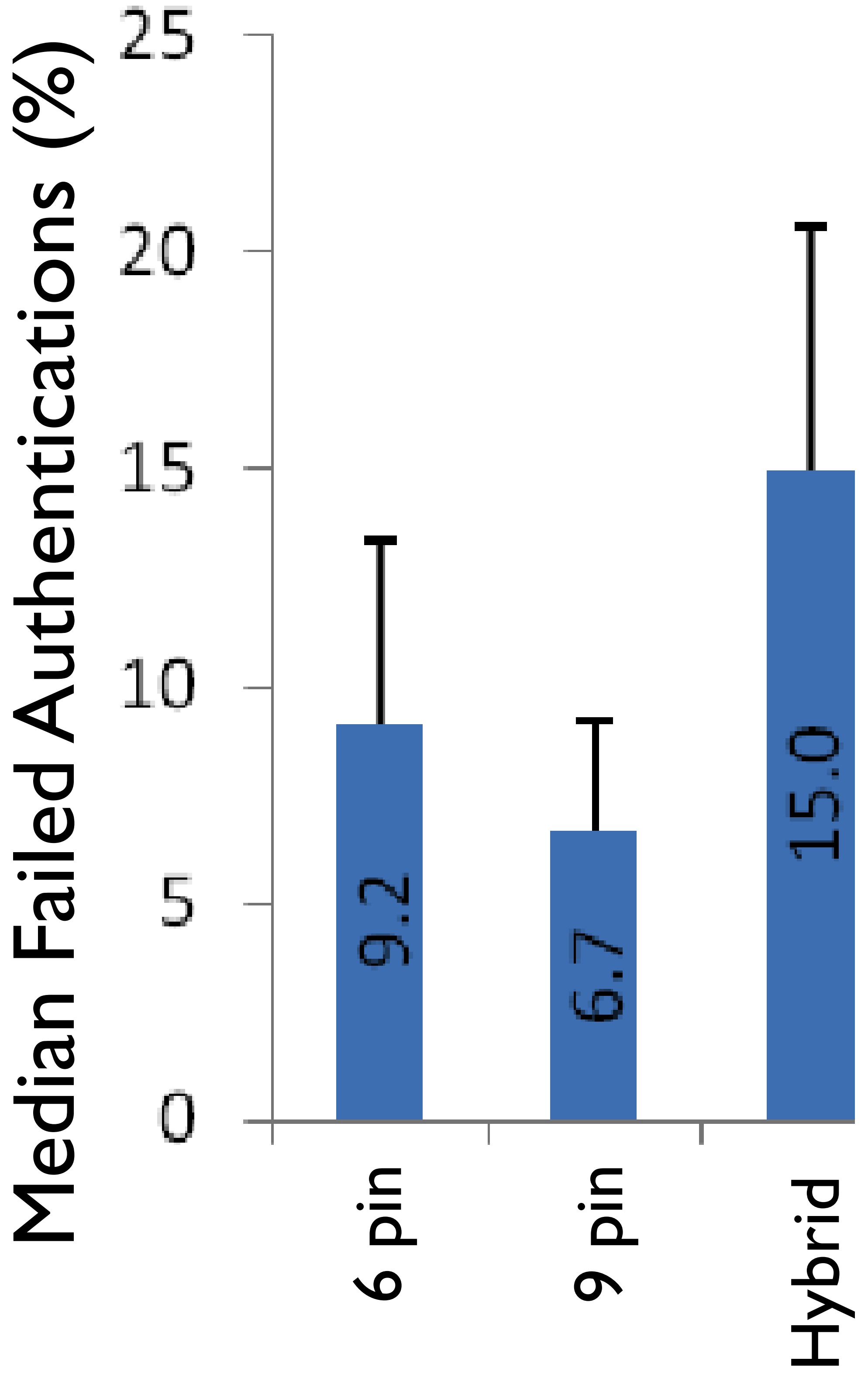
ANOVA and post-hoc **pair-wise t-tests** significants.



2. Experiment Results: Errors

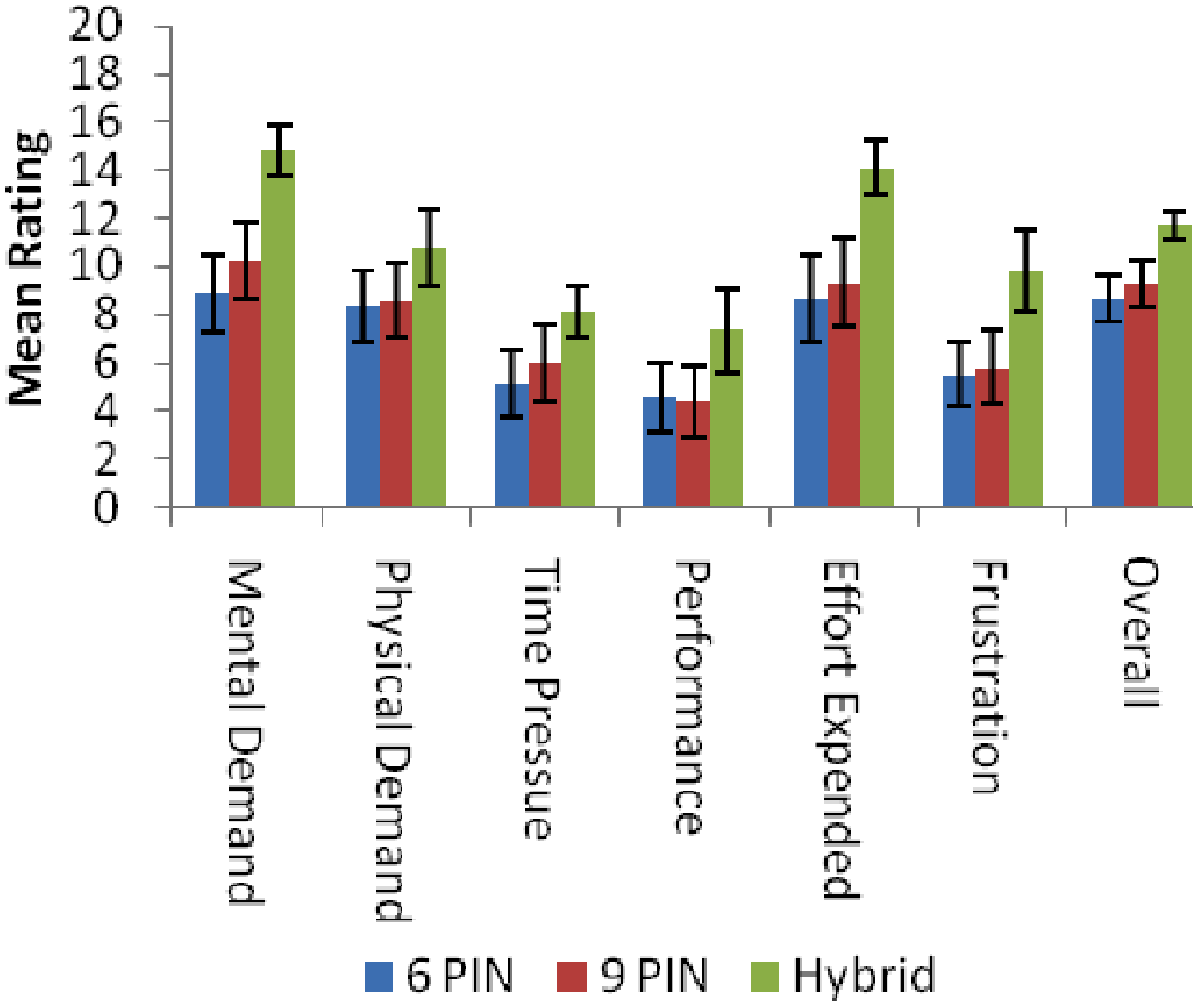
Mean number of Errors
per Authentication Session

An **ANOVA** not significant
(perhaps due to high variance)



2. Experiment Results: NASA TLX

ANOVA on overall workload (Nasa TLX) significant involving the Hybrid condition.



Discussion

Type	Performance	Security	Comments
6 PIN	Fast Time / Low Error **3.7s per selection (2.5s in Pilot study: 3.7 < 2.5*3)**	Low	User as reference value
9 PIN	Fast Time / Low Error **3.7s per selection**	Safe	•Users didn't find more challenging entering additional PINs •(linear proportion with 6 pin: **1.5 ratio** between password length and time) •PIN relatively easy to remember
HYBRID	Slow Time / High Error **6.5s per selection**	Observation Safe	High cognitive load (**overhead**)

Comparison with Previous Systems

	6 PIN	9 PIN	HYBRID	UNDERCOVER (CHI 08)
Time (s)	22.2	33.8	39.5	39 - 49 (avg)
Errors	9.2%	6.7%	15%	26%

Data From Undercover

- Go for unimodal !
- Simplicity of a pure recognition process:
  feel -> recognize -> select

Contributions

- Introducing the *Haptic Password model*

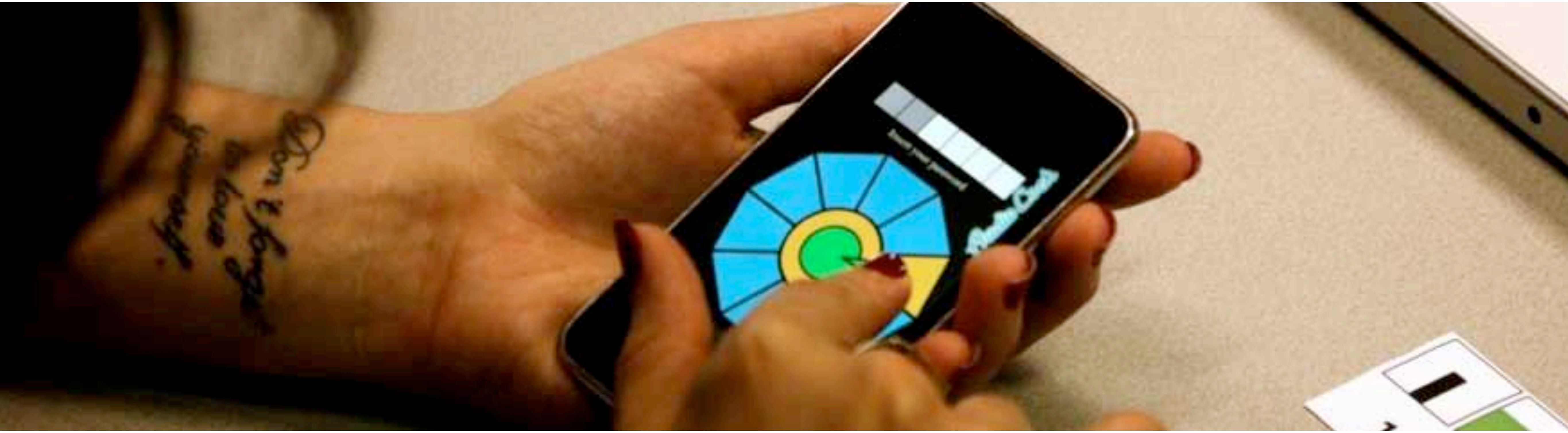
- Introducing one possible *interface and method* (Haptic Keypad) to use a Haptic Password

- Preliminary user tests suggests that *Haptic Password is a better alternative to Haptic Obfuscation*

    - *Unimodal*
    - *Simple cognitive task such as recognition*

The Phone Lock

Audio and Haptic Shoulder-Surfing Resistant
PIN Entry Methods for Mobile Devices



Bianchi, A., Oakley, I., Lee, J., Kwon, D. The haptic wheel: design & evaluation of a tactile password system.
In Proceedings of CHI 2010, ACM, New York, NY, pp. 3625-3630.

Bianchi, A., Oakley, I., Kostakos, V., Kwon, D., The Phone Lock: Audio and Haptic shoulder-surfing resistant PIN entry methods.
In Proc. of ACM TEI'11, ACM, New York, pp. 197-200.

Shift in computing, shift in interaction

From private user to collaborative

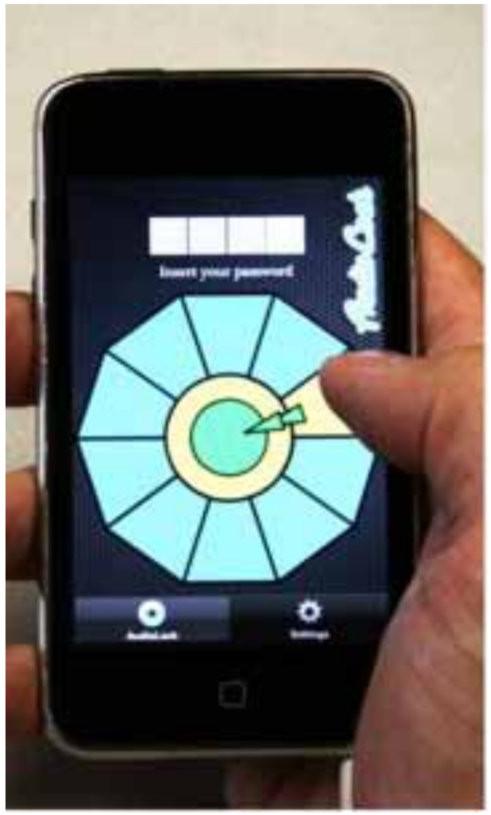
From fixed to mobile

Observation: The New Old threat

Large screens + public spaces =

Observation remains one of the most simple and common way to steal a PIN.

Two Objectives



1

Introducing a new PIN entry system for mobile devices resistant against observation.

- **Non-visual PIN** and its role in tangible and ubiquitous interfaces

VS

2

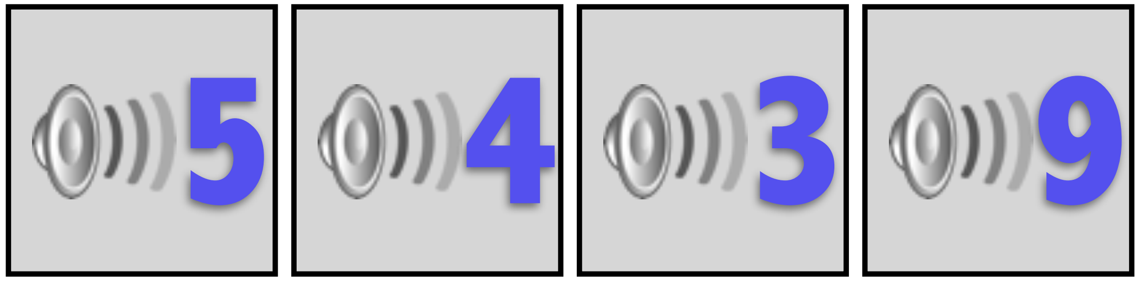
Comparing authentication performance of audio and haptic stimuli as PIN.

- What is the **best non-visual PIN**?

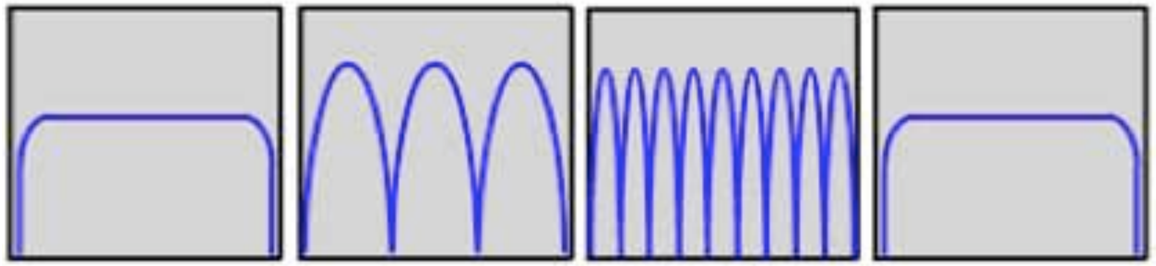
How can we make an invisible PIN?

- Make a PIN invisible using invisible cues and a new interaction method

Audio PIN
computer speech



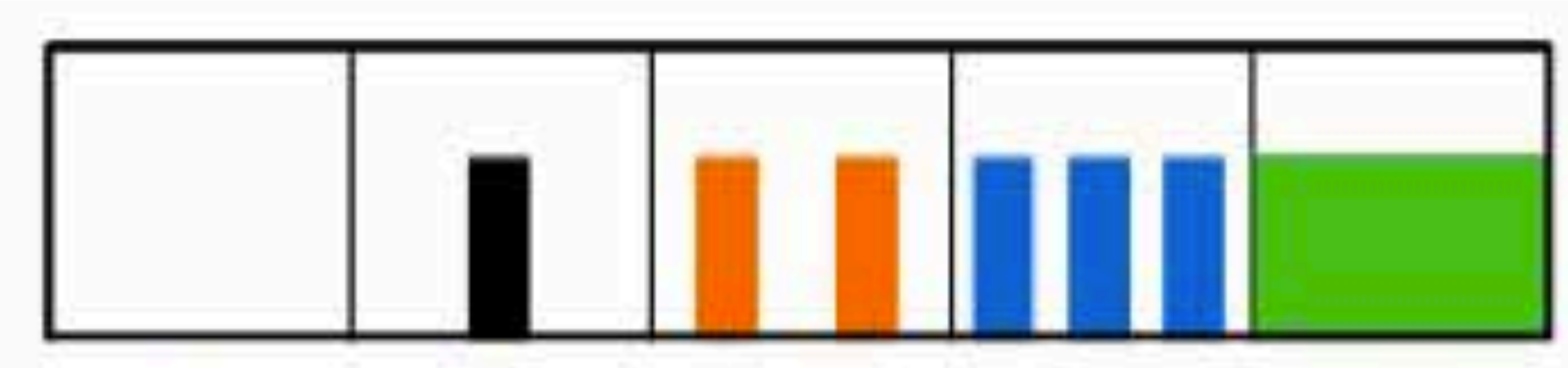
Haptic PIN
vibration patterns



A sequence of **audio cues** (sound) or **tactile cues** (tactons) inherently **invisible** to everyone.

Our Alphabet Cues: example sets

Haptics

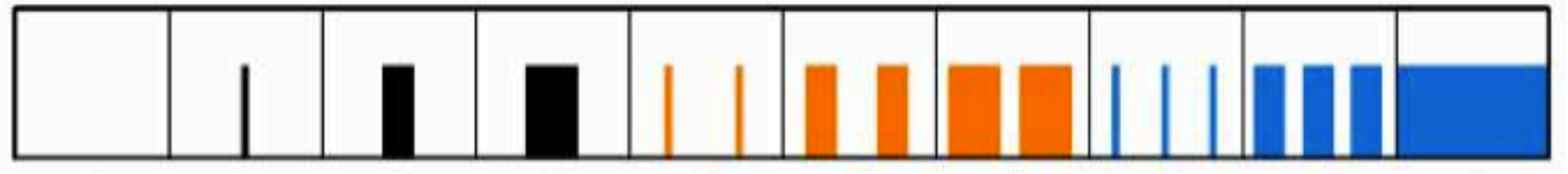


Audio 0 1 2 3 4

Our Alphabet Cues: example sets

System

Haptics

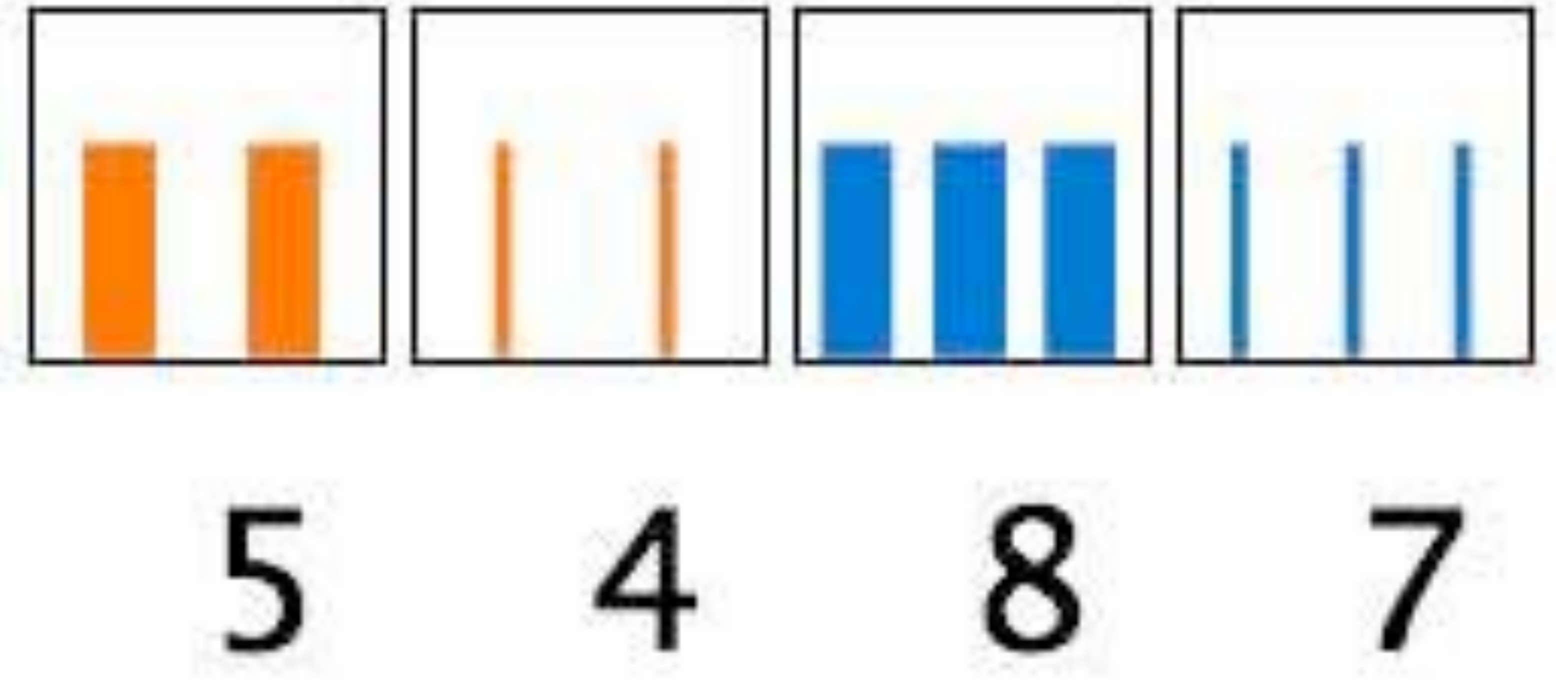


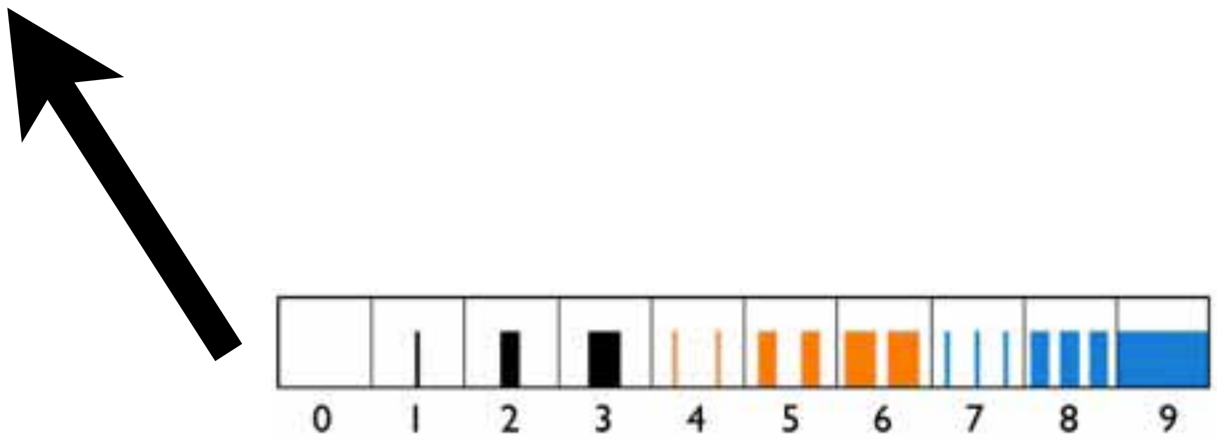
Audio 0 1 2 3 4 5 6 7 8 9

Our Cues

System

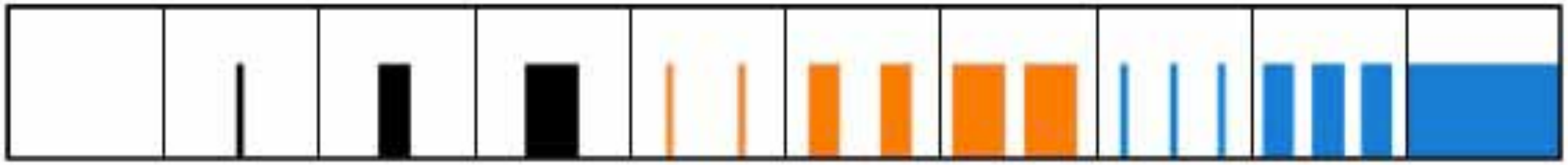
Use these sets to make a PIN





Our Cues

Haptic
vibration patterns

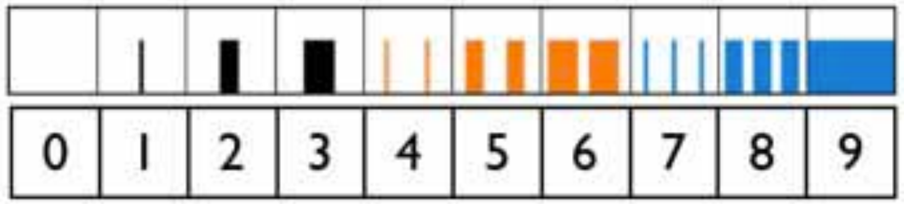


ORDERED SET OF POSSIBLE CUES

Audio
computer speech

0	1	2	3	4	5	6	7	8	9

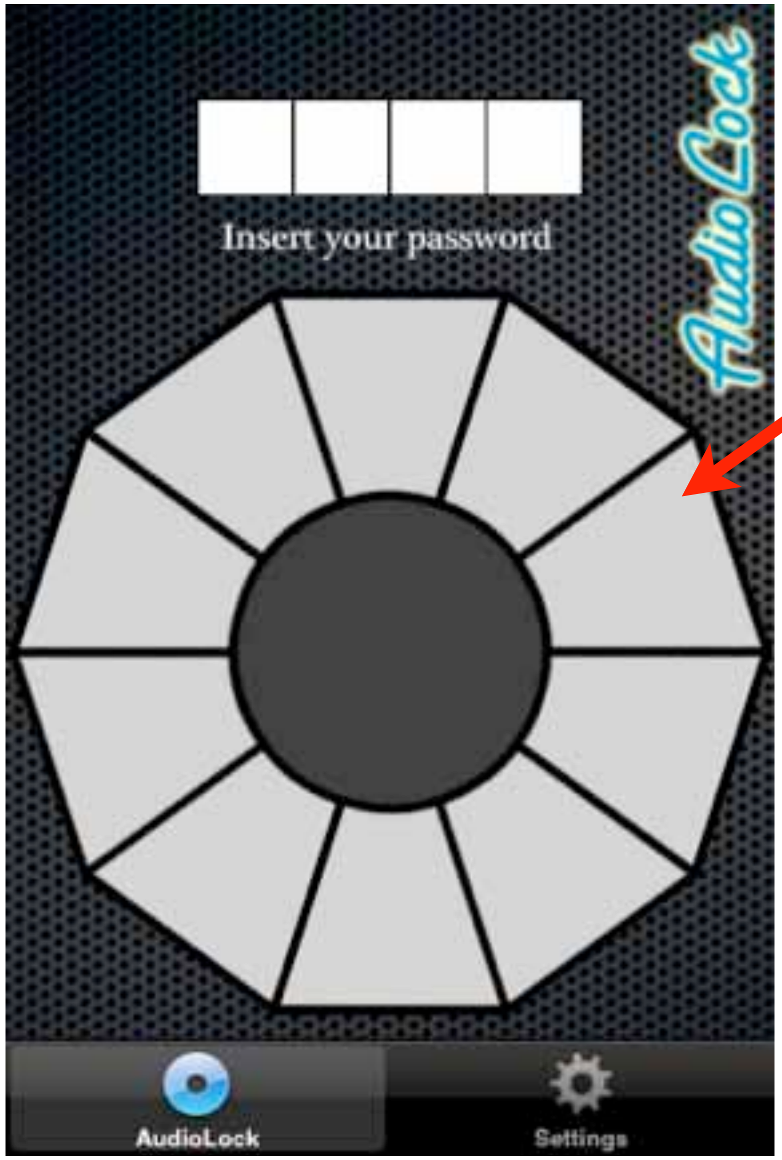
Mapping to Interface



→

C0	C1	C2	C3	...	...	Cn

Generalizing: cues with order

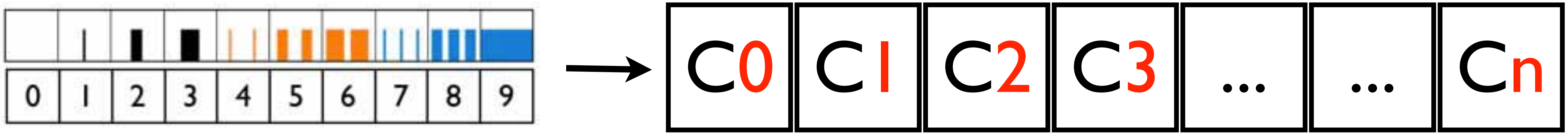


Insert your password

The Wheel GUI

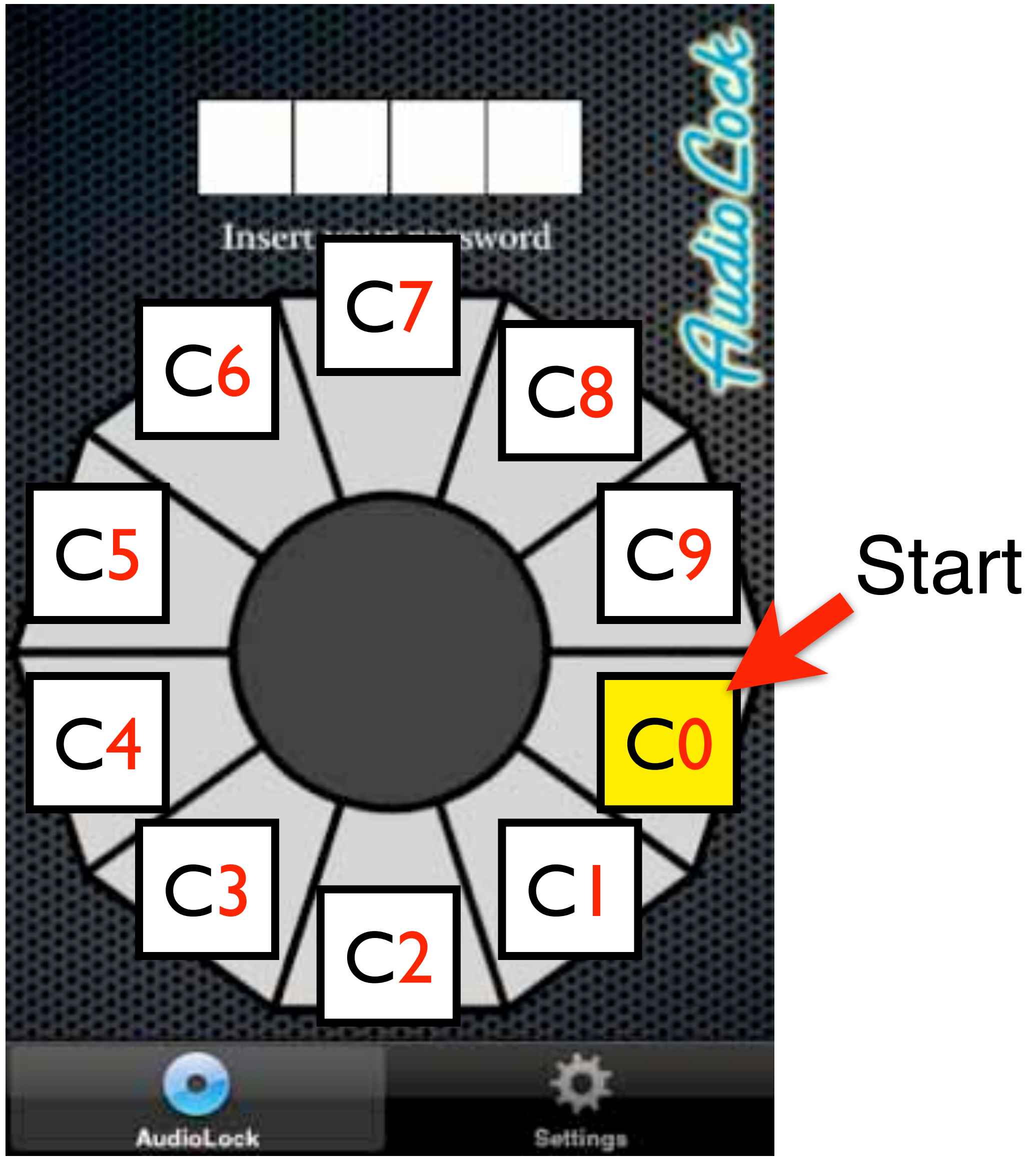
1 to 1 assignment of **cues to slots**

Mapping to Interface



Generalizing: cues with order

The Wheel GUI

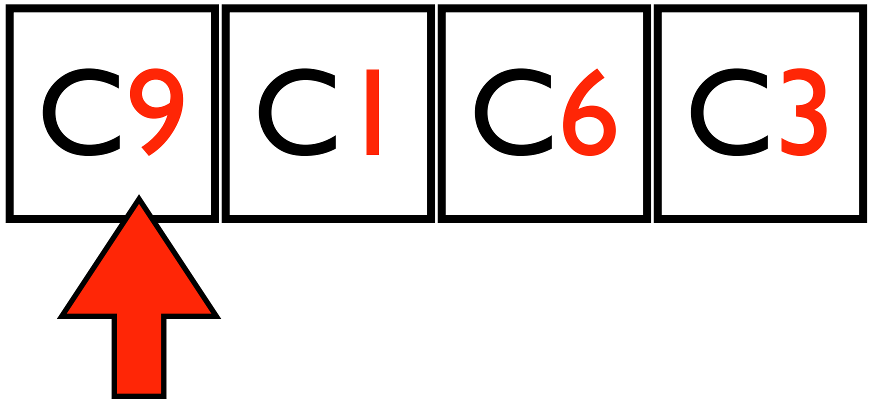


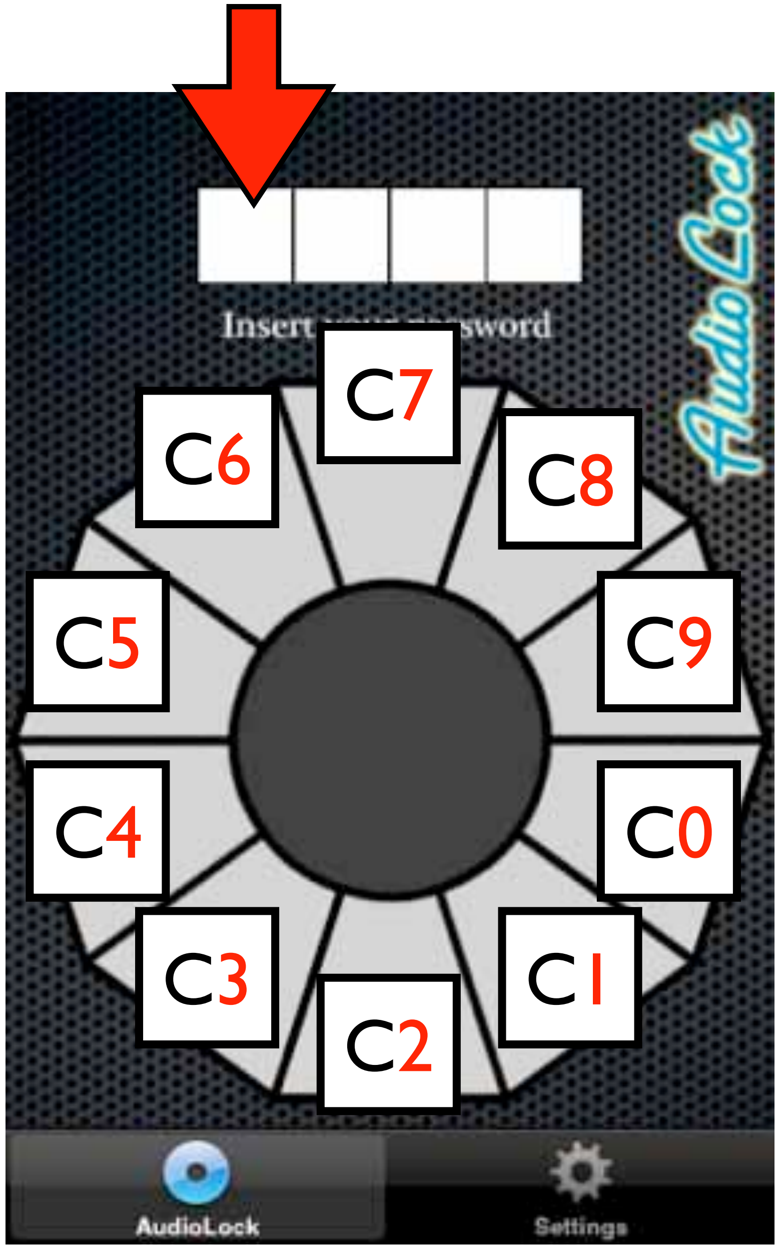
Map every cue to a slot

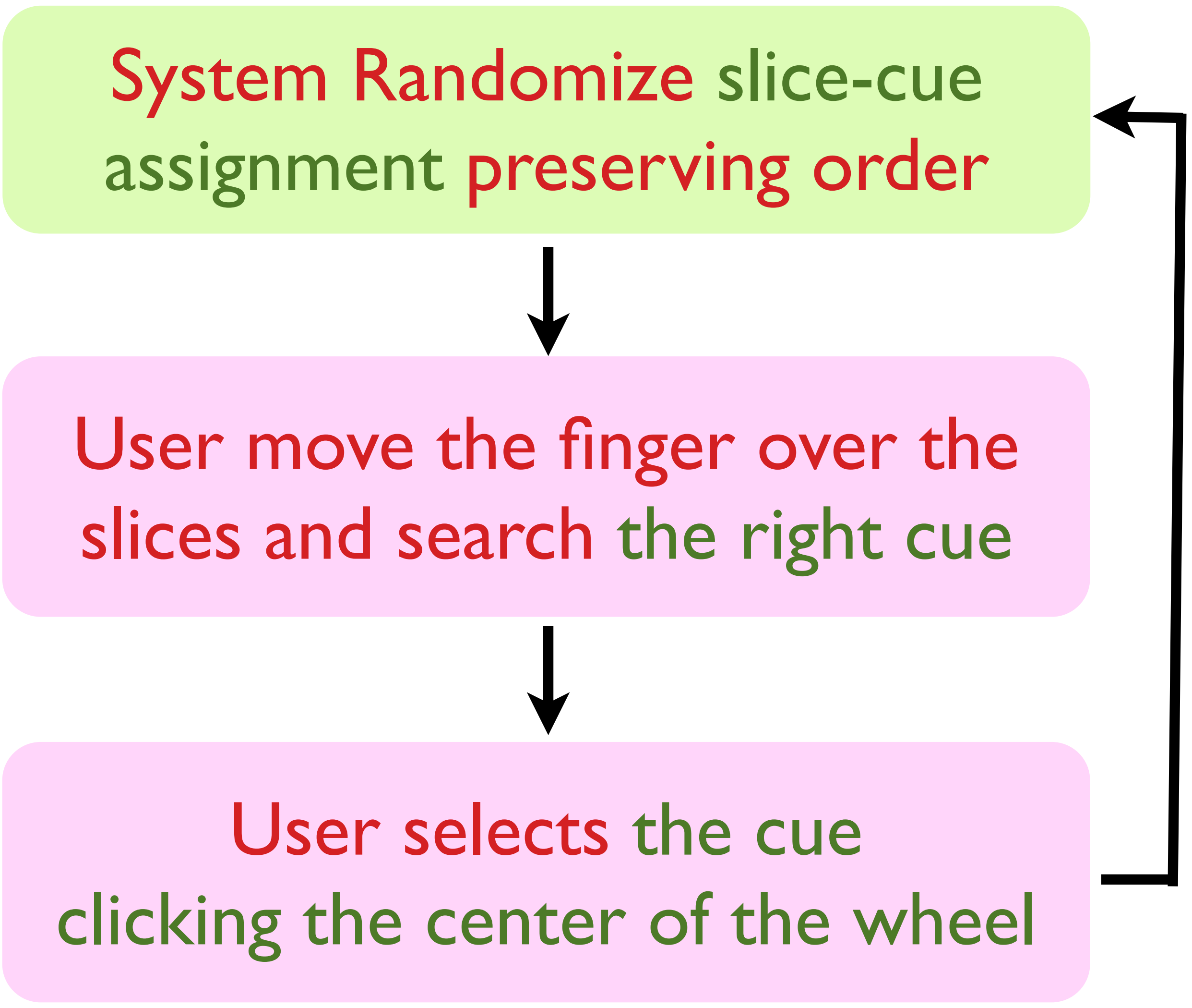
- **randomly**
- **preserving order**

Interaction

Let’s make a password using the cues







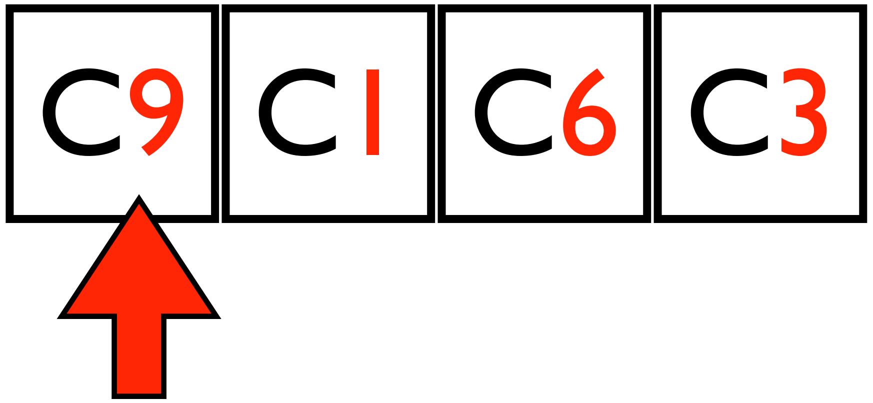
System Randomize slice-cue assignment preserving order

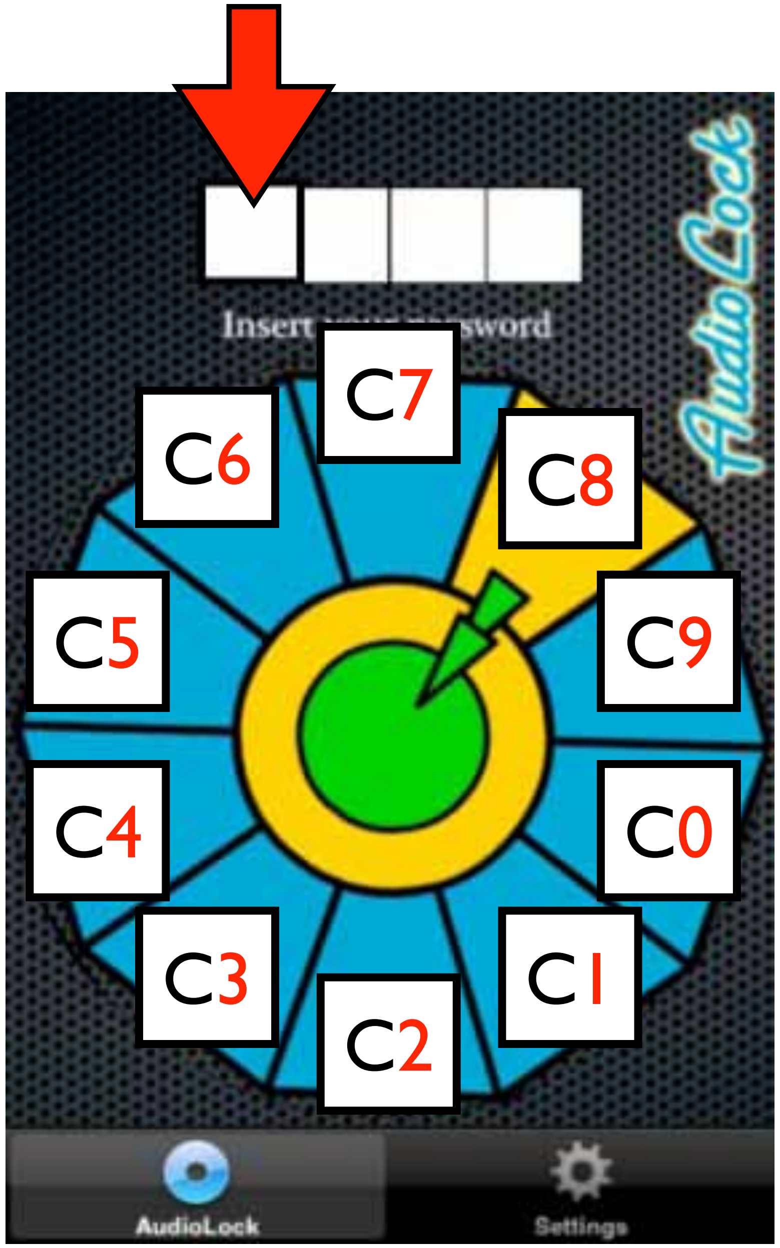
User move the finger over the slices and search the right cue

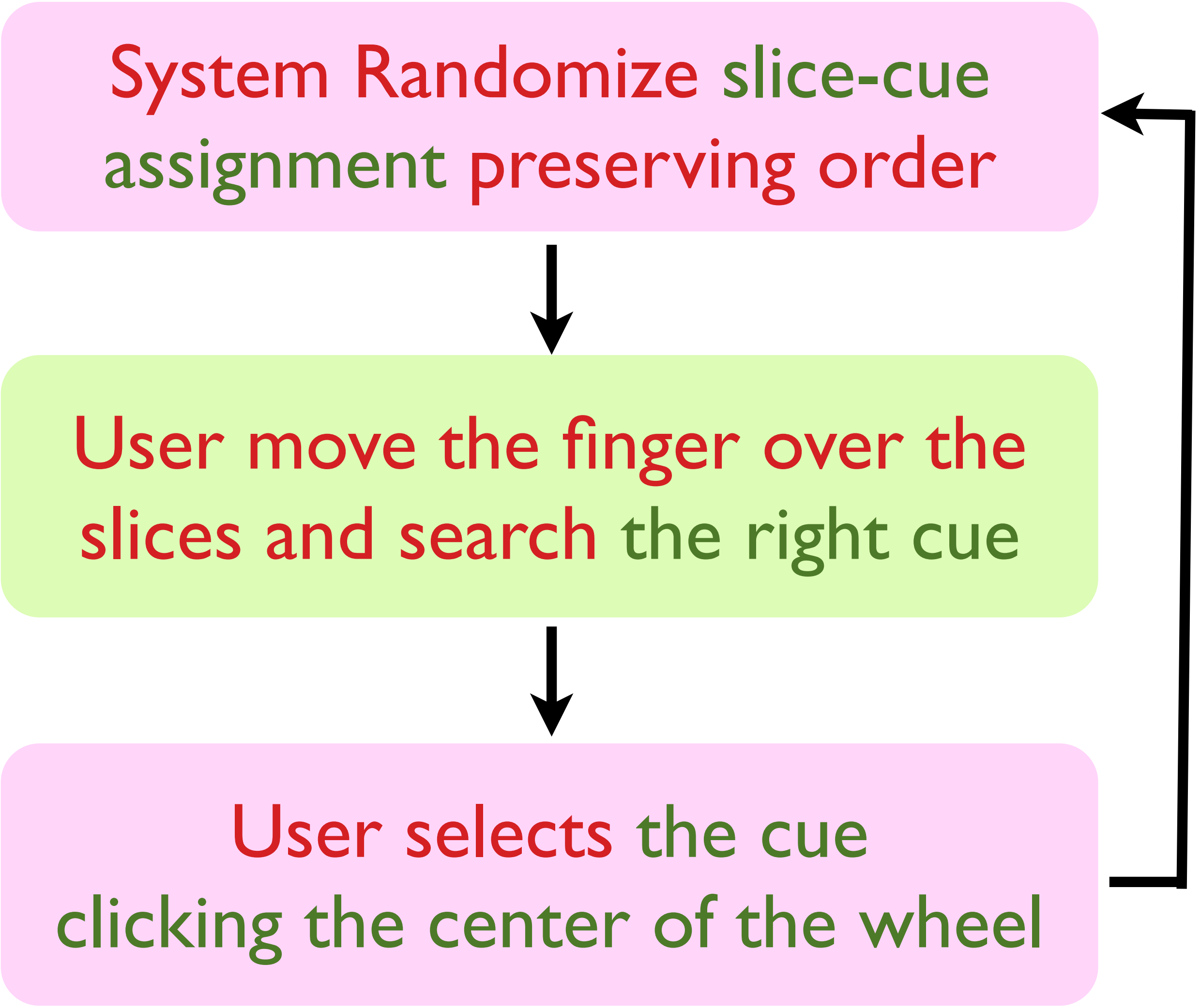
User selects the cue clicking the center of the wheel

Interaction

Let's make a password using the cues







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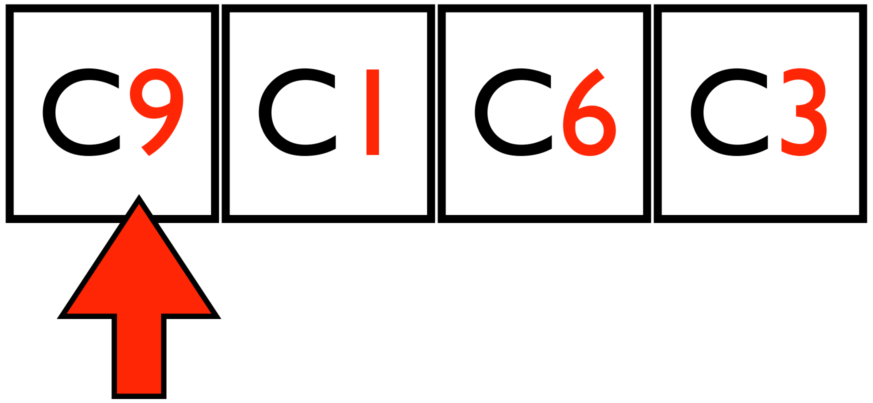

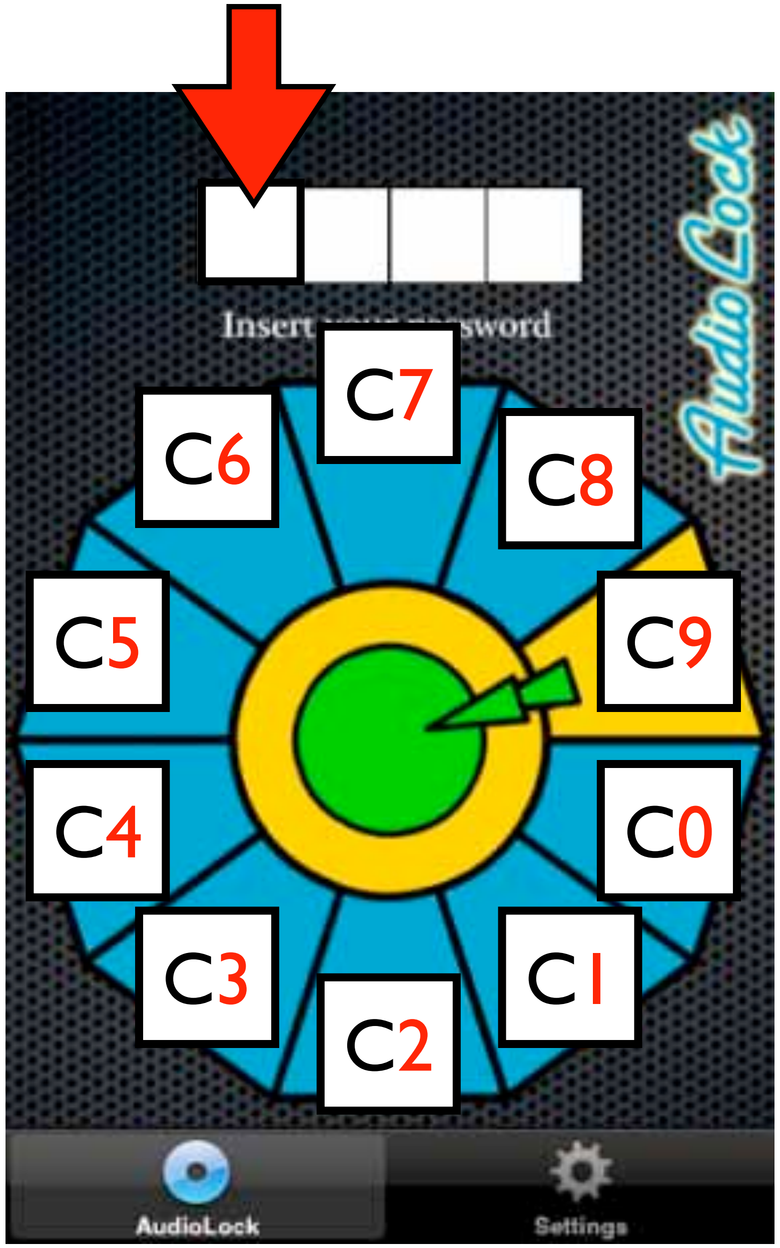

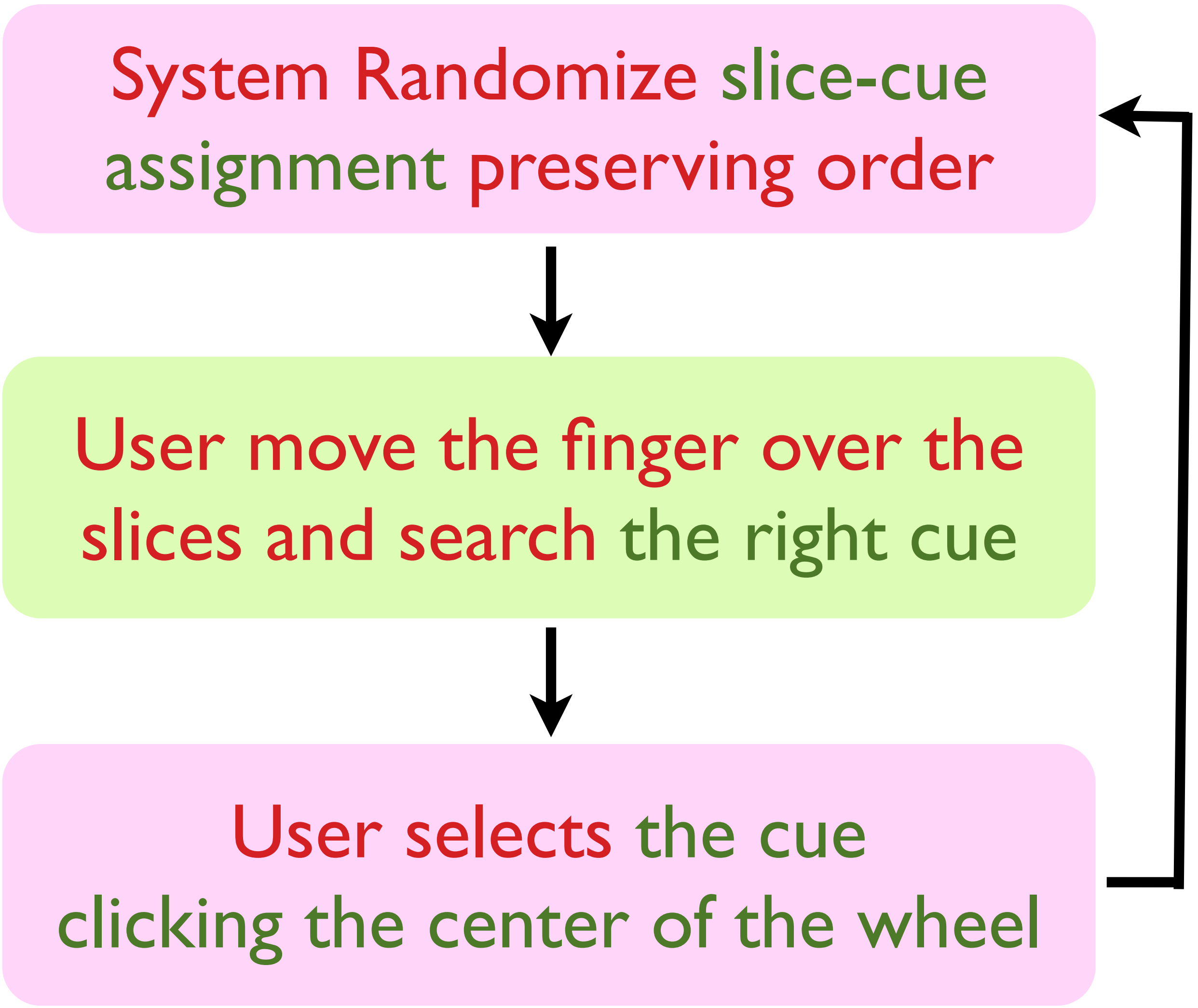

System Randomize slice-cue assignment preserving order

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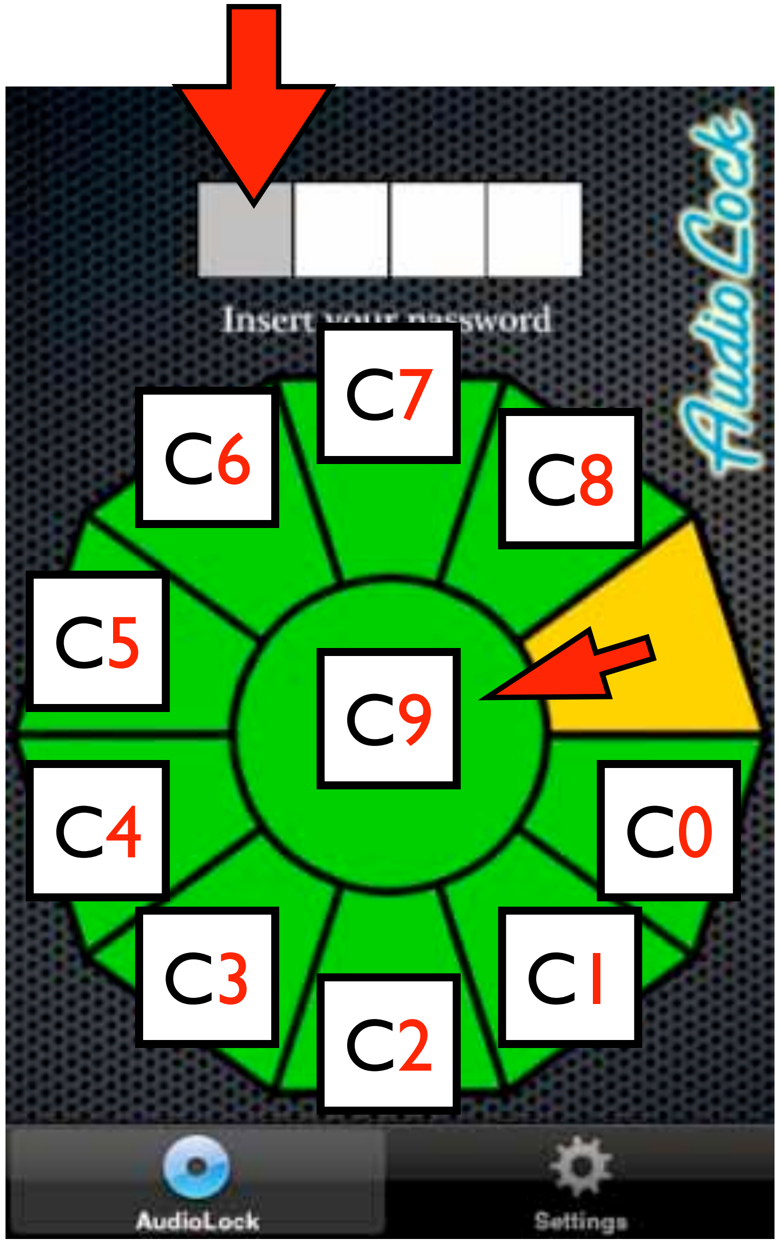
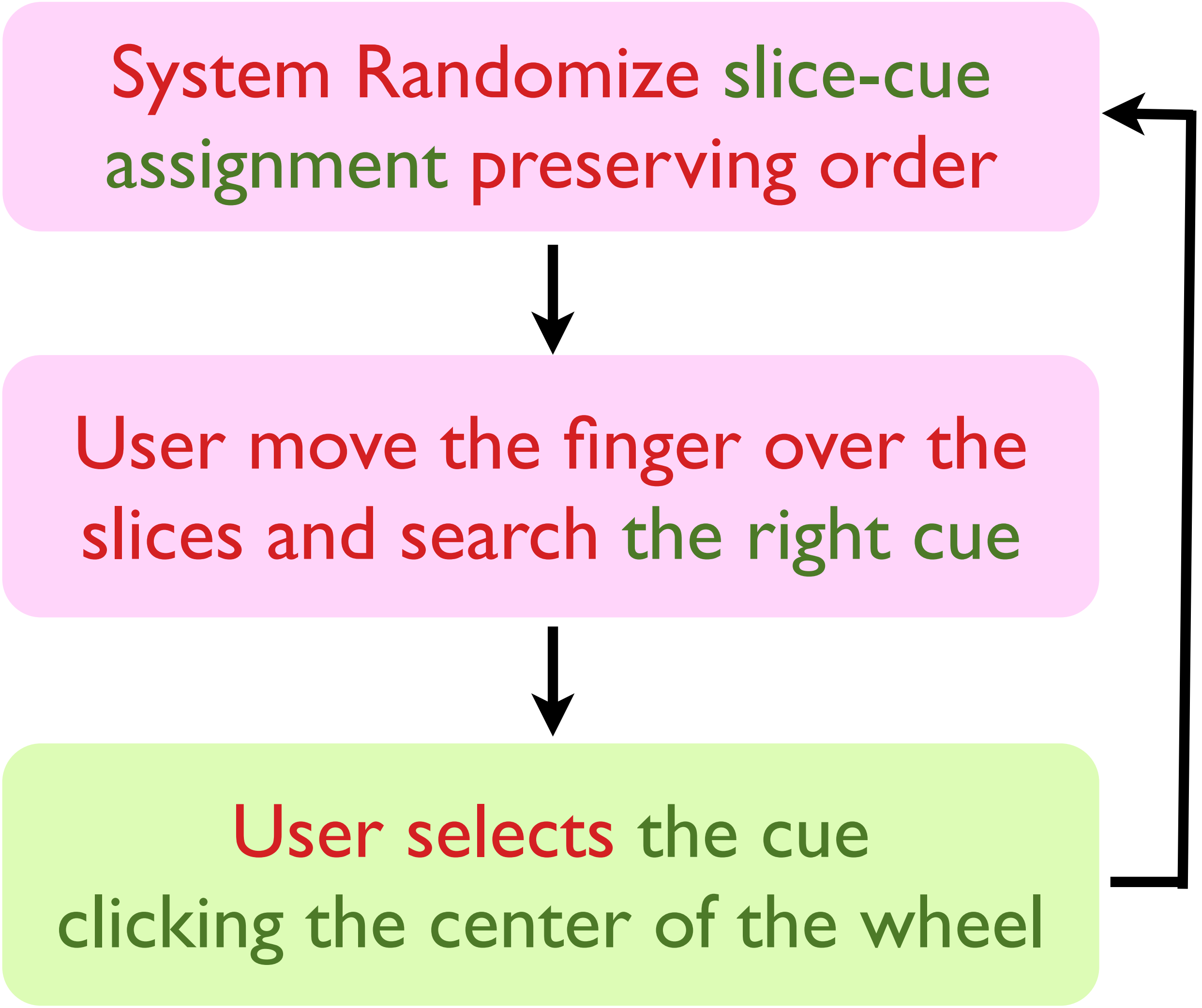
User selects the cue clicking the center of the wheel

Interaction

Let’s make a password using the cues

C9	C1	C6	C3





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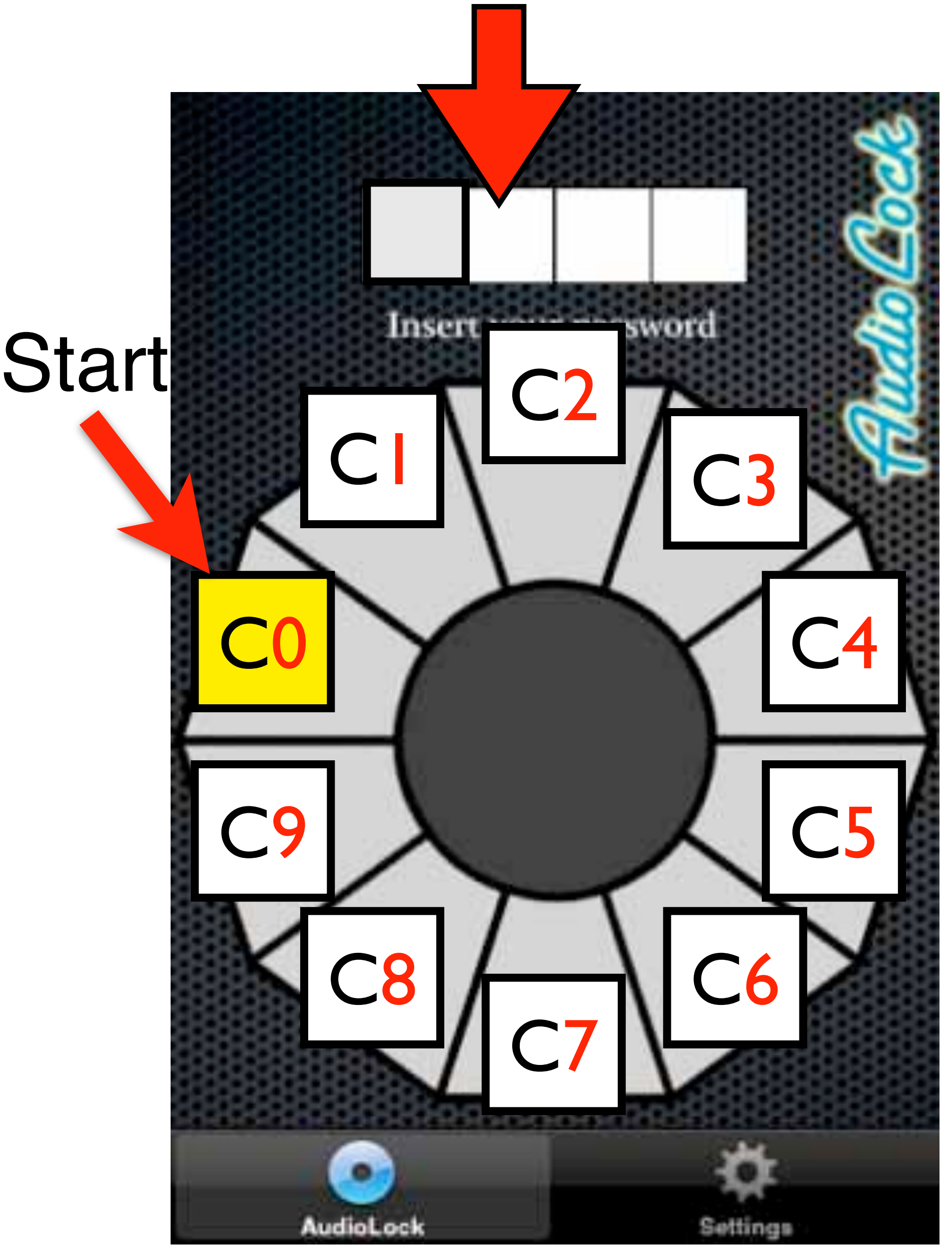
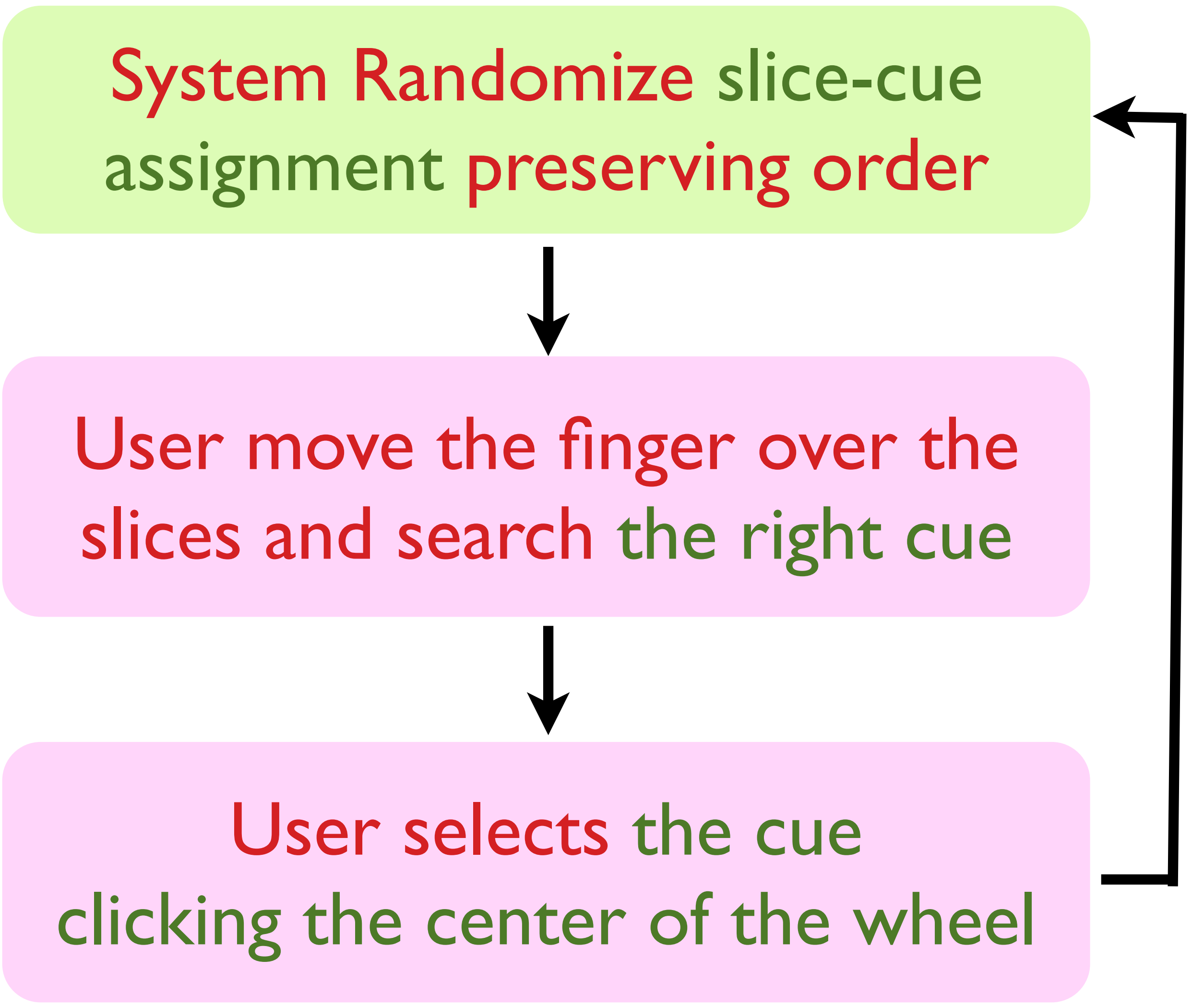
Interaction

Let’s make a password using the cues

C9	C1	C6	C3



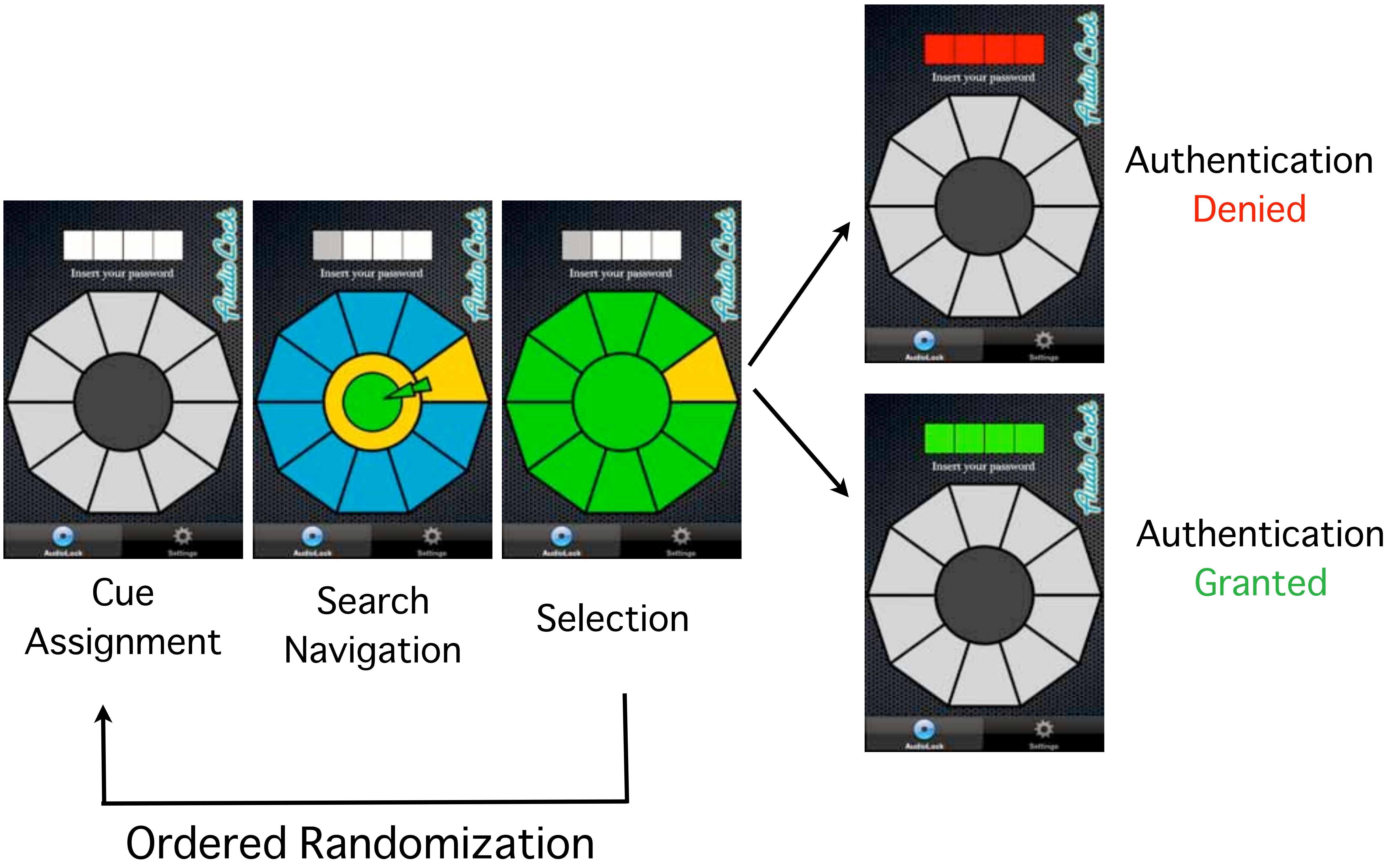

System Randomize slice-cue assignment preserving order

User move the finger over the slices and search the right cue

User selects the cue clicking the center of the wheel

System

Interaction map



Cue Assignment

Search Navigation

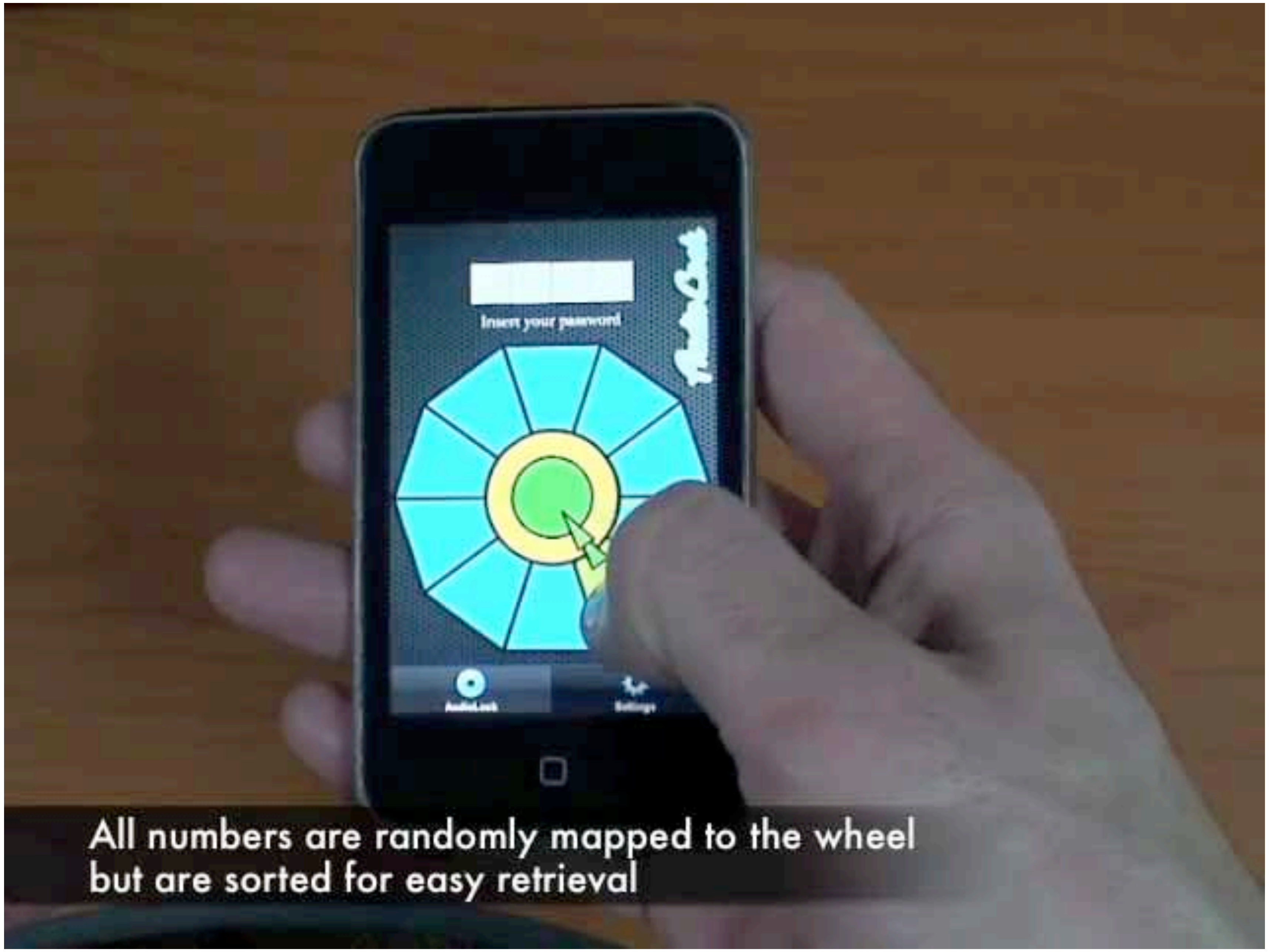
Selection

Authentication Denied

Authentication Granted

Ordered Randomization

In practice: demo



All numbers are randomly mapped to the wheel
but are sorted for easy retrieval

Inserting the PIN 1 2 4 3

Evaluation: 2 studies

To gauge our interface we conducted 2 experiments

Pilot Study

Test cue recognition rate

Evaluate if cues are perceptually distinct (recognition time and error)

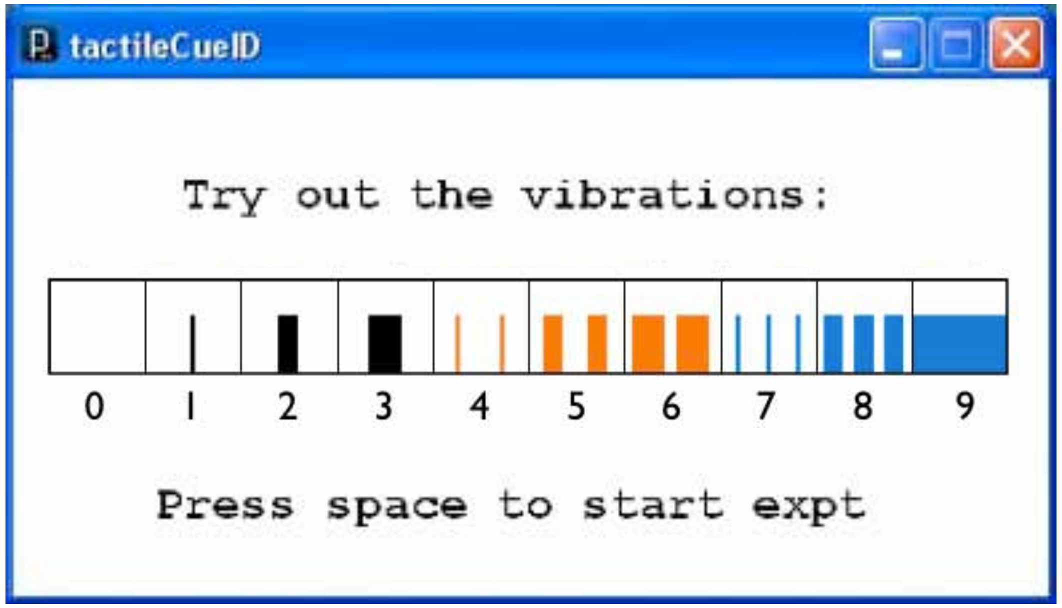
User Study

Evaluation of interface to explore 2 trade-offs.

Audio **VS** Haptics

Large alphabet **VS** Small alphabet

Pilot Study - Highlights

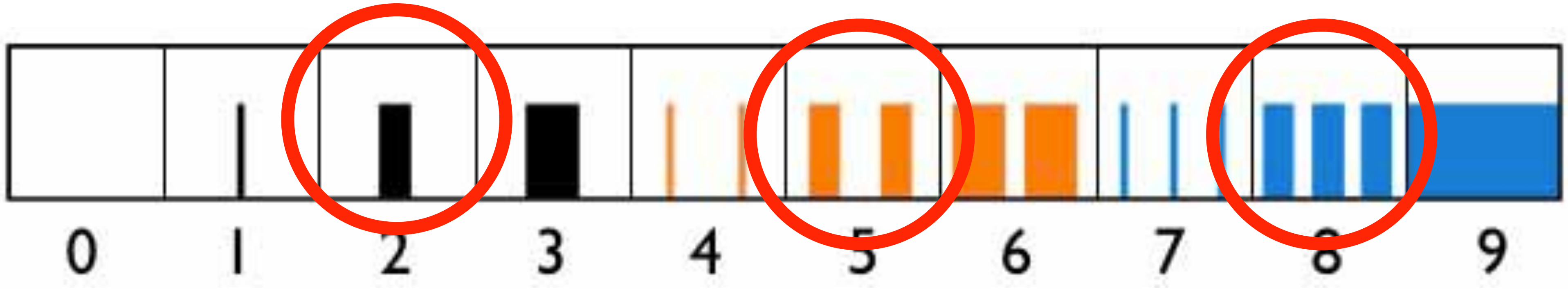


Try out the vibrations:

Press space to start expt

- Simple recognition task. Simplified system.
- Mean cue recognition time: 2.25s
- Mean error:14% (for the large haptic alphabet)

Mid-length 80ms element were the most challenging



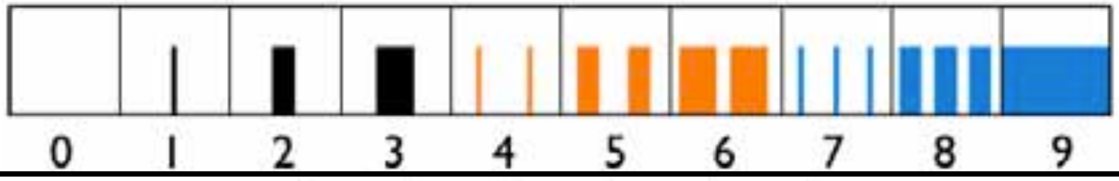
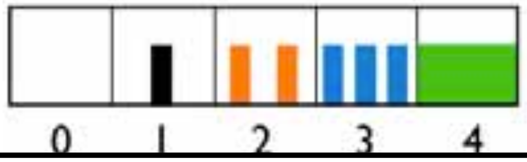
User Study: analyze the trade-offs

We analyze 2 trade offs, maintaining a security level of 1/10000 (the security of a standard numerical 4 digit PIN).

We are interested in authentication time and errors.

1 Audio **VS** Haptics

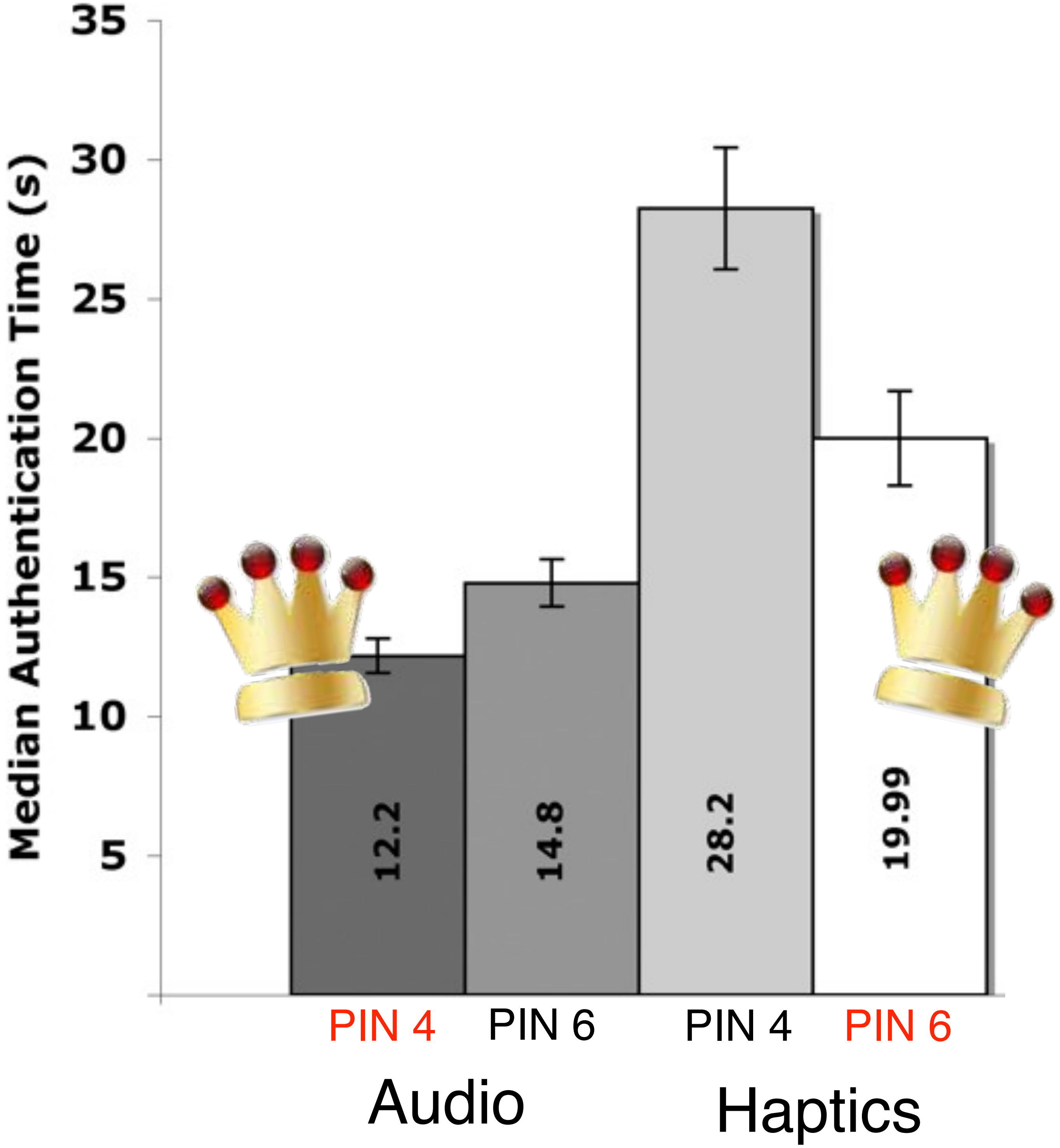
2 Large alphabet (short PIN) **VS** Small alphabet (long PIN)

	Audio	**Haptics**
4 digits PIN	0,1,2,3,4,5,6,7,8,9	
6 digits PIN*	0,1,2,3,4	

*The 6 digits PIN test is to compare Phone Lock against previous work

Results

1. Experiment Results: Authentication Time



Trade-offs (2-way ANOVA)

Modality significant (p<0.01)

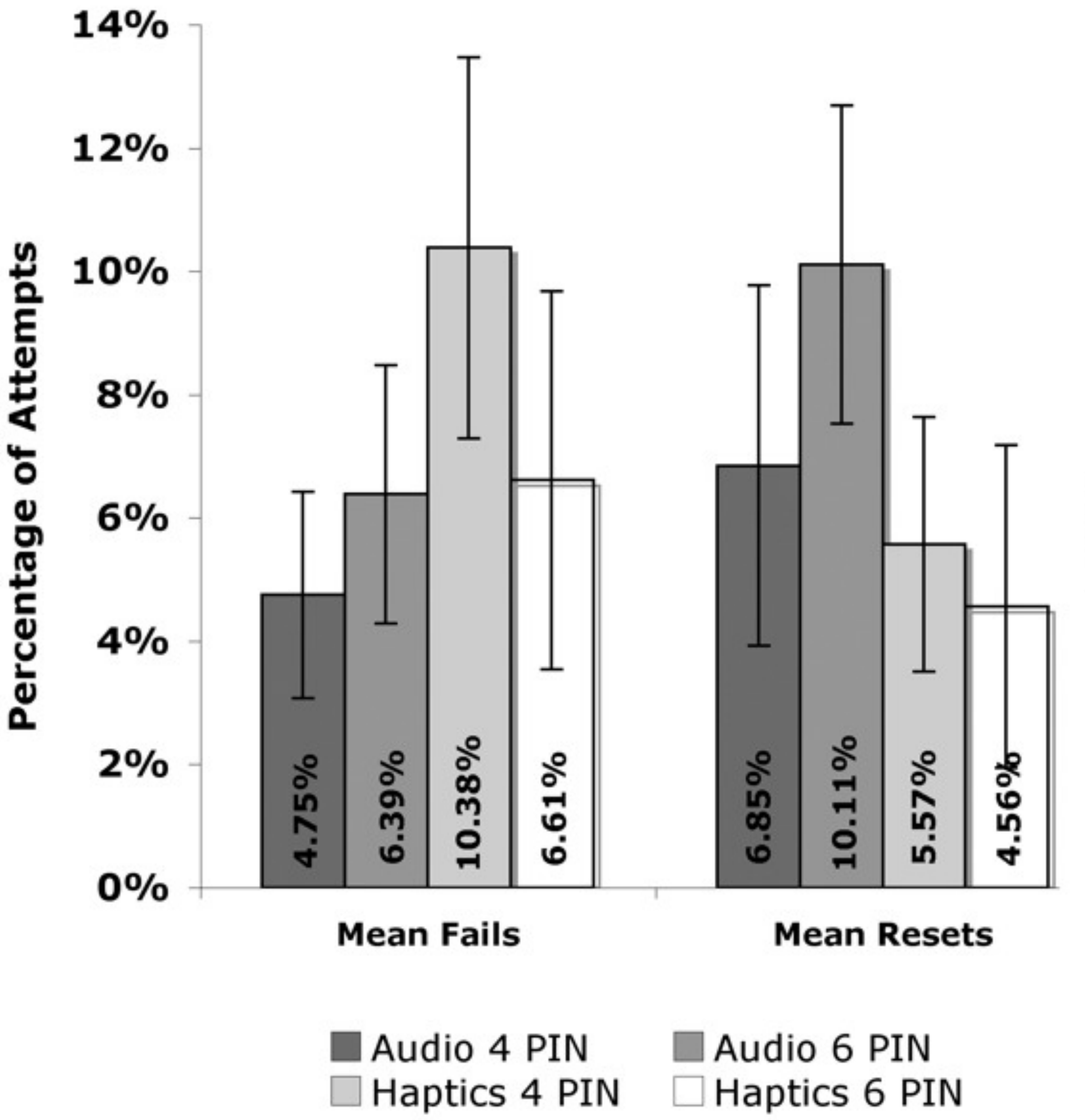
PIN length not significant

Overall

ANOVA and post-hoc **pair-wise t-tests** significants (p<0.01).

2. Experiment Results: Authentication Errors

Results



Mean error 7% (<14% pilot)

Effect of Modality and PIN length and their interaction were not significant.

Discussion - Highlights

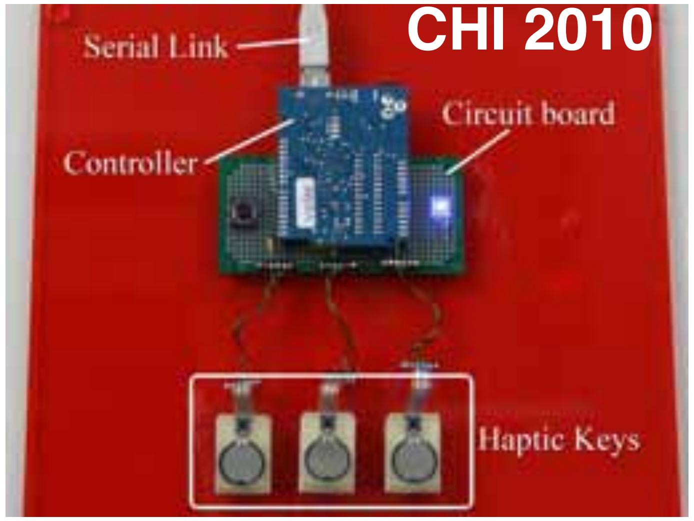
- Audio > Haptics.

  Is because it is more familiar?

- Error rate: 7% study < 14% pilot

  People understood how to navigate the interface

- Better performing than previous similar systems



CHI 2010

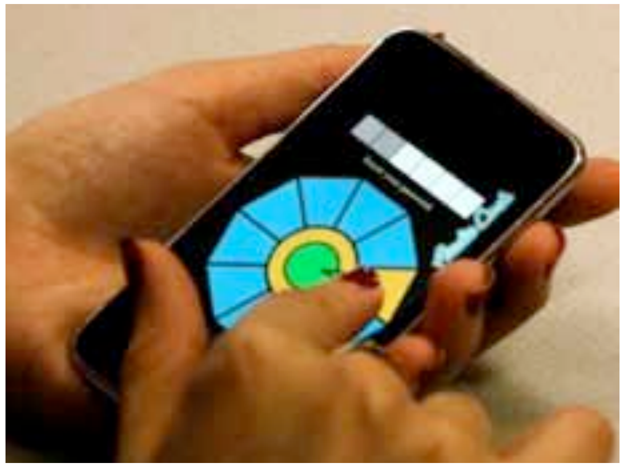
Contributions

- Introducing the *Invisible Password* model using audio and tactile cues

- Introducing one possible *interface and method for mobile phones* (Phone Lock) to use with Haptic and Audio PINs

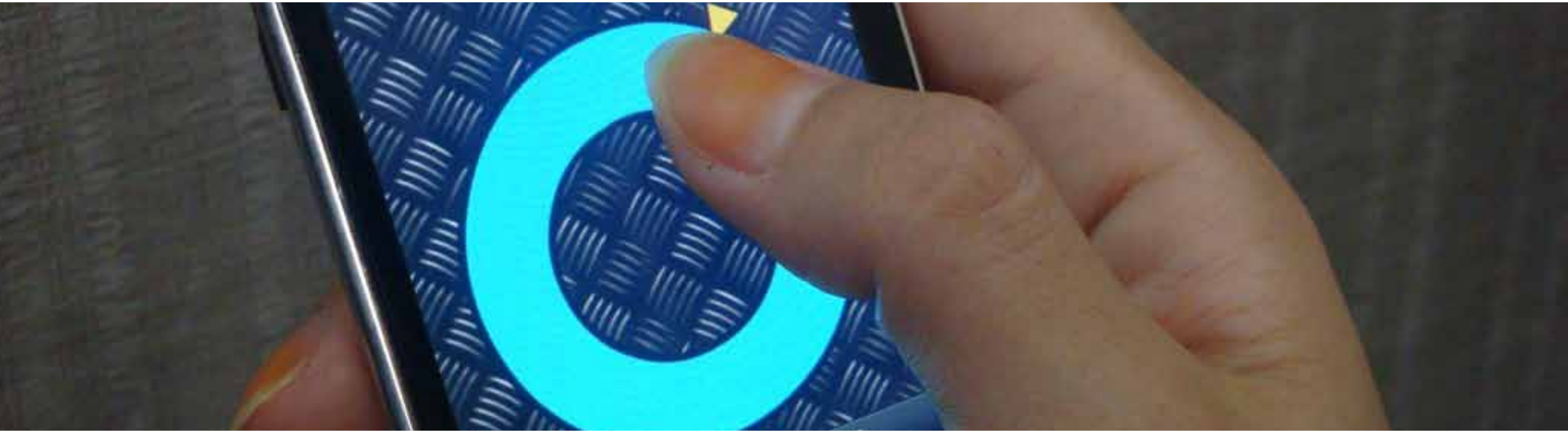
- Preliminary user tests suggests that *Invisible Password thought haptic and audio have a lot of potential*

  - *They are good fit for tangible user interfaces*
  - *Simple cognitive task such as recognition is good*



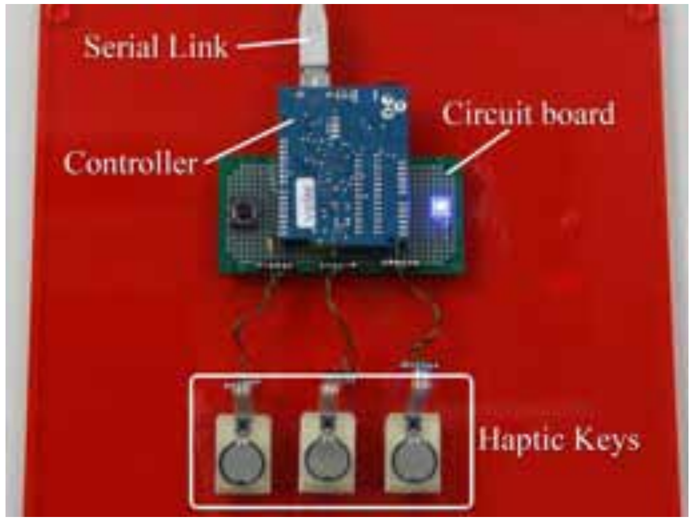
The SpinLock

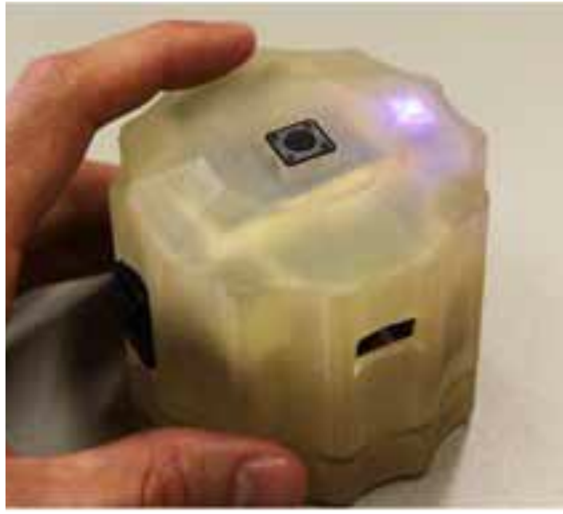
Spinlock: a Single-Cue Haptic and Audio PIN Input Technique for Authentication

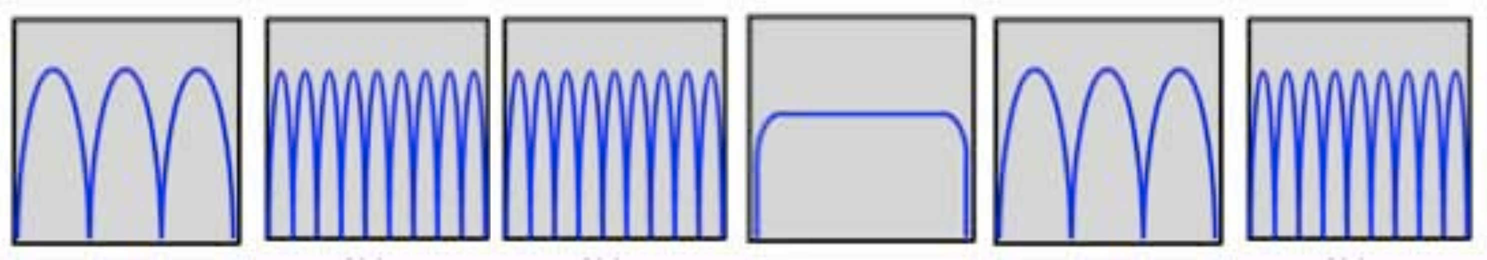


Bianchi, A., Oakley, I., Kwon, D. Spinlock: a Single-Cue Haptic and Audio PIN Input Technique for Authentication. To Appear in Proceedings of HAID 2011, LNCS, Springer, 2011.

The problem with haptic passwords





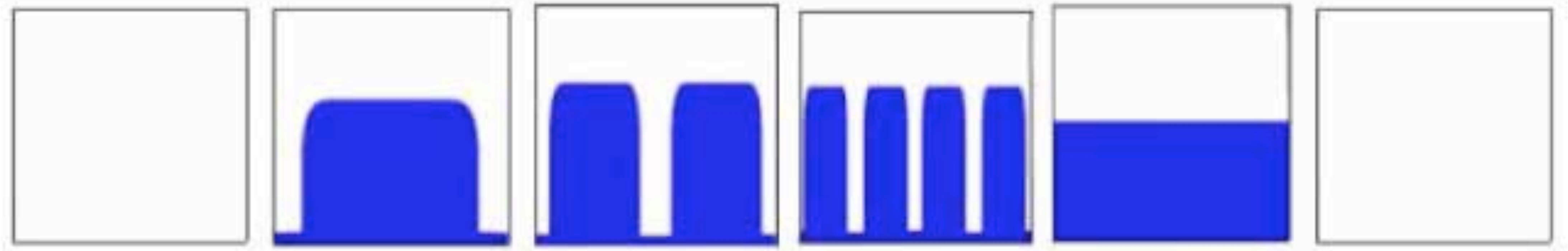


Haptic Password using tactons is based on recognition:

high cognitive load, memorability issues, high error rates and input time

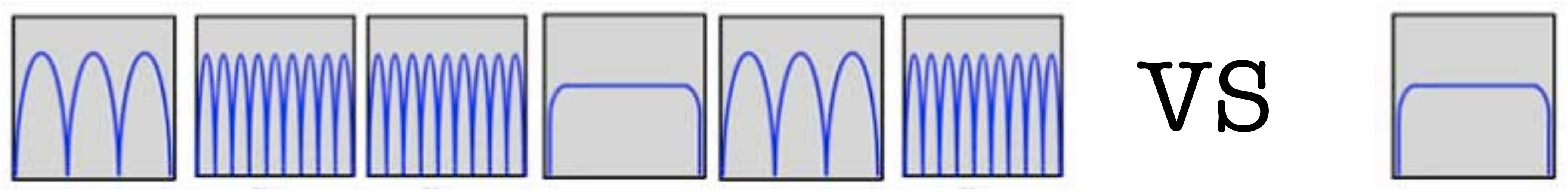
Motivations

The problem with haptic: example



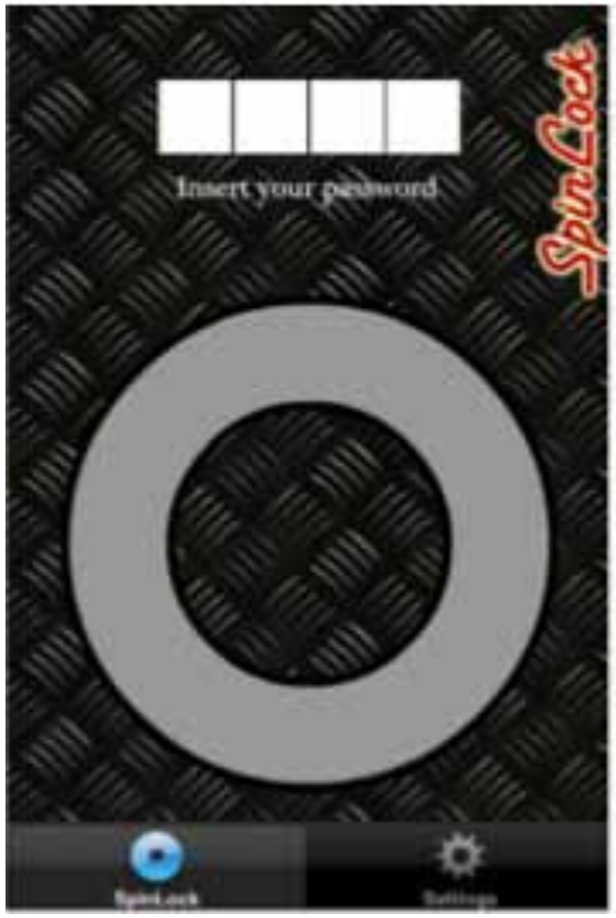
The problem with haptic: example

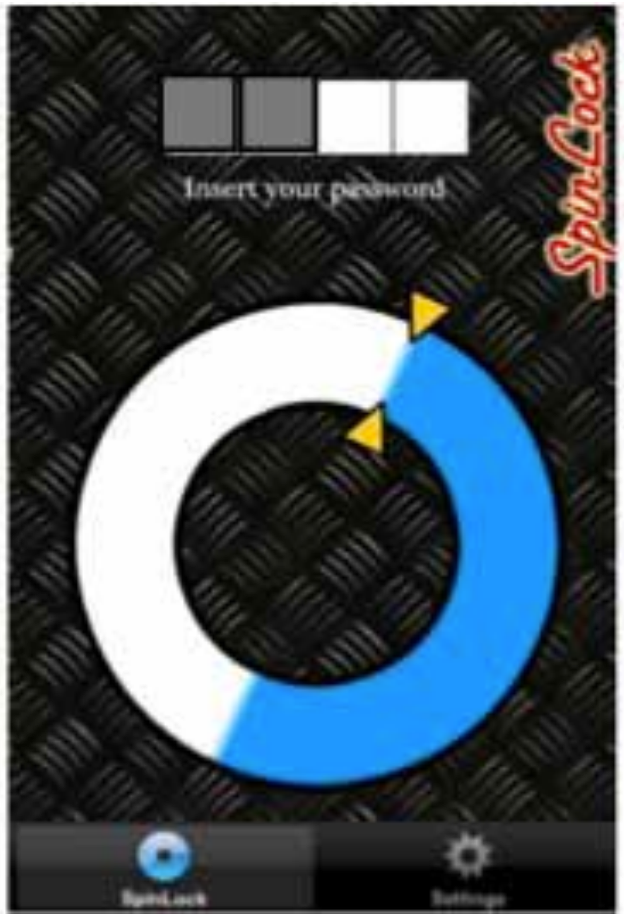
Can we create an interface with only 1 tactile cue instead of using many?

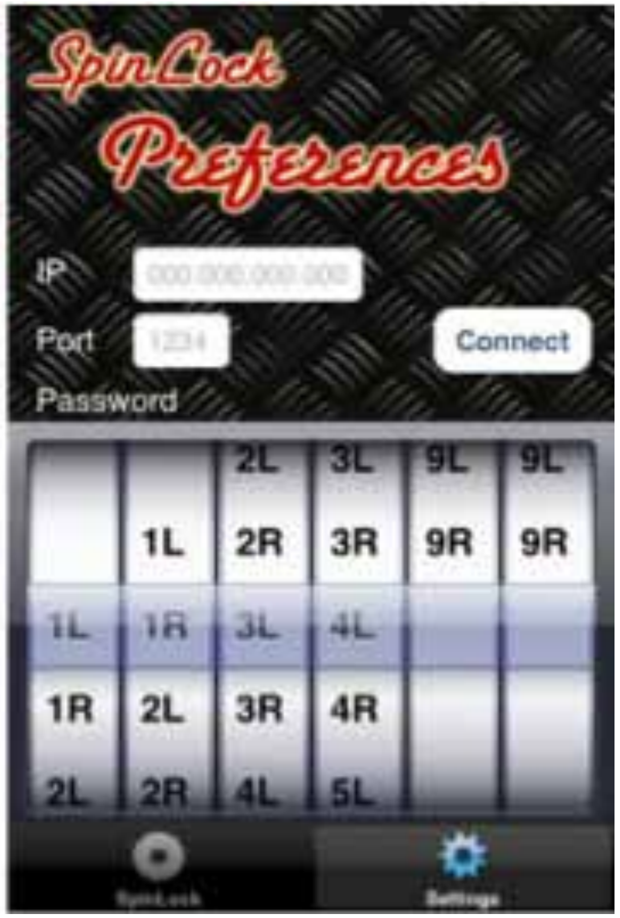


Can we build an interface with a different interaction methods that doesn’t require recognition but only counting?

Interaction principle







IP 000.000.000.000

Port 1234

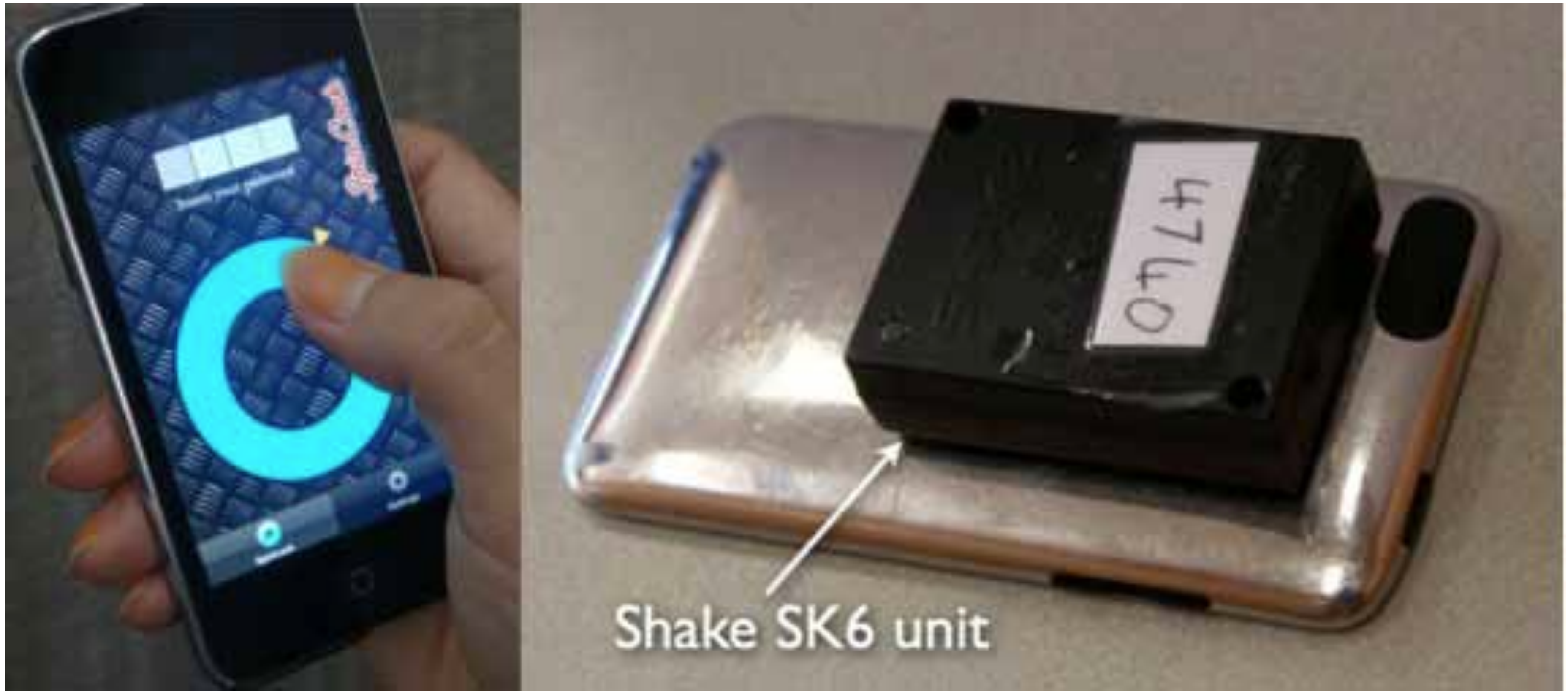
Password

		2L	3L	9L	9L
	1L	2R	3R	9R	9R
1L	1R	3L	4L		
1R	2L	3R	4R		
2L	2R	4L	5L		

Using a similar interaction of a safe dial:

directions + numbers (e.g. 2 left, 3 right, 4 left...)

Implementation for a phone

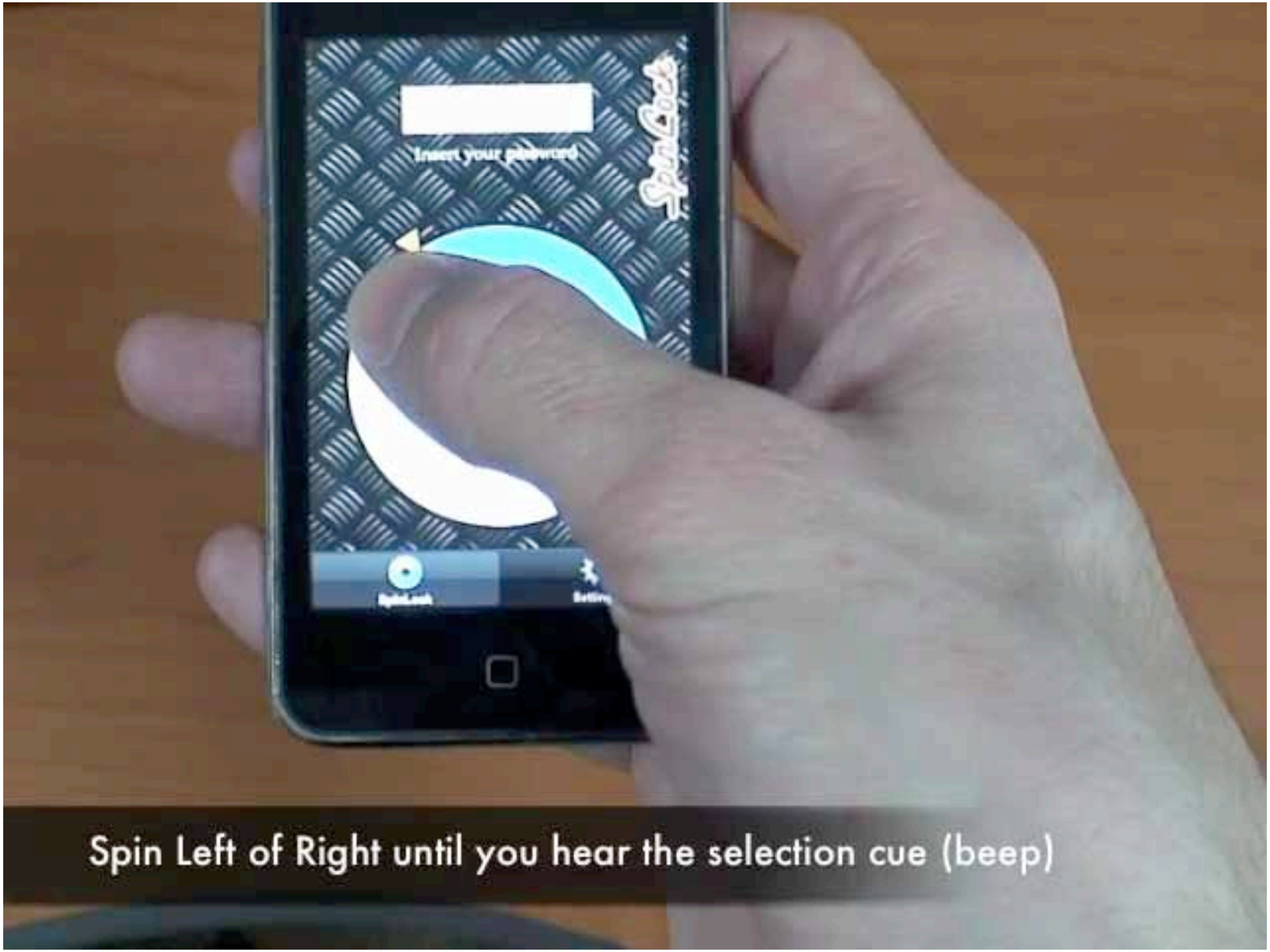


Password are a sequence of direction-number of buzzes or beeps

Implemented for phone devices

Using haptics and audio output

How it works: example



Spin Left of Right until you hear the selection cue (beep)

User Study Planning

User study to compare performance of audio vs haptics, with different password sizes.

Hypothesis 1:

counting is faster than recognition

Hypothesis 2:

counting is less error prone than recognition

Hypothesis 3:

counting comports smaller cognitive load than recognition

The user study

2 modalities x 2 PIN complexity

haptic/audio numbers 1-5 / numbers 1-10

12 participants (7 male, 5 female with age between 22 and 30 years)

15 trials (first 5 as training)= 480 complete correct PIN entries and 1920 individual data input

PIN randomly generated

User Study Balancing

Repeated measures experiment

	PIN	Modality
User 1	Short	Haptic
User 2	Long	Haptic
User 3	Short	Haptic
User 4	Long	Audio
User 5	Short	Audio
User 6	Long	Audio
User 7	Short	Haptic
User 8	Long	Haptic
User 9	Short	Haptic
User 10	Long	Audio
User 11	Short	Audio
User 12	Long	Audio

PIN complexity was balanced among participants

Modality was balanced within each PIN complexity block

User Study Setup

Quiet room

Procedure:

Demographic + Instruction + Free test + 4 studies + TLX

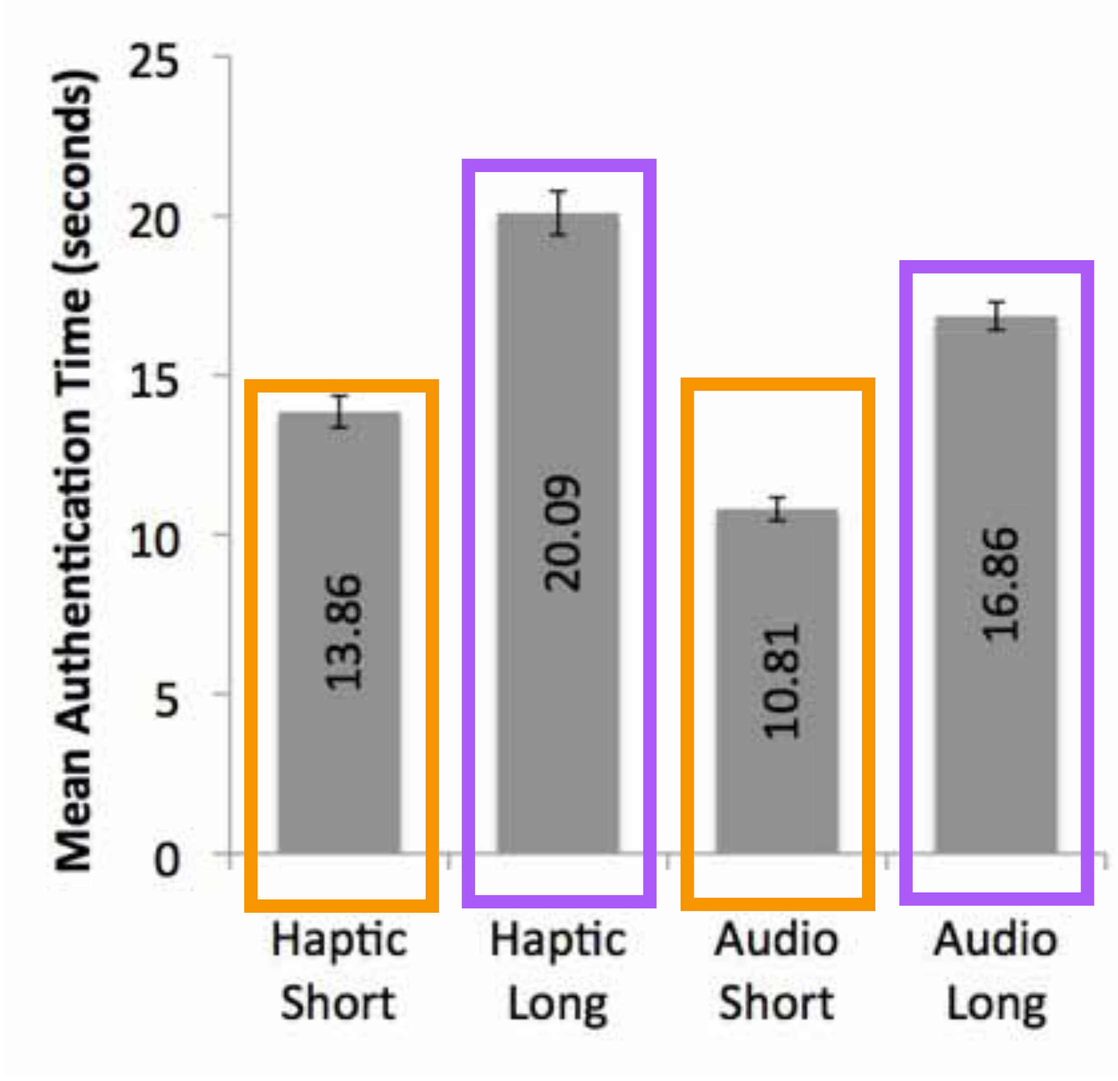
Mobile devices + connected to PC and Bluetooth for generating haptics

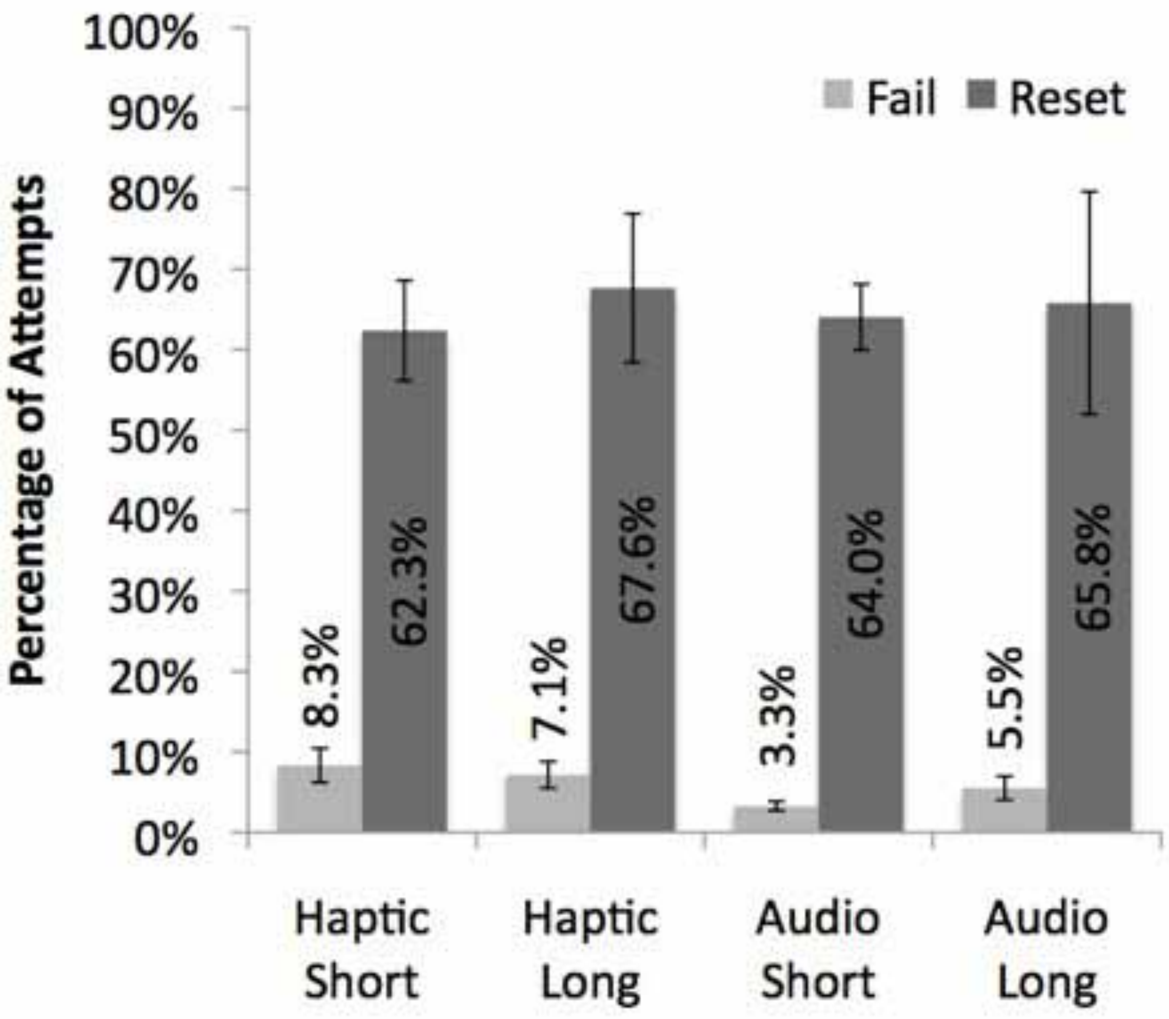
All data were tested using two-way repeated measures ANOVAs.

Results: time and errors

Time: *significant effect on modality and PIN complexity* (p<0.05) but no interaction

Error: *significant effect only on modality* (p<0.05)

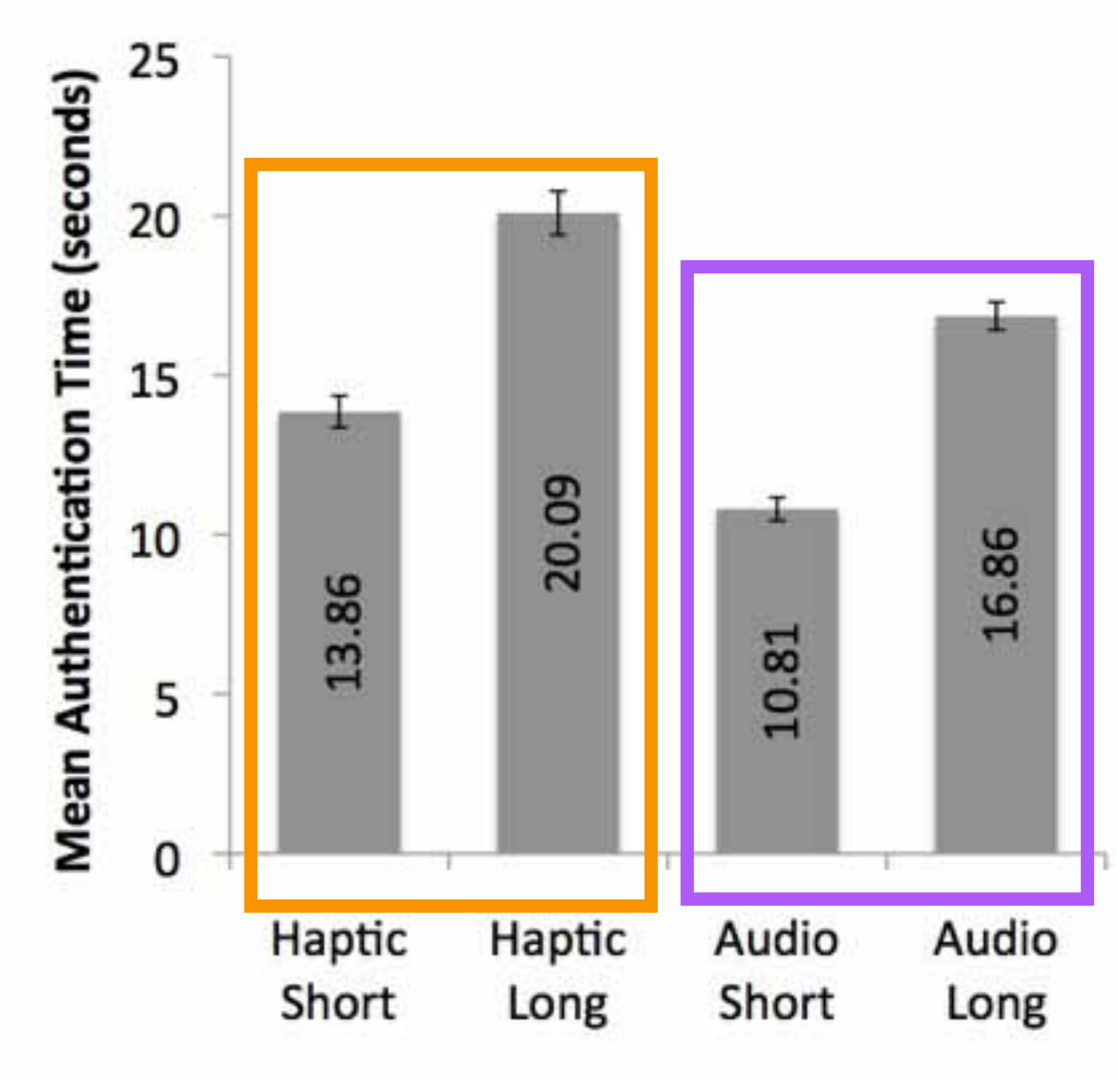


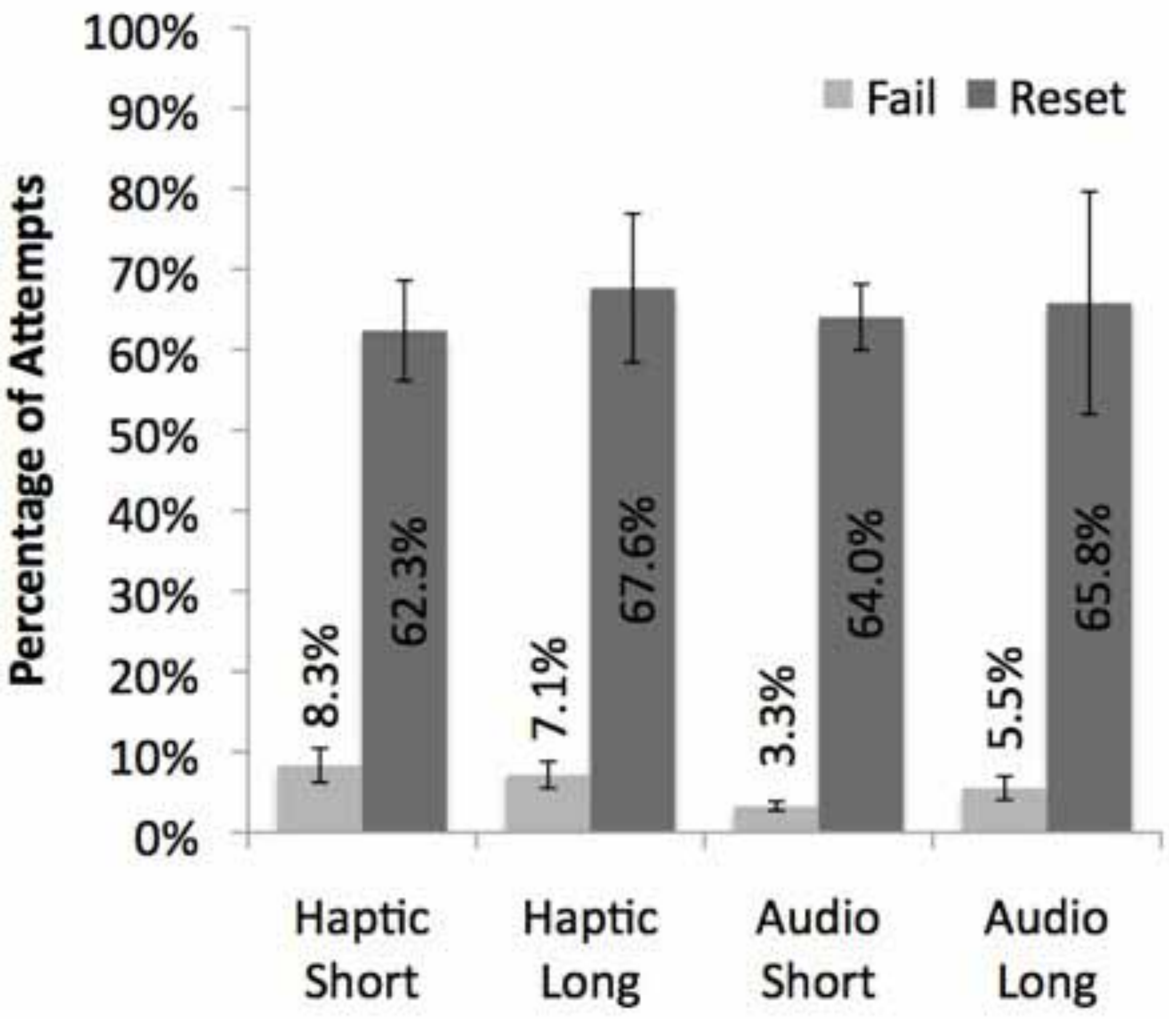


Results: time and errors

Time: *significant effect on modality and PIN complexity* (p<0.05) but no interaction

Error: *significant effect only on modality* (p<0.05)

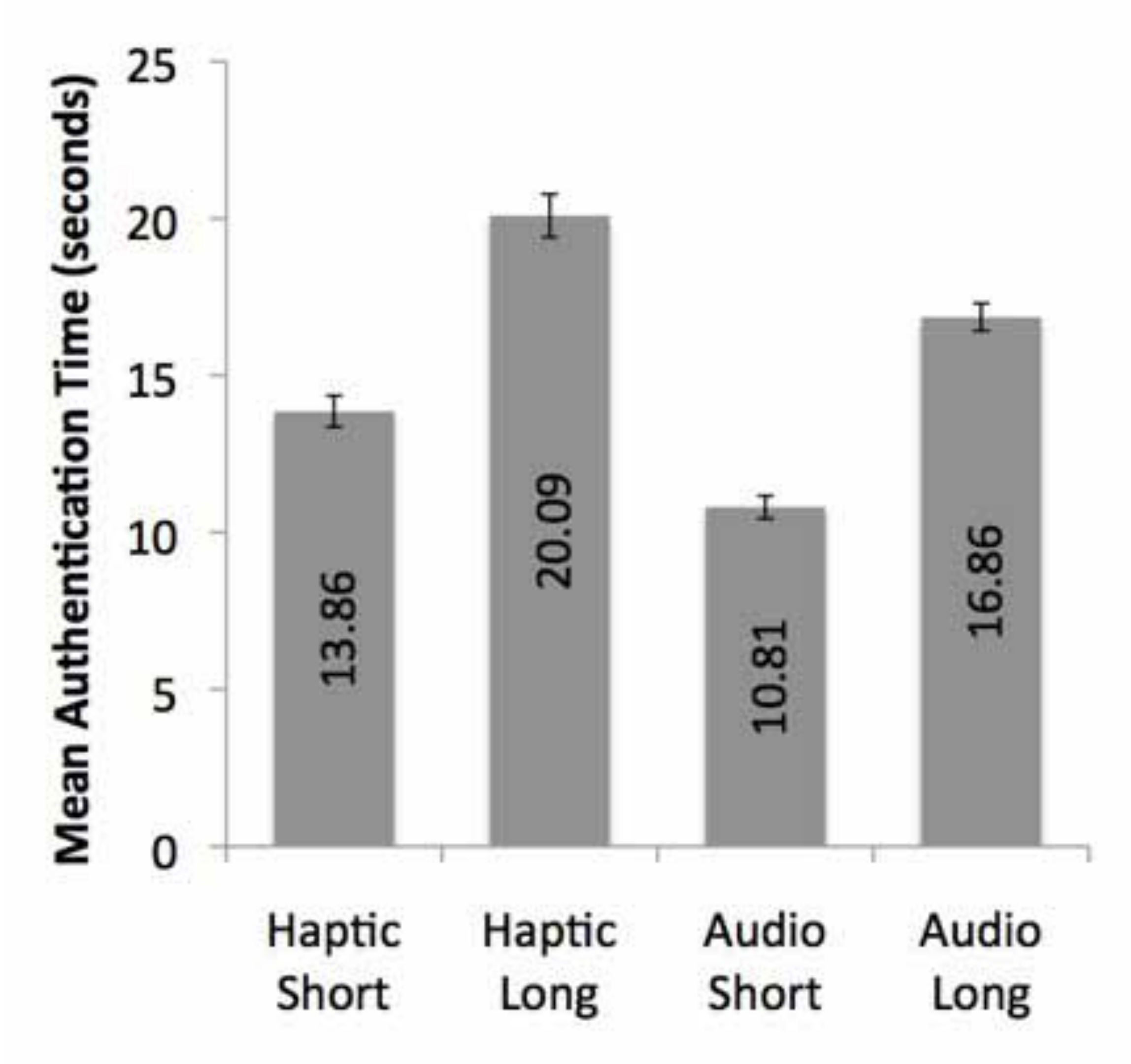


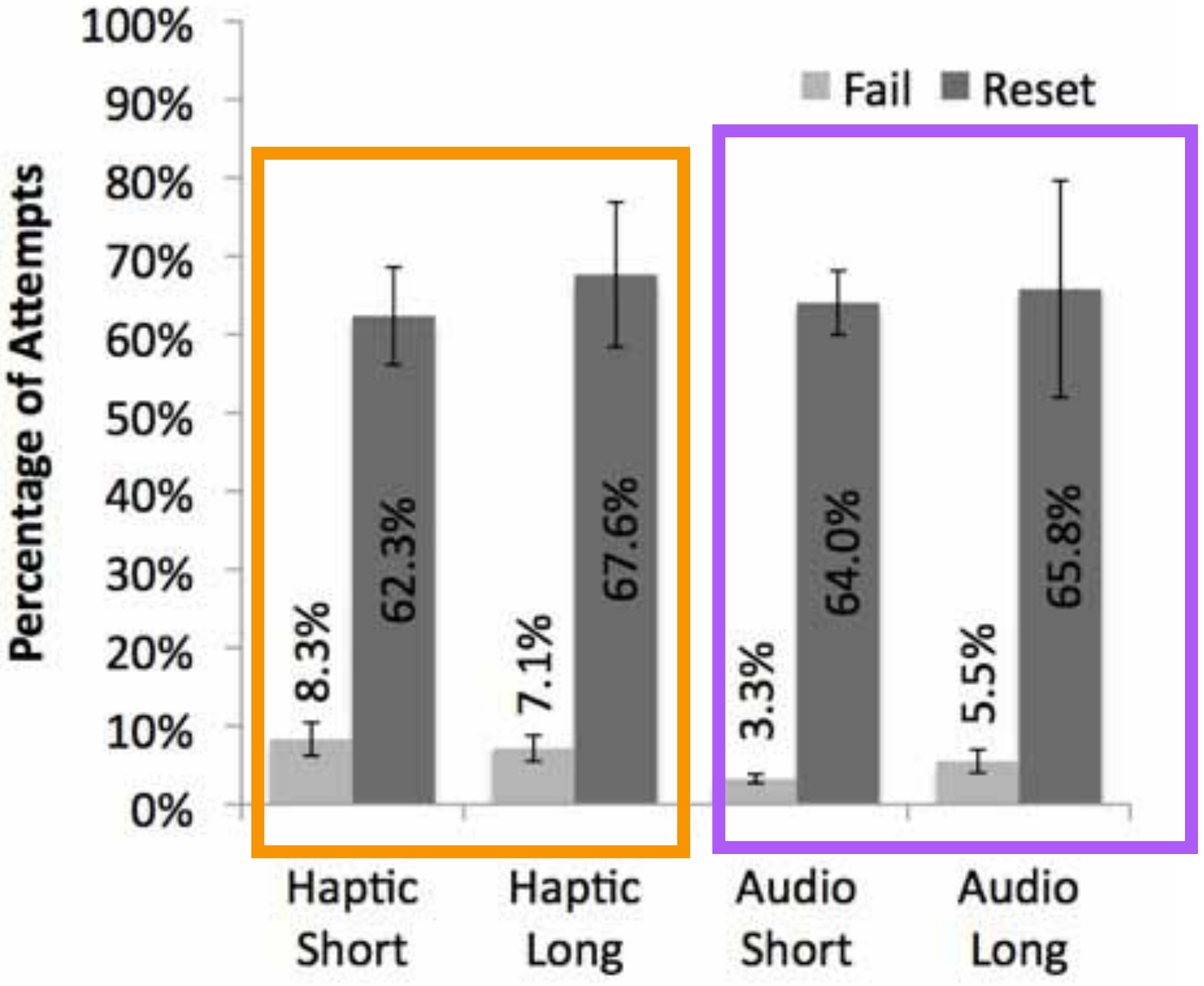


Results: time and errors

Time: *significant effect on modality and PIN complexity* (p<0.05) but no interaction

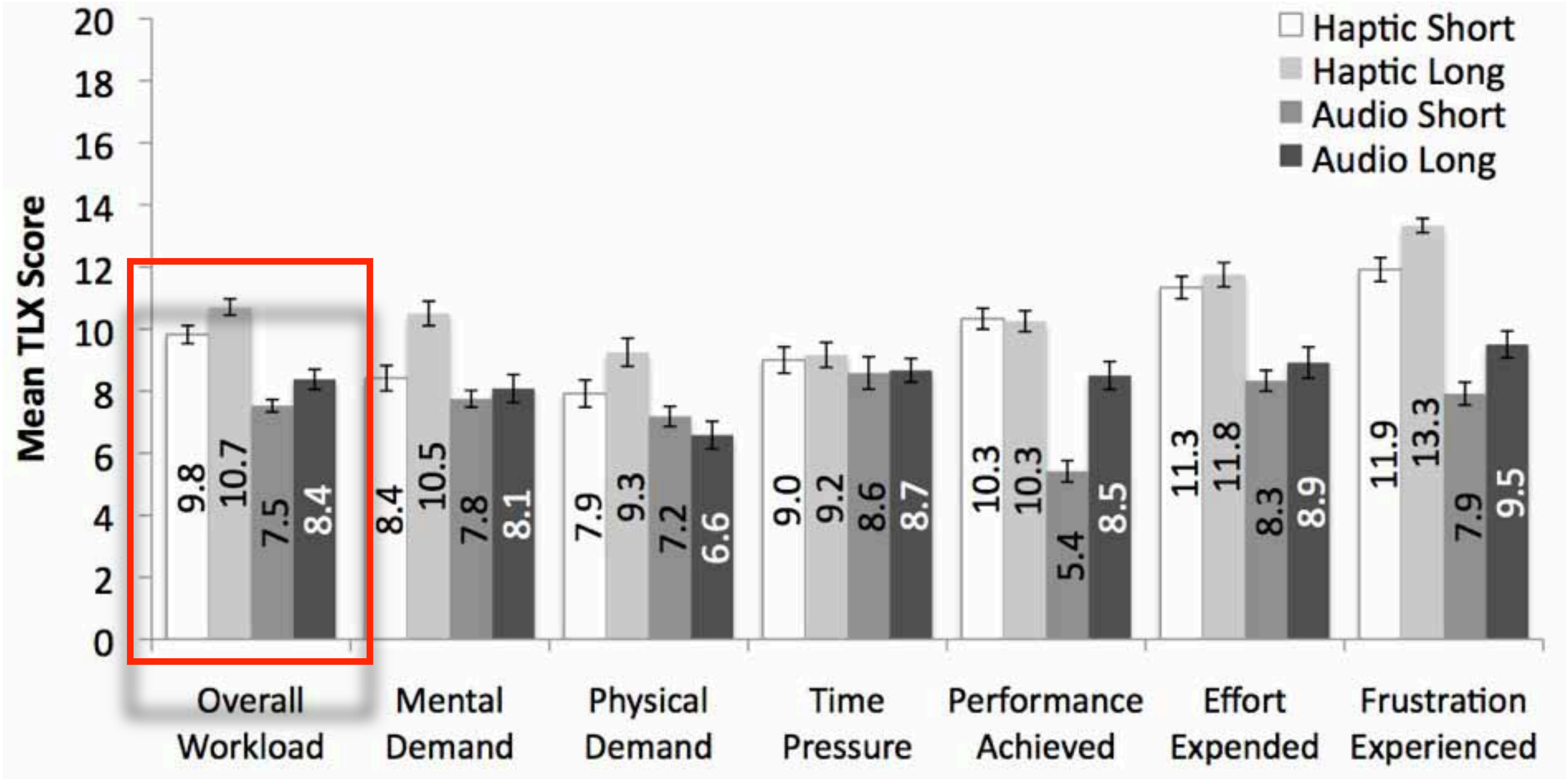
Error: *significant effect only on modality* (p<0.05)





Results: cognitive load

The two-way ANOVA on the overall workload of the TLX showed a *significant effect of modality* (p=0.002) but not PIN complexity



Discussion

Haptic modality more challenging but preferred as it was **more “private”.**

HAPTIC

Significant differences were observed in the mean PIN entry times, failed authentication rates and overall workload.

One possible explanation for this is system **latency**.

PIN COMPLEXITY

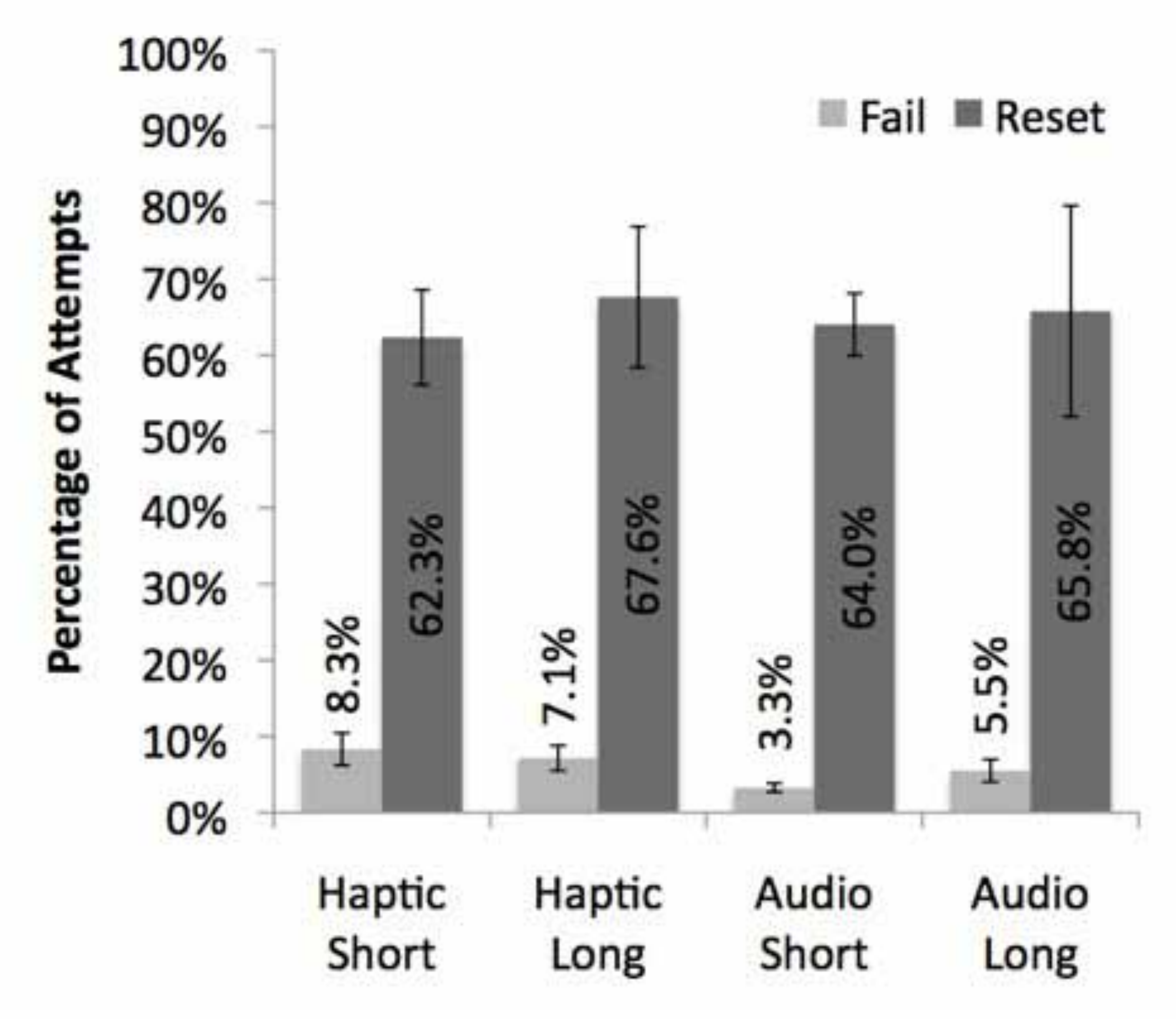
PIN complexity, on the other hand, resulted in **increased task completion times**, but had no significant effect on other metrics.

Discussion

82% of error trials involved a mistake in only one PIN item.

The majority of errors (78%) involved entering digits one higher or lower than the target item.

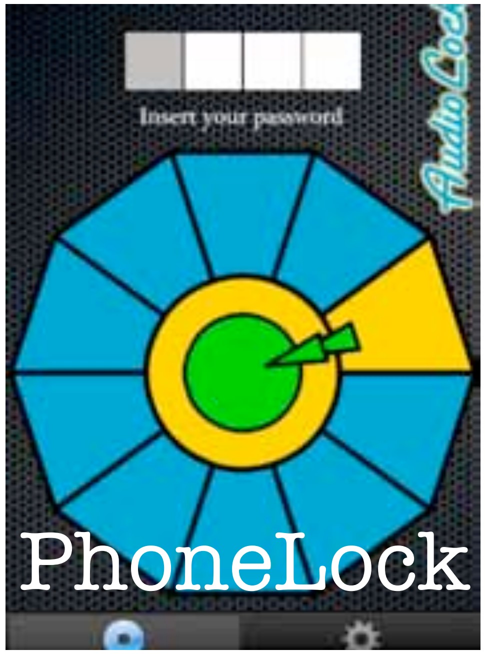
That participants were typically aware of such errors (= resets)



Comparison

Spinlock also performs well compared to previous systems

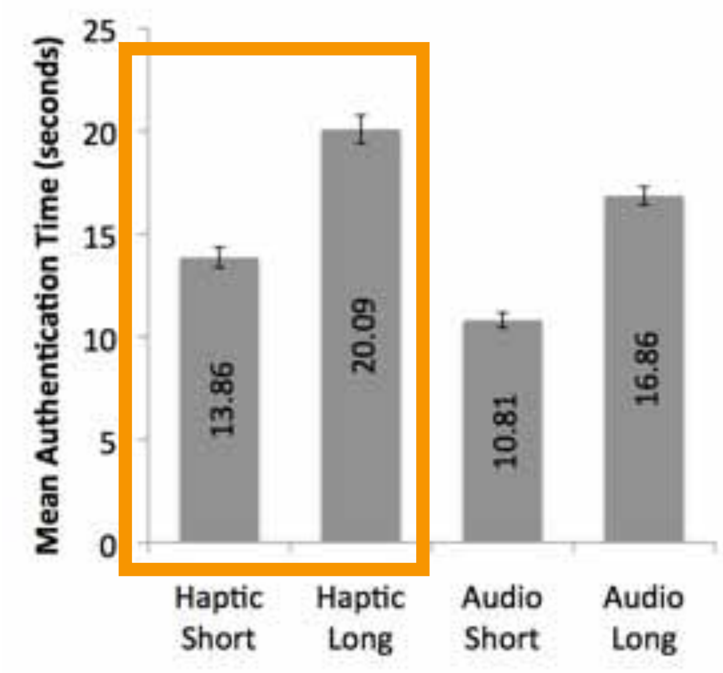
15.4 seconds and 6%

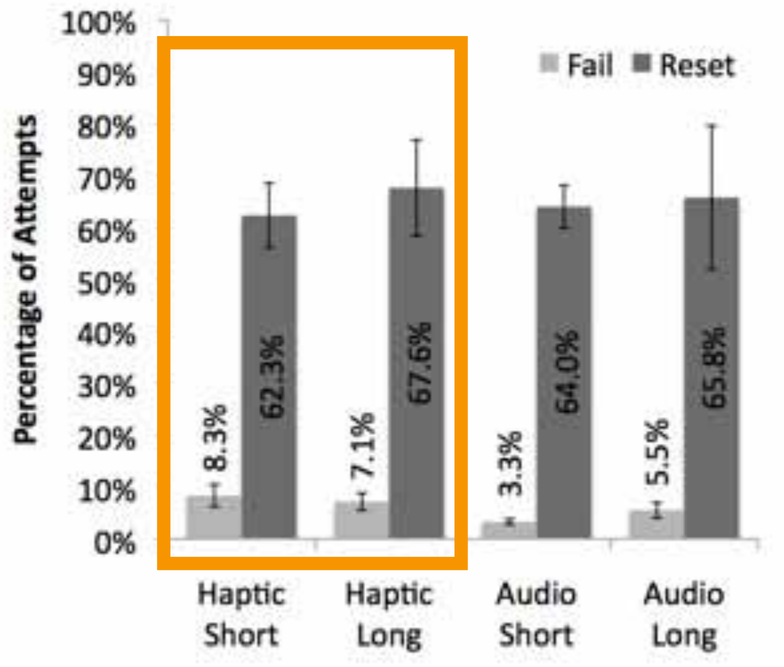


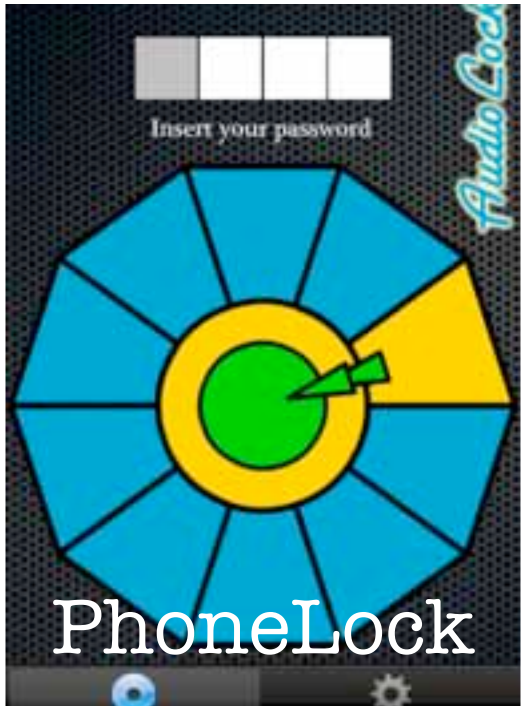
18.7 seconds and 7% errors

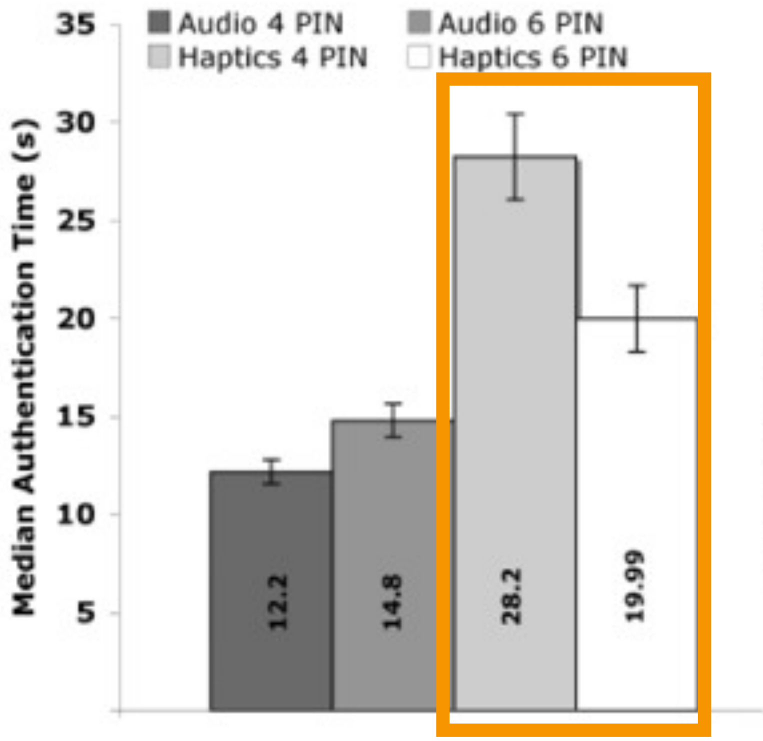
Haptic Comparison

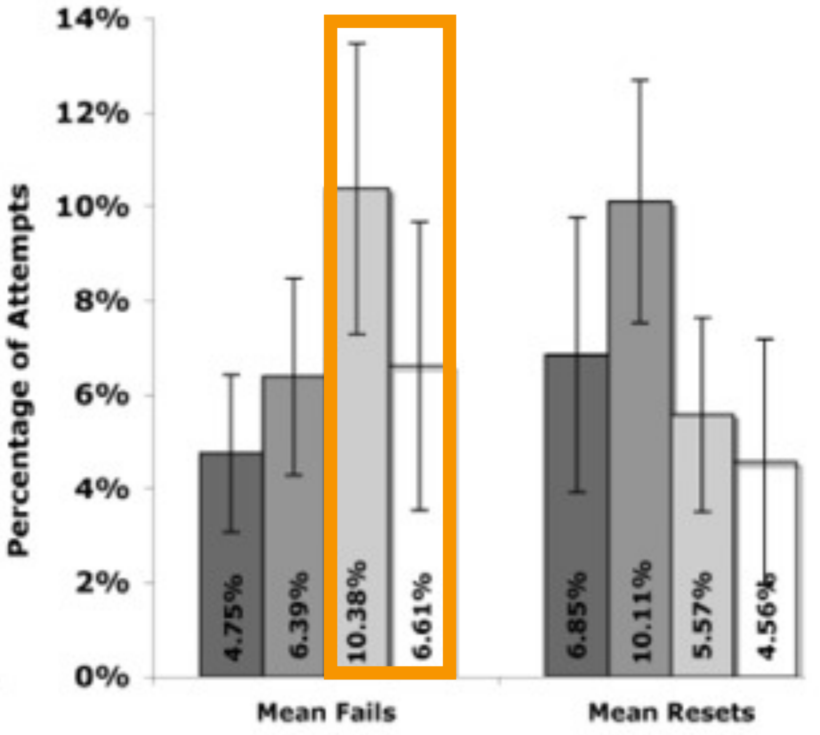
Results







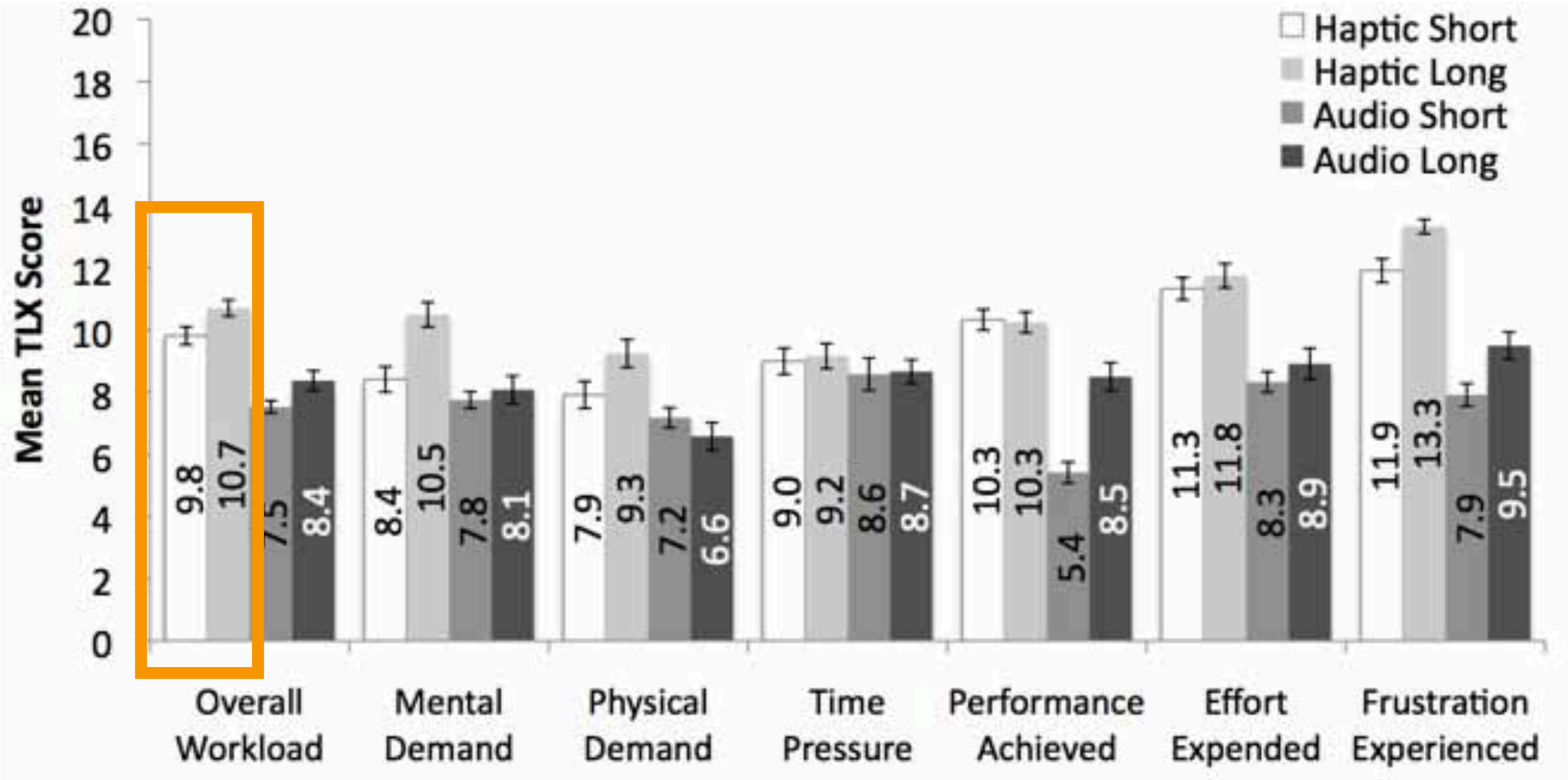


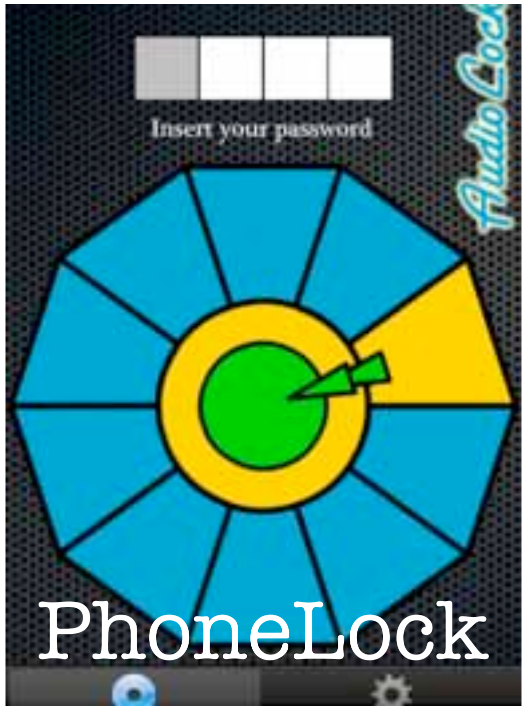


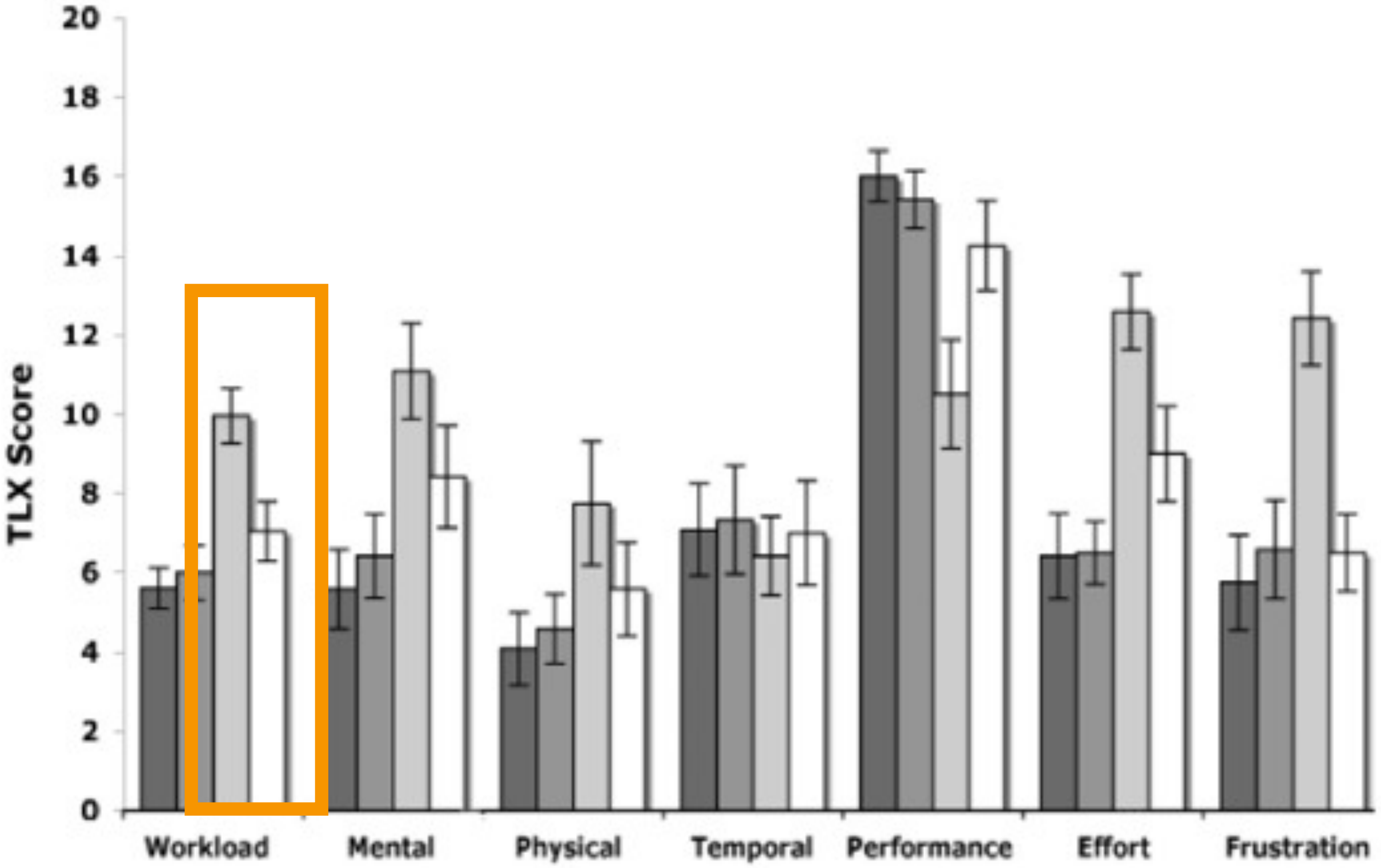
Haptic Spinlock system improves 30% over that reported in PhoneLock

Haptic Comparison

Results







Conclusions

User study to compare performance of audio vs haptics, with different password sizes.

Hypothesis 1:

counting is faster than recognition

ACCEPTED

Hypothesis 2:

counting is less error prone than recognition

ACCEPTED

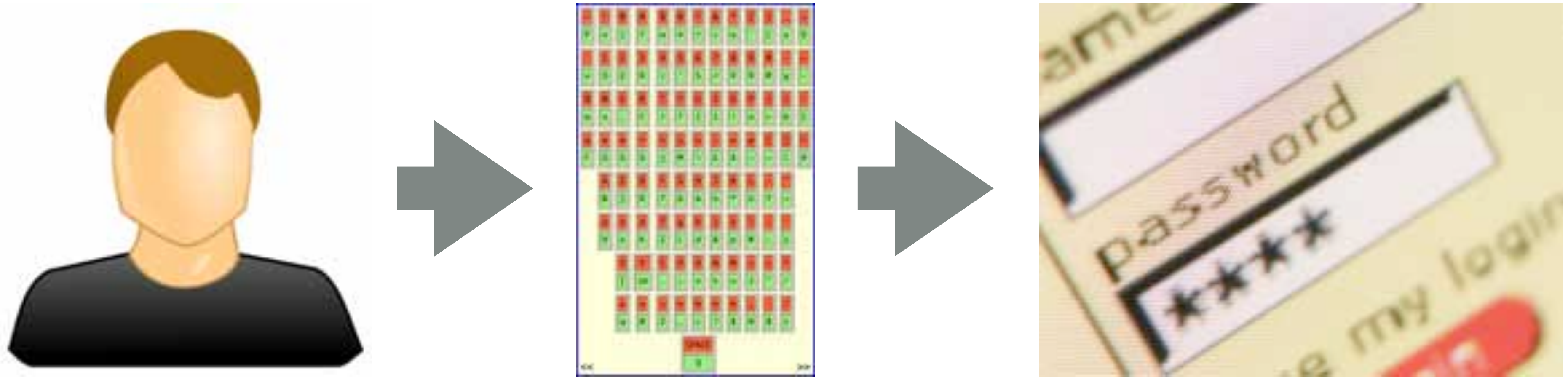
Hypothesis 3:

counting comports smaller cognitive load than recognition

ACCEPTED

PART II

THE ENEMY WITHIN: PROTECTED KEY COMMUNICATION FOR UNTRUSTED TERMINALS



SOFTWARE MEDIATED INPUT

UNTRUSTED TERMINALS

The password can be kept secret by the user...

...and encryption can keep it secure within the network...

...but it still has to be entered "in the clear" at the terminal!

keystroke loggers are a major method of password observation & compromise.

- OS-level loggers on pwned machines
- Malicious logging hardware

BEING RECORDED

Many examples of malware install logging software...

...as do stalkers such as jealous husbands, employers, governments...

Some UI elements that may be logged:

- Keystrokes
- Mouse clicks
- Screenshots
- Mouse movements

PASSWORD MANAGEMENT

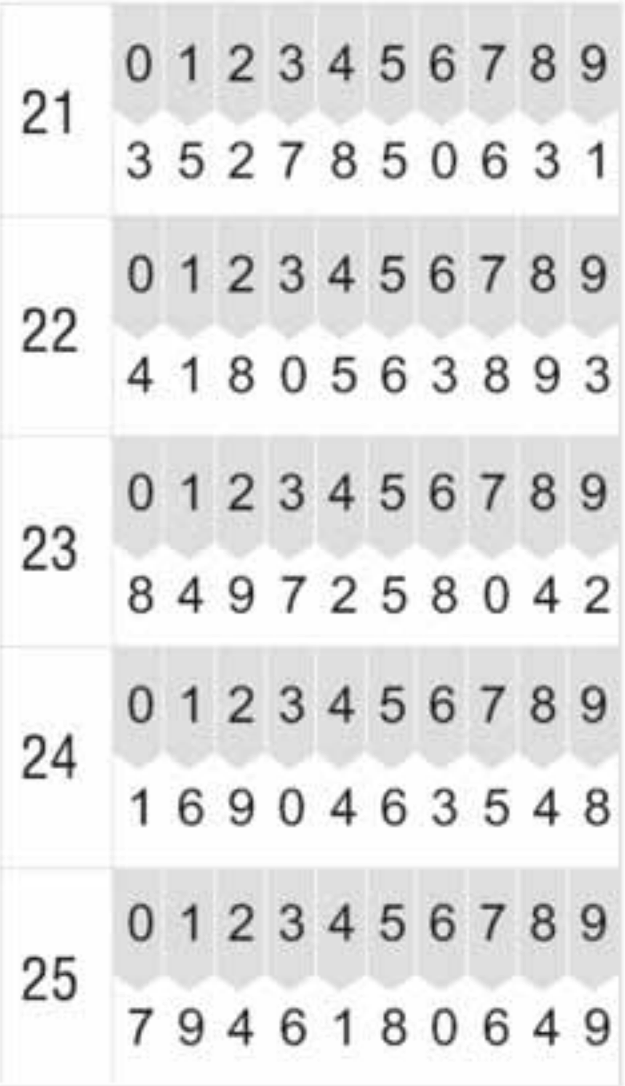
Computers & browsers now commonly contain “Keychain” password management software...

...but that’s no help on an untrusted public terminal...

...and sometimes you just have no choice but to use that internet café in Uzbekistan.

SOME WEB PROTECTIONS

- Forced password changes
  - Damage control
- Image-based access methods
- Changing security questions
- One-time-password via SMS
  - Phone theft gives bonus account access
- One-time-PIN token
  - Reduces value of stealing password
- Printed list of one-time password modifiers



21	0	1	2	3	4	5	6	7	8	9
	3	5	2	7	8	5	0	6	3	1
22	0	1	2	3	4	5	6	7	8	9
	4	1	8	0	5	6	3	8	9	3
23	0	1	2	3	4	5	6	7	8	9
	8	4	9	7	2	5	8	0	4	2
24	0	1	2	3	4	5	6	7	8	9
	1	6	9	0	4	6	3	5	4	8
25	0	1	2	3	4	5	6	7	8	9
	7	9	4	6	1	8	0	6	4	9

Few sites offer multiple options, and in many cases not even one!

PROBLEM SUMMARY

Ideal outcome:

Application software for increased resistance to credential loss & replay attack for **any website**

Public terminal constraints:

- Can't verify integrity of system
- Usually can't install or run application software

BUT

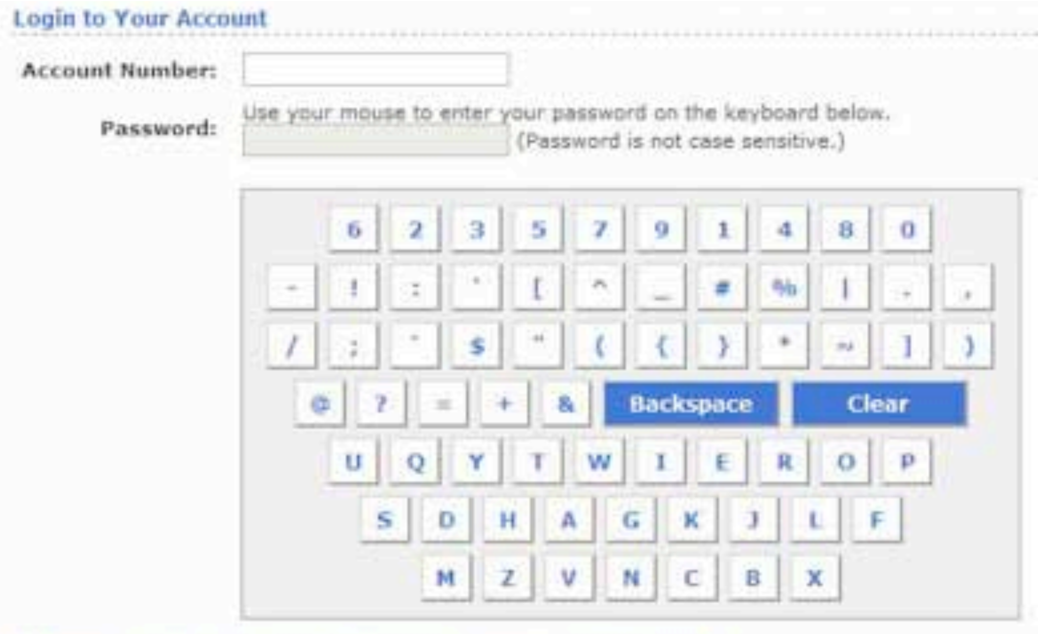
- Can access pretty much any web content

Goal: obfuscate data entry via simple, minimally tedious web mechanics

COMMON NAÏVE APPROACHES

- Defense: "Scissor" password copy-paste
  - Counterattack: Clipboard logging

- Defense: Character select-drag-drop
- Defense: Onscreen keyboards
  - Counterattack: Mouse click screen region capture



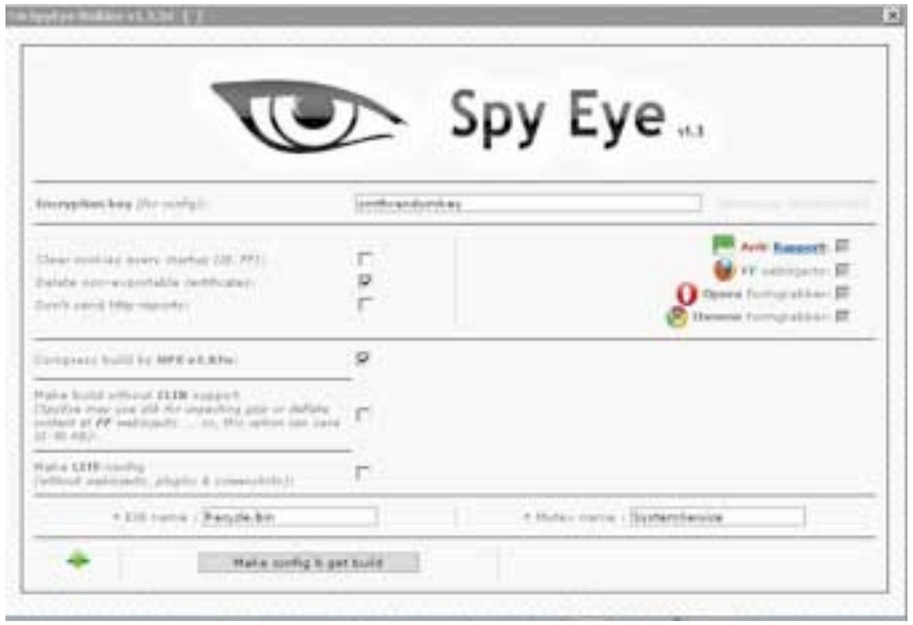
Login to Your Account

Account Number:

Password: Use your mouse to enter your password on the keyboard below. (Password is not case sensitive.)

- Defense: Chaff logs via tedious extraneous character entry
  - Counterattack: Log mining in concert with screen & mouse logging and timestamping (theoretical)

WHAT ABOUT FORM GRABBERS?



Spy Eye v1.3

Encryption key (for config): [illegible]

Clear cookies every startup (IE, FF): □
Delete non-exportable certificates: ☑
Don't send http reports: □

Anti Rapport: ☑
FF webinjects: ☑
Opera formgrabber: ☑
Chrome formgrabber: ☑

Compress build by UPX v3.07w: ☑

Make build without ZLIB support (SpyEye may use zlib for unpacking gzip or deflate content of FF webinjects ... so, this option can save 10-40 KB): □

Make LITE config (without webinjects, plugins & screenshots): □

* EXE name : Recycle.bin
* Mutex name : Systemdevice

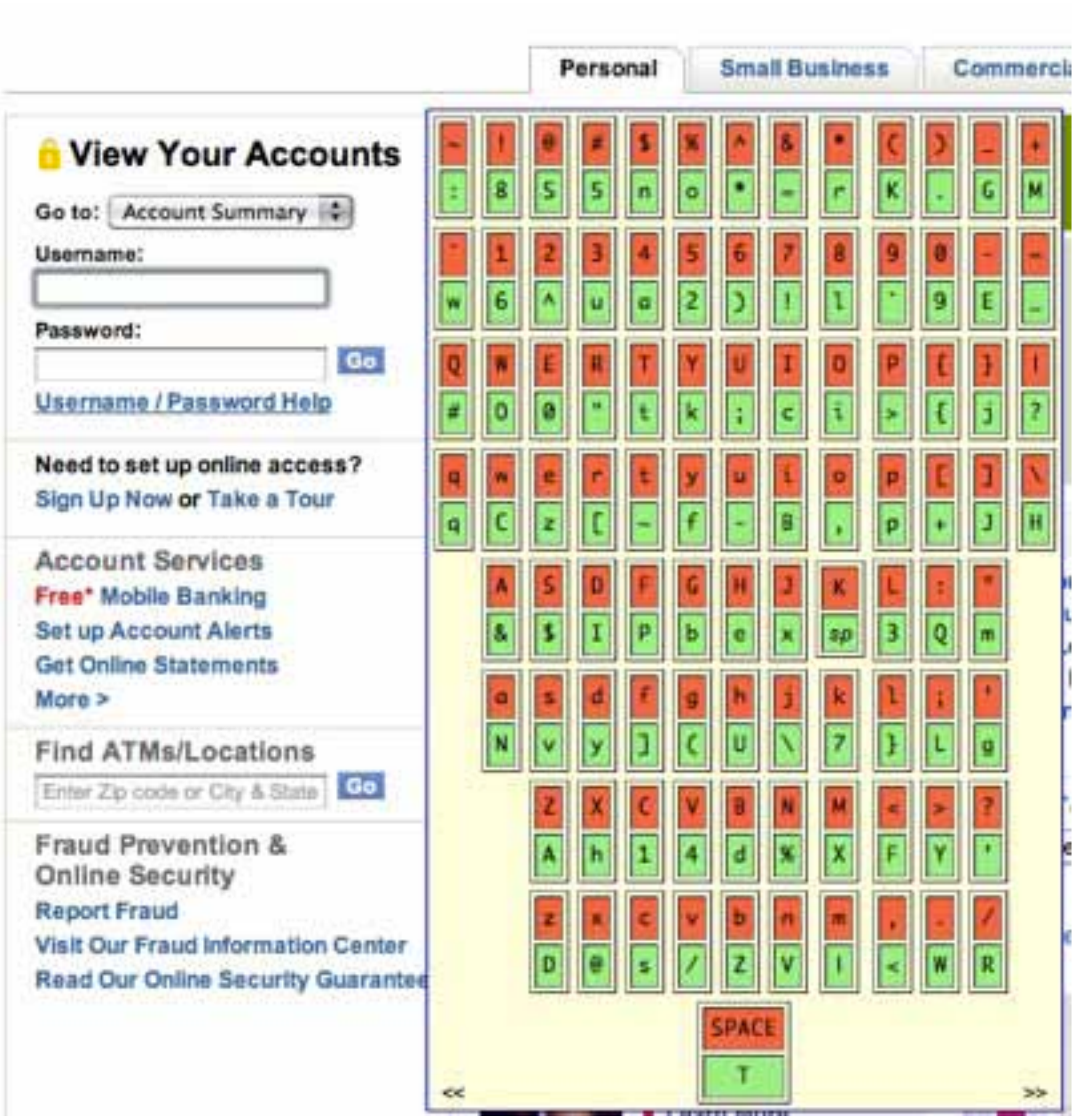
- Form grabbing malware hooks browser form submit pre-encryption
  - e.g. Online banking theft trojans ZeuS, SpyEye
- Represents majority of password-stealing trojans
- However:
  - Limited platform/browser support (currently Windows-only)
  - There is no UI mechanism that can defend against this tactic anyway
    - We are primarily interested in interface design
- Still worth defending against UI-device-level loggers

BASIC APPROACH

- Keep any sensitive text entirely out of key log
- Minimize data leakage via other UI logging mechanisms
- Novel interaction methods while trying to minimize tedium
- Support evolutionary ecosystem: force attackers to adapt
- Custom interface element production via JavaScript injection:

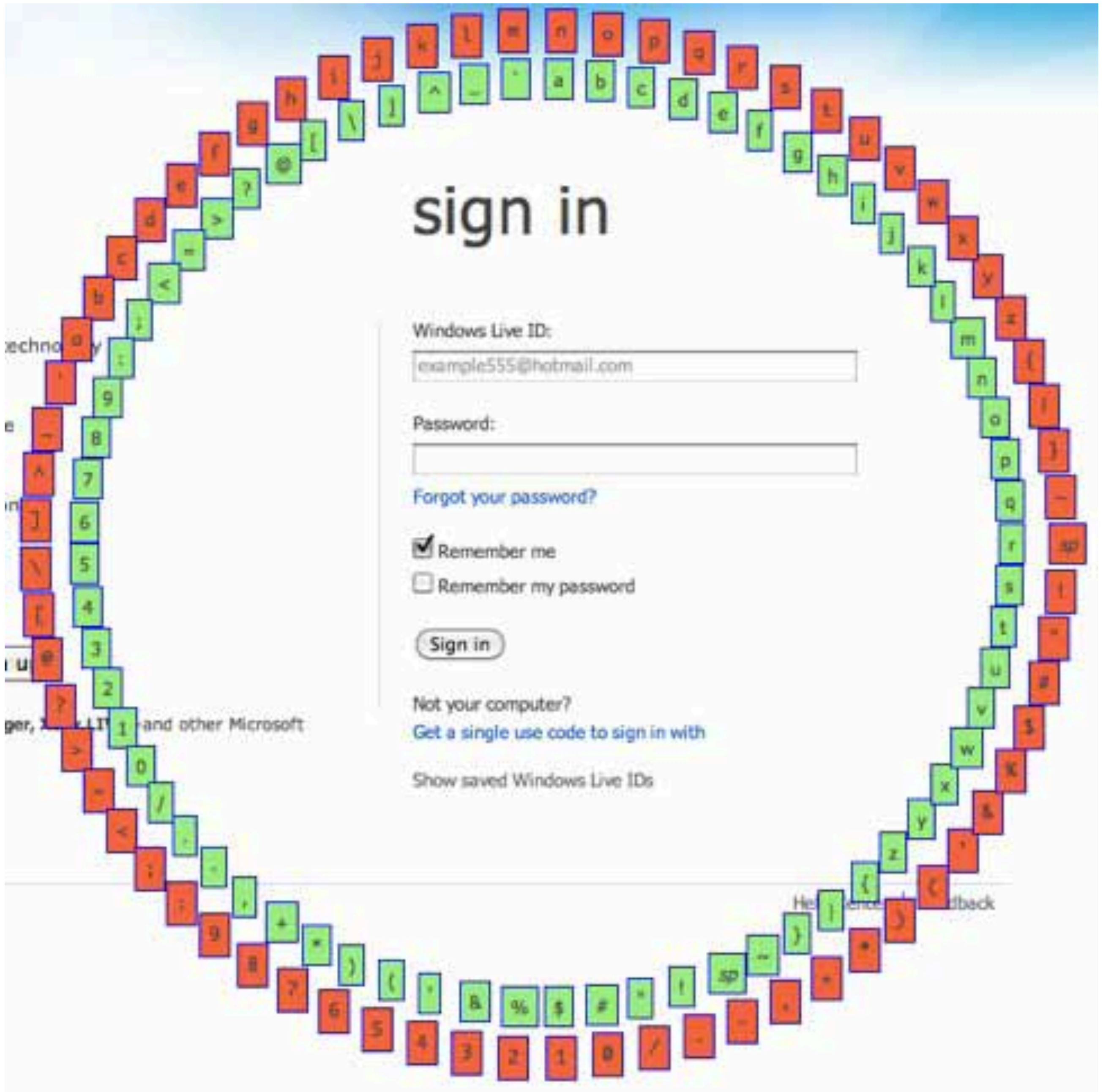
```
javascript:void((function() {var element=document.createElement('script');
element.setAttribute('type', 'text/javascript'); element.setAttribute('language',
'JavaScript'); element.setAttribute('src', 'https://path/to/logresist.js');
document.getElementsByTagName("head")[0].appendChild(element);})())
```

ONE-TIME-PAD SCRAMBLER



- Key remapper (no mouse)
- User interface metaphor: hunt-and-peck keyboard
- Can be regenerated on per-keystroke basis if required
- Susceptible to screen capture, but only if triggered by keystroke
- Keylog output: encrypted stream equal in length to plaintext
- Time cost: visual search

ROTARY INJECTOR



sign in

Windows Live ID:

example555@hotmail.com

Password:

Forgot your password?

☑ Remember me

□ Remember my password

Sign in

Not your computer?

Get a single use code to sign in with

Show saved Windows Live IDs

- Animated key selector
- User interface metaphor: combo lock
- Uses mouse but no clicks
- Susceptible to screen capture, but only if triggered by keystroke and synchronized with mouse pointer location history
- Keylog output: string of identical characters, arbitrary length
- Time cost: visual search plus (variable) animation

AUDIO KEYMAPPER

- Auditory stimulus to key location
- User interface metaphor: audio phone lock
- Immune to screen capture
- Keylog output: string of identical characters, arbitrary length
- Time cost: fixed animation

SUMMARY

- Give users choice of obfuscation methods independent of support offered by web service
- Seed ecosystem of custom methods easy to implement and select
- Offer modalities not traditionally logged (e.g. audio)
    - Force attackers to expend more effort
- Examples of methods from very large potential space
- User evaluation studies yet to be performed

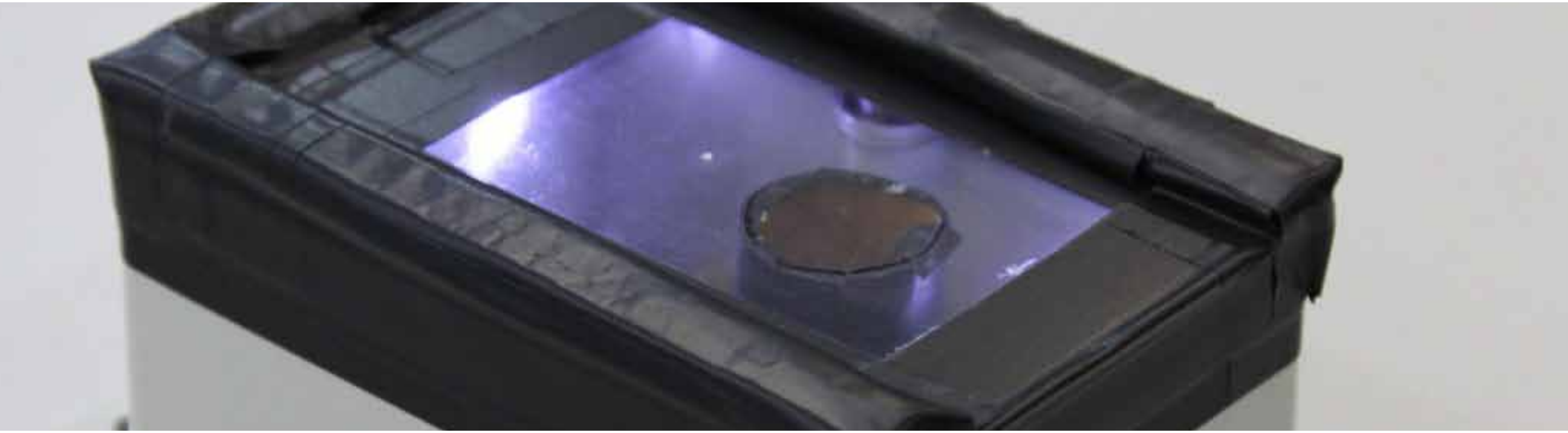
PART III

DESITUATING THE INTERACTION: PROTECTED KEY TRANSMISSION FOR PRIVATE DEVICE SOLUTIONS

HARDWARE MEDIATED INPUT

Luxpass

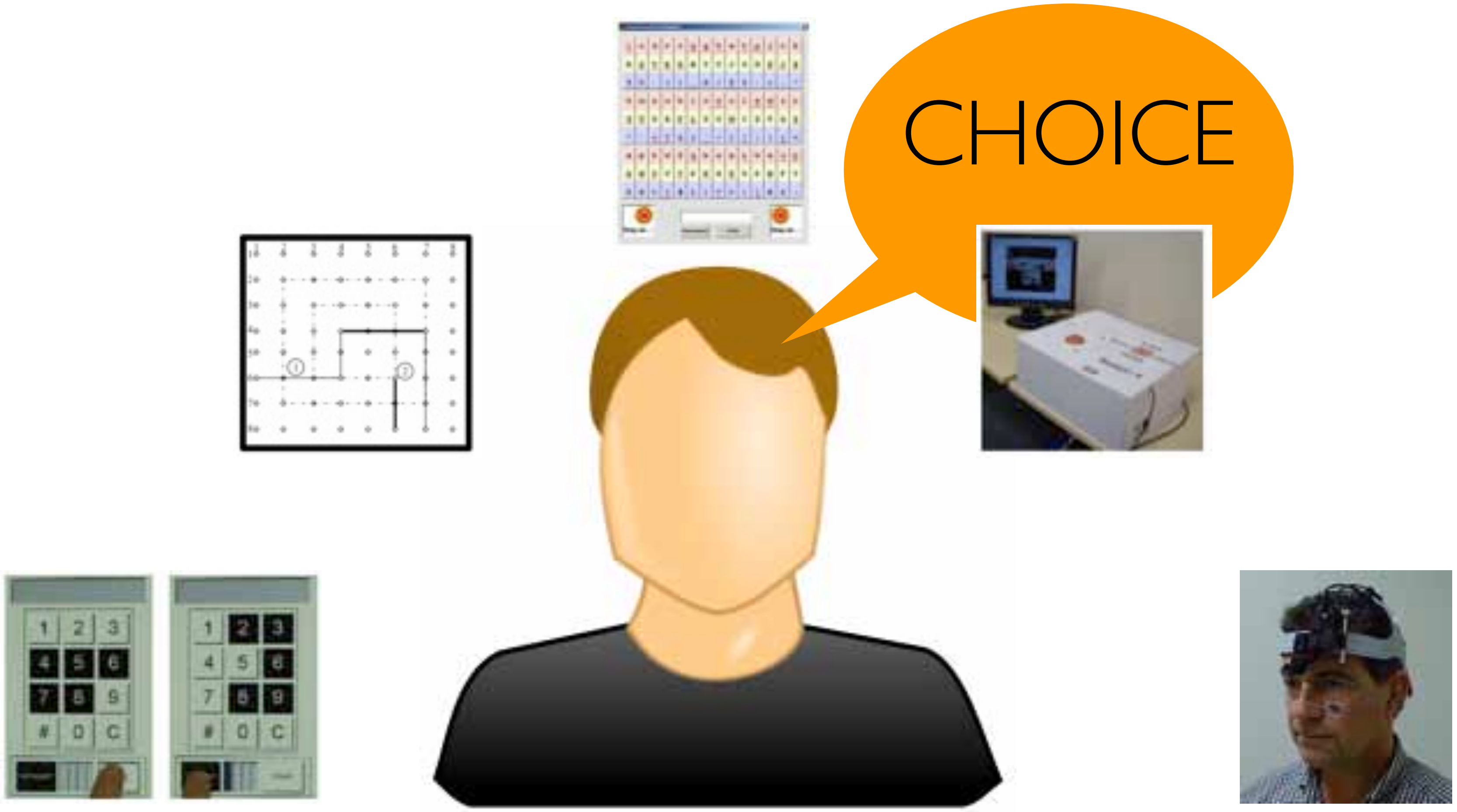
Using Light Patterns to Secretly Transmit a PIN



PRIVATE DEVICE MEDIATION

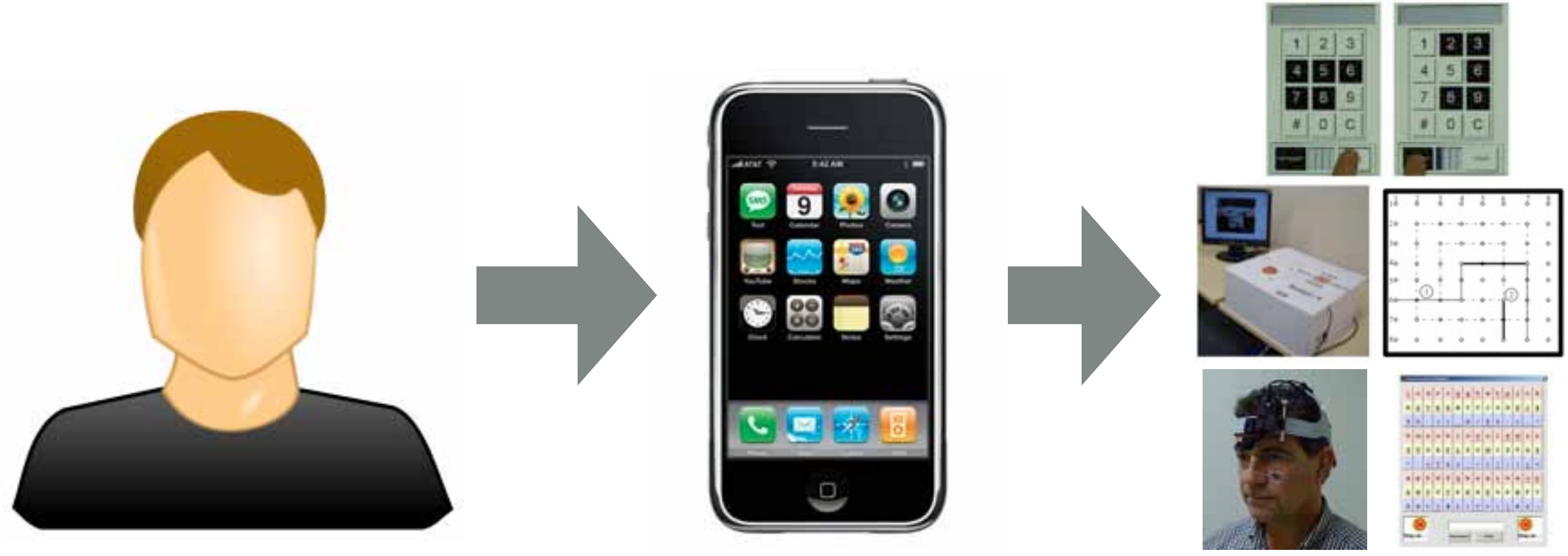
1. Different people want **different password schemes**

and a personal private device is where this is possible



PRIVATE DEVICE MEDIATION

2. **We want to move away the interaction** from the physical terminal **and a private device can help us in this too!**

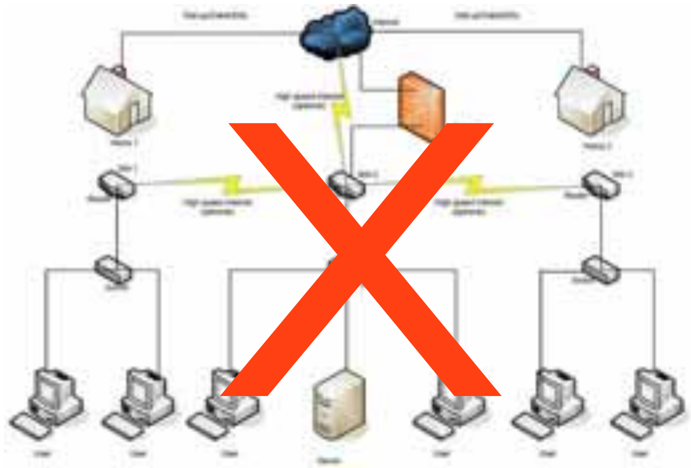


We shift the problem **from authentication to secure communication chanel**

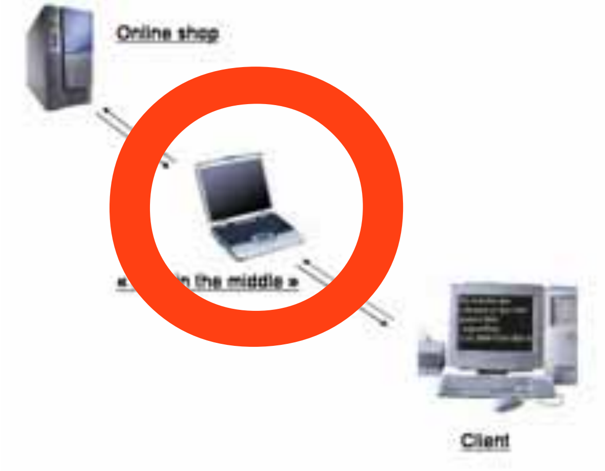
CURRENT PROBLEMS

Current problems with hardware mediated interaction

1. **Spontaneous interaction** - No pairing needed



2. **No wireless** - Safe against Man In The Middle Attack



3. **Fast** interaction, **easy** to use

PROPOSED MODEL

1) **Shift the interaction** away from the terminal, on a private device

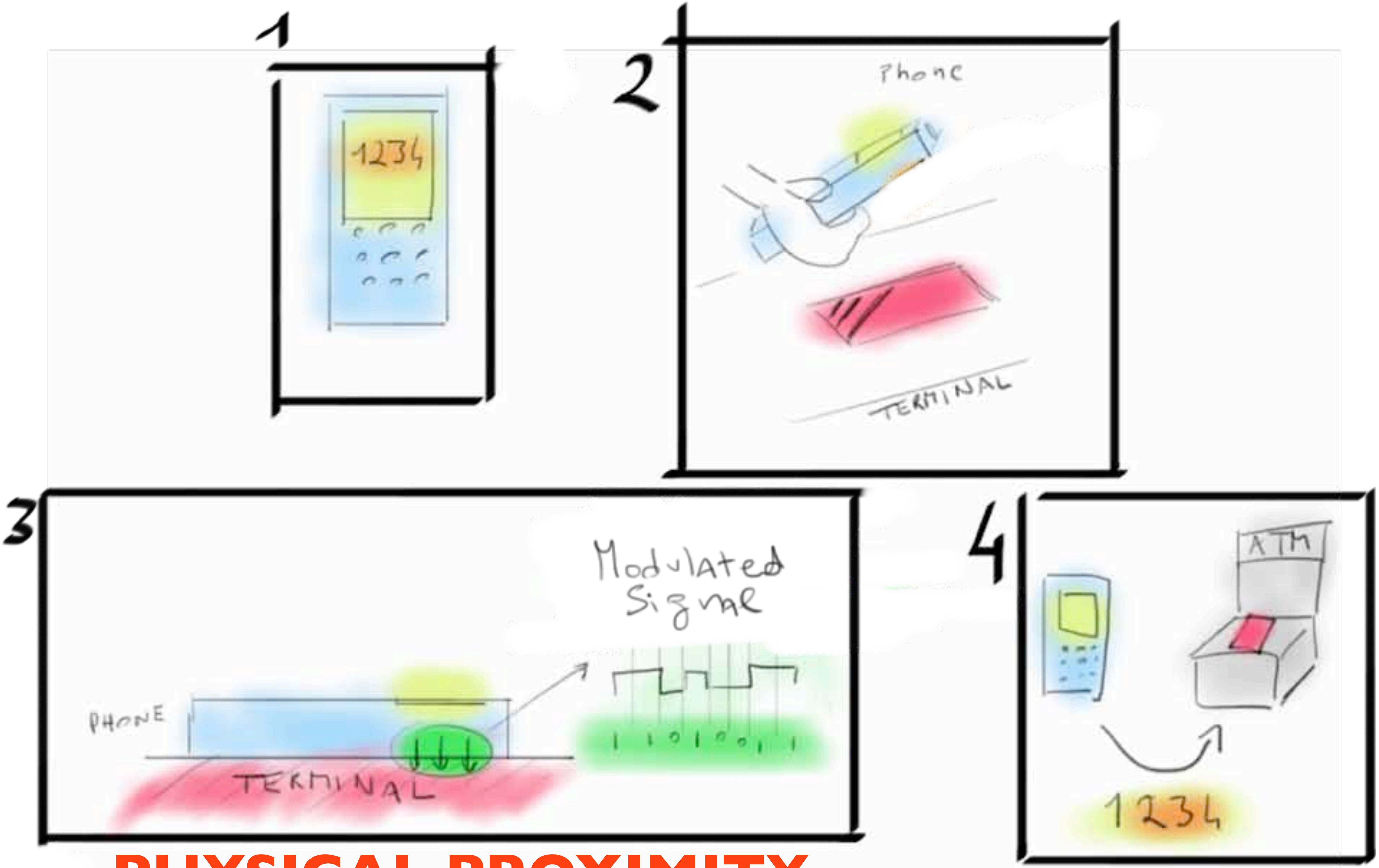
2) **Avoid wireless** to avoid a Man In The Middle (MITM) attack.

3) Secure authentication with **no pairing requirements**:
you cannot pair a phone to any terminal you will ever use. PKI is not always possible.

4) **Authentication, not identification**: RFID can be stolen more easily than passwords. Also passwords are easier to replace.

5) Must be **cheap** to make, to install. **Easy to use.**

WANTED INTERACTION



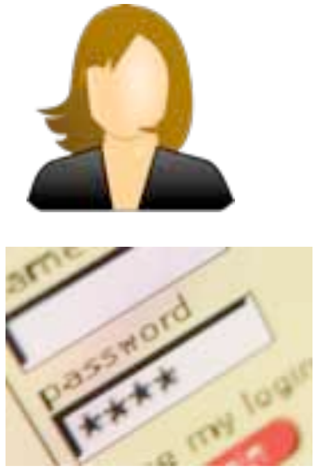
PHYSICAL PROXIMITY

LUXPASS

LuxPass (under submission)

INPUT ON PRIVATE INTERFACES

Encoding a password in light patterns



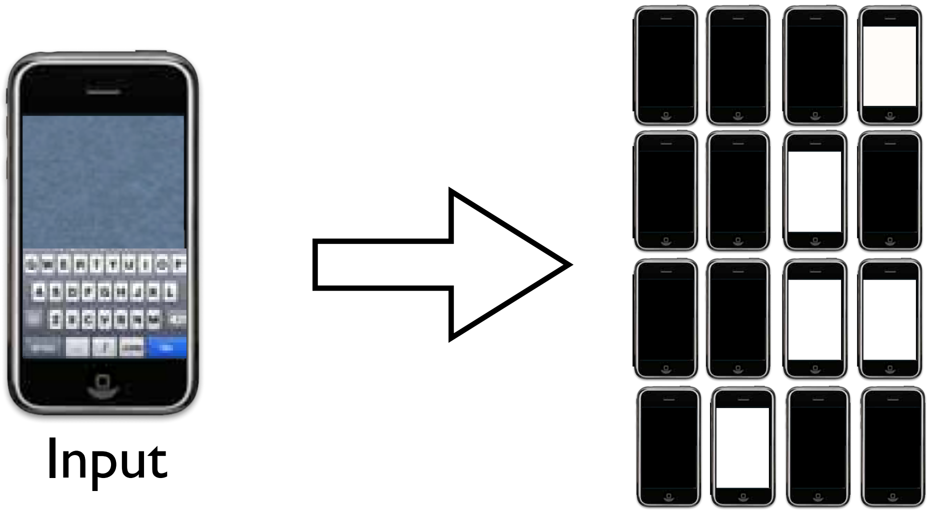
User has a password

Inserts a password on mobile phone

The password is encoded in a light signal (as with Morse)

Computer + light scanner get the signal and translate it

Authentication

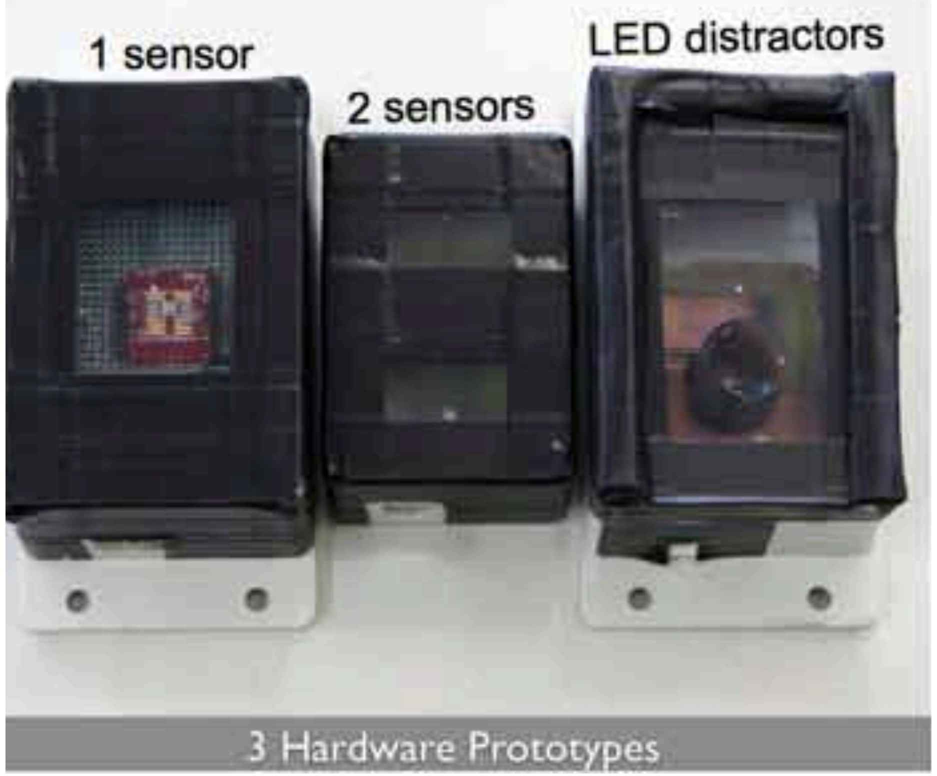


Input

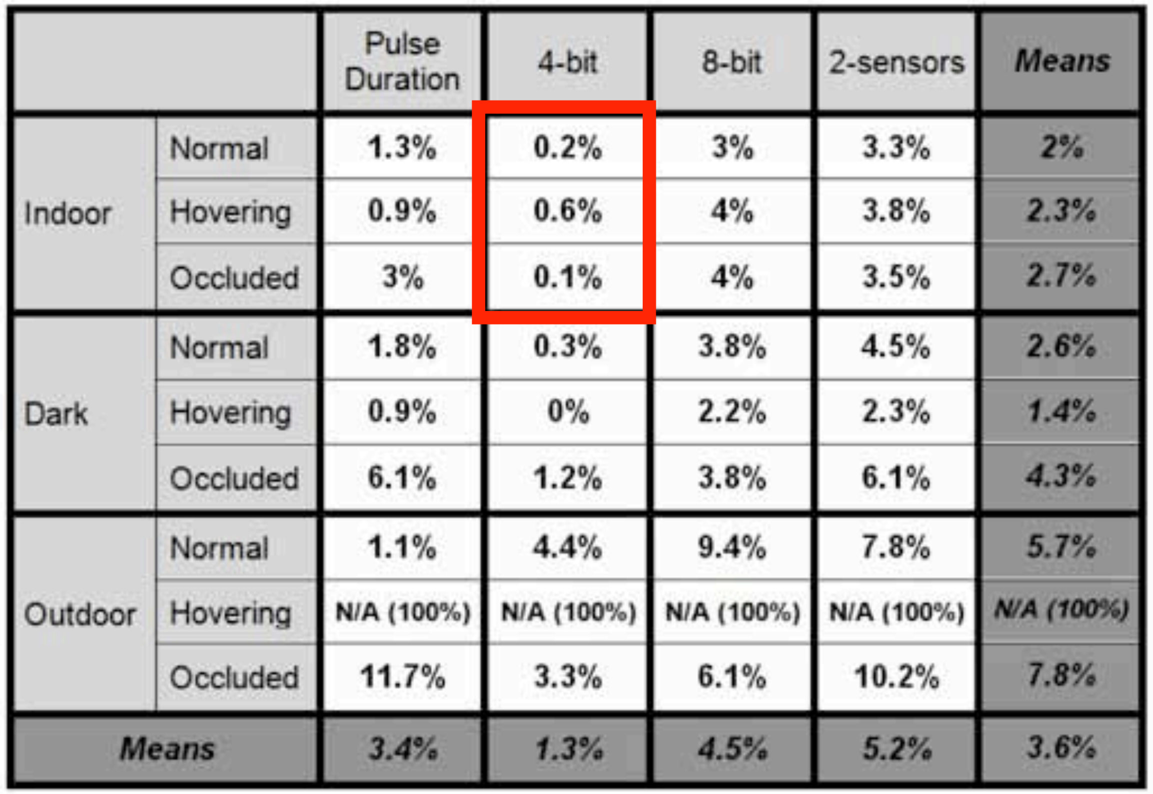
0001
0010
0011
0100

Light

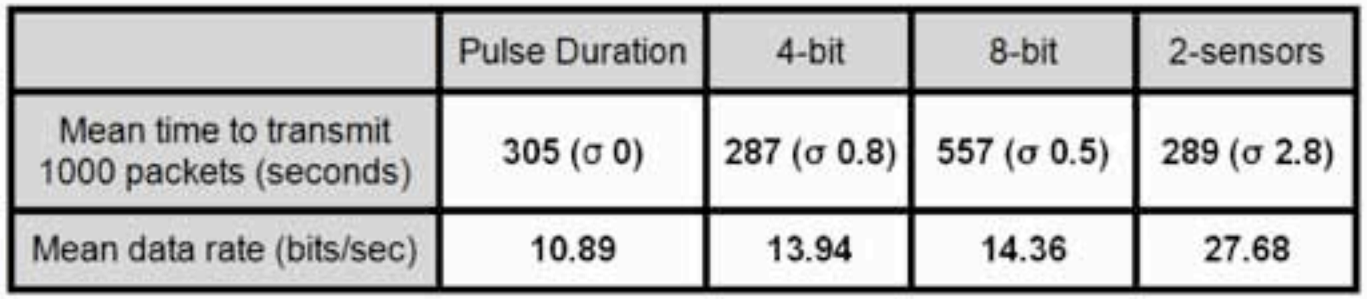
LUXPASS: TECHNICAL EVALUATION



3 Hardware Prototypes



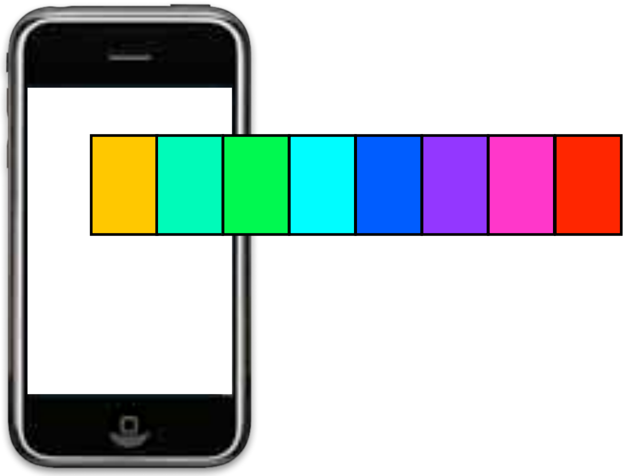
		Pulse Duration	4-bit	8-bit	2-sensors	*Means*
Indoor	Normal	1.3%	0.2%	3%	3.3%	*2%*
	Hovering	0.9%	0.6%	4%	3.8%	*2.3%*
	Occluded	3%	0.1%	4%	3.5%	*2.7%*
Dark	Normal	1.8%	0.3%	3.8%	4.5%	*2.6%*
	Hovering	0.9%	0%	2.2%	2.3%	*1.4%*
	Occluded	6.1%	1.2%	3.8%	6.1%	*4.3%*
Outdoor	Normal	1.1%	4.4%	9.4%	7.8%	*5.7%*
	Hovering	N/A (100%)	N/A (100%)	N/A (100%)	N/A (100%)	*N/A (100%)*
	Occluded	11.7%	3.3%	6.1%	10.2%	*7.8%*
Means		*3.4%*	*1.3%*	*4.5%*	*5.2%*	*3.6%*

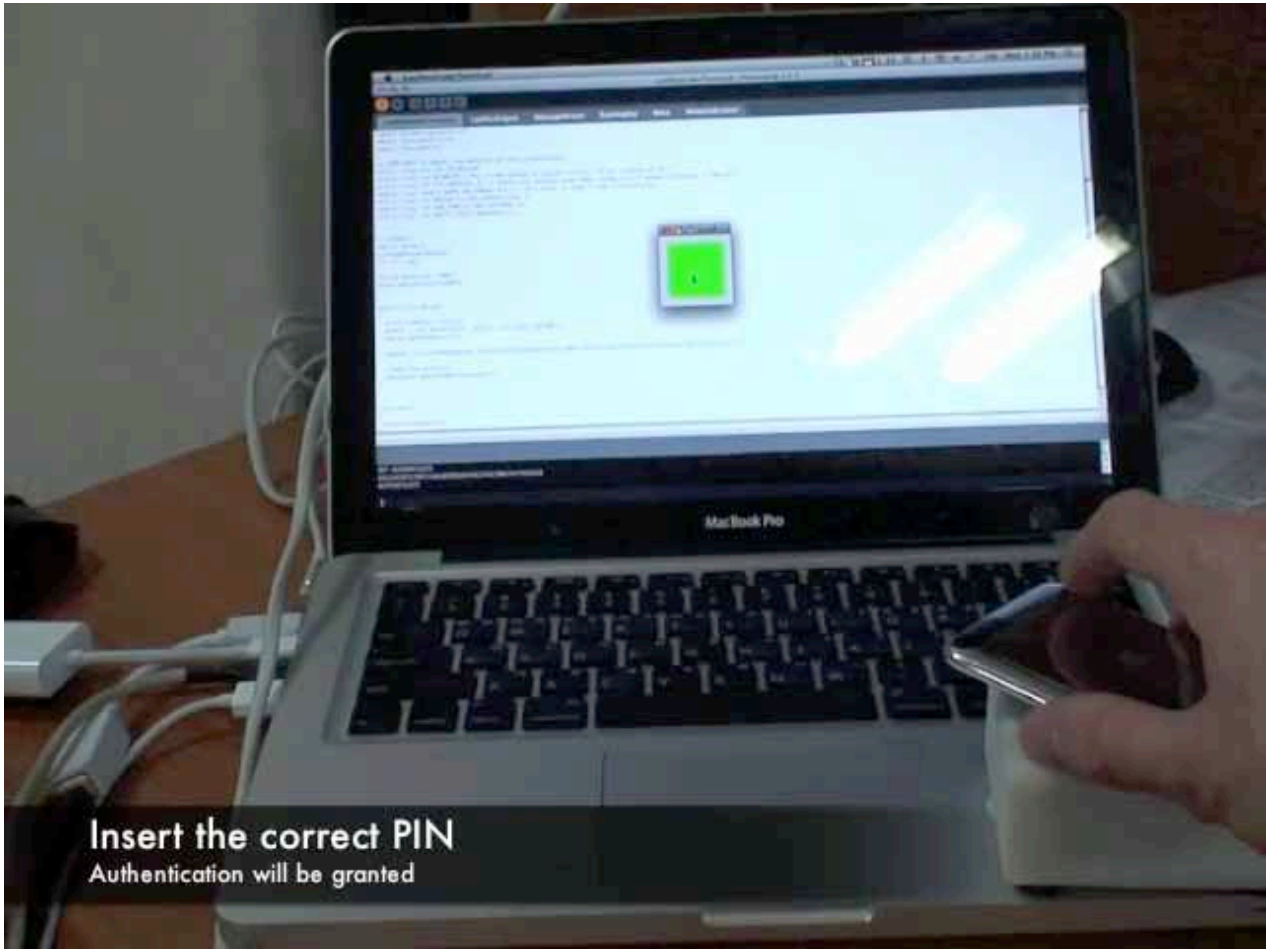


	Pulse Duration	4-bit	8-bit	2-sensors
Mean time to transmit 1000 packets (seconds)	305 (σ 0)	287 (σ 0.8)	557 (σ 0.5)	289 (σ 2.8)
Mean data rate (bits/sec)	10.89	13.94	14.36	27.68

- Error rate < 1%
- Plain text transmission time < 1 second
- MD5- 128 bit hashing encryption: 5.5 seconds

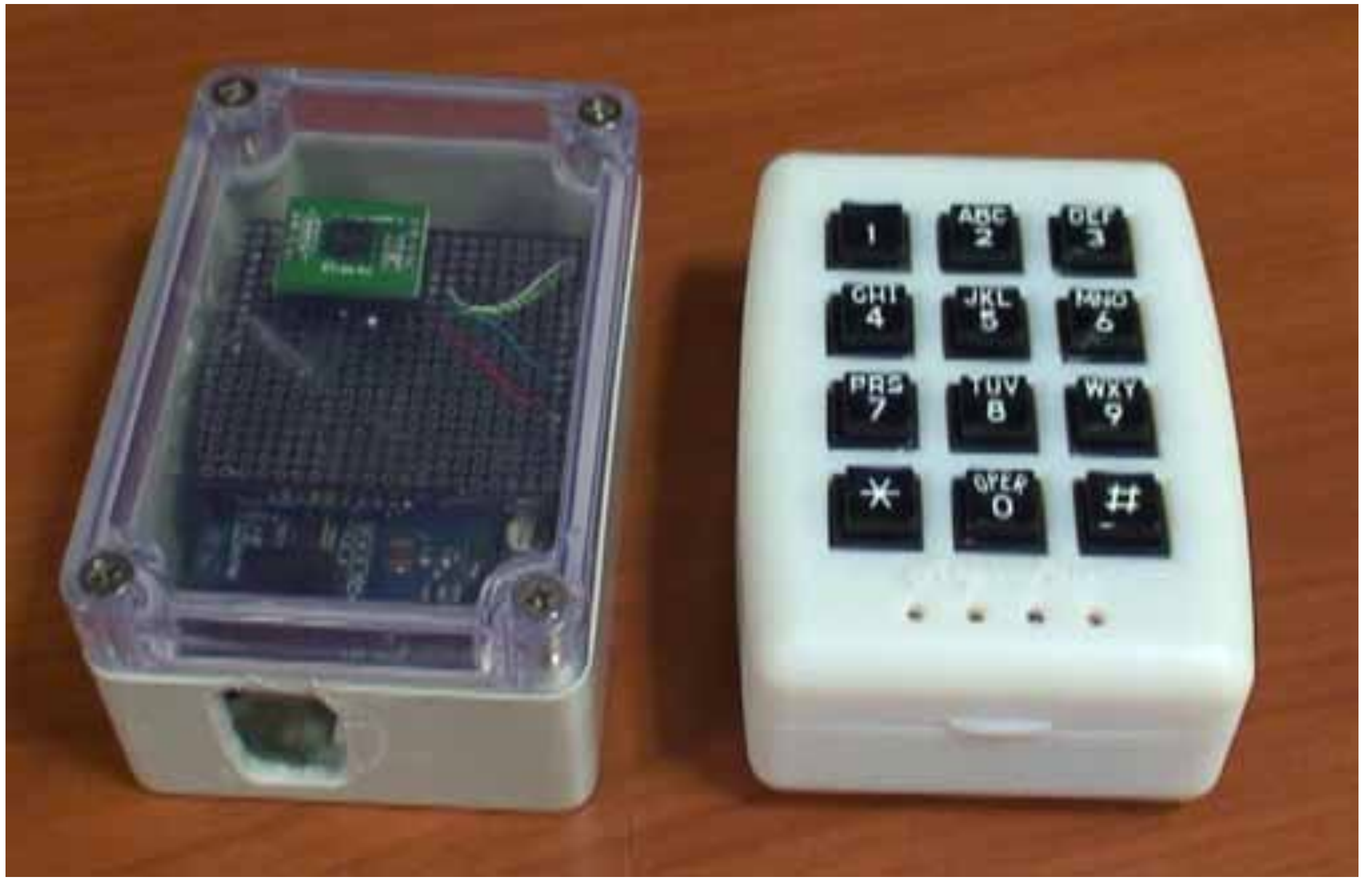
LUXPASS COLOR



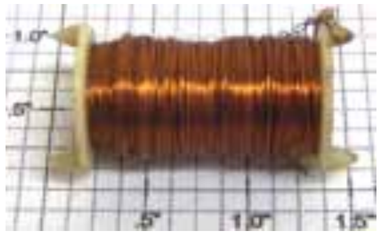


Work In Progress - LuxPass Color

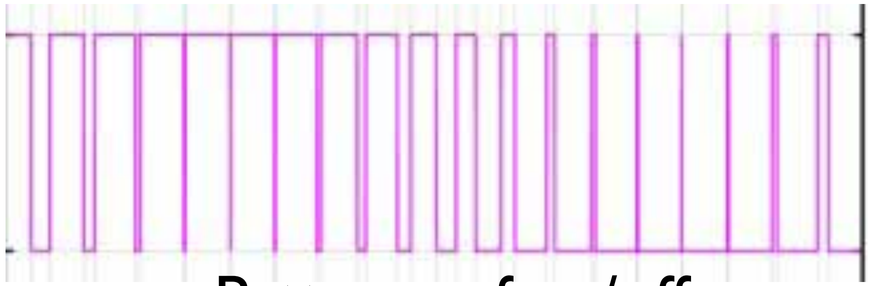
MAGNOPASS



Work In Progress



Solenoid



Patterns of on/off magnetic field

Mag Sensor

Conclusions

- Passwords & PINs are not going away
- We still need to authenticate with public locations/terminals
- Generally simple methods can improve their security in potential observation risk scenarios
  - Diversifying ecosystem of entry methods
  - Mediated obfuscation of entered data
- Presented novel key entry systems for terminals & private devices
- Presented software & hardware mediators for observation resistance
- Attacks will always be developed – you don't have to run faster than the bear, just faster than everyone else!