Monoxalyze

Verifying Smoking Cessation with a Keychain-sized Carbon Monoxide Breathalyzer

Joshua Adkins and Prabal Dutta

In the United States alone over 40 million people smoke tobacco (16.8%)

50% of smokers attempt to quit every year

Just 4-6% succeed

In the United States alone over 40 million people smoke tobacco (16.8%)

1 in 5 deaths can be linked to tobacco

50% of smokers attempt to quit every year

Just 4-6% succeed

In the United States alone over 40 million people smoke tobacco (16.8%)

1 in 5 deaths can be linked to tobacco

Government spending on tobacco related health exceeds education, environment, housing and science

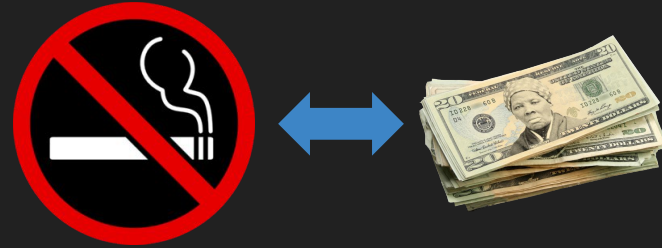50% of smokers attempt to quit every year

Just 4-6% succeed

Specific intervention can triple cessation rates

Specific intervention can triple cessation rates

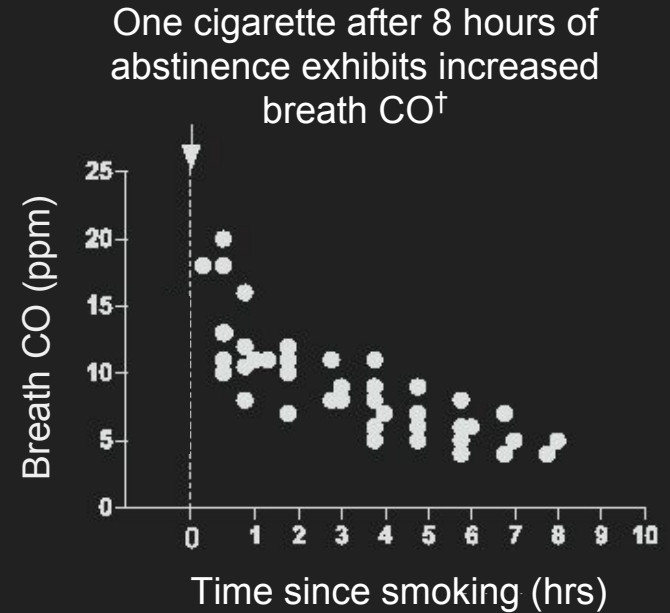# Specific intervention can triple cessation rates

Specific intervention can triple cessation rates

Leave the cigarettes at home today!

How do we confirm smoking cessation?

Use a breathalyzer to detect if people are smoking

Intervention Provider

Smoking increases CO in exhaled breath

- Non-smoker CO concentration: 0-4 ppm
- Smoker CO concentration: 6+ ppm
- Half life of ~5 hours after smoking

One cigarette after 8 hours of abstinence exhibits increased breath CO[†]

Breath CO (ppm)

Time since smoking (hrs)

† Sandberg A, Sköld CM, Grunewald J, Eklund A, Wheelock ÅM (2011) Assessing Recent Smoking Status by Measuring Exhaled Carbon Monoxide Levels. PLoS ONE 6(12): e28864. doi: 10.1371/journal.pone.0028864
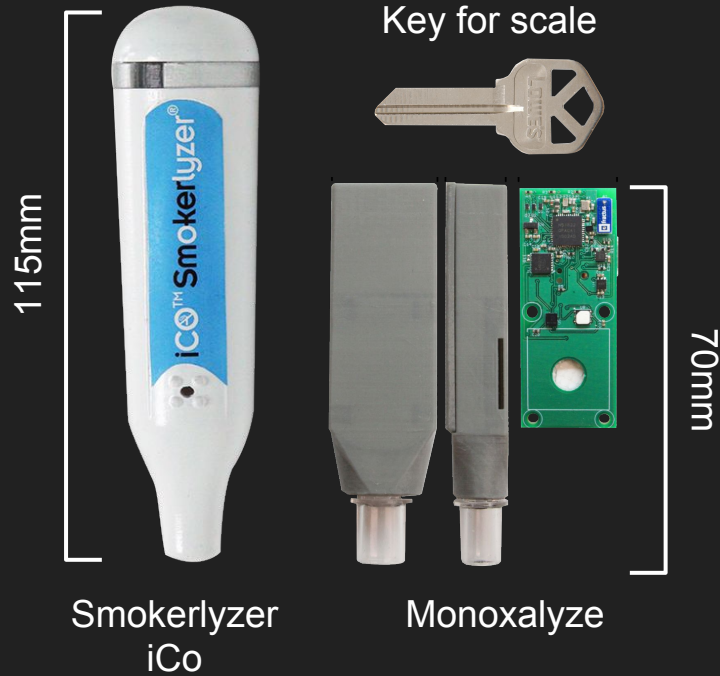
Current CO breathalyzers have several drawbacks

Smokerlyzer
iCo

Smokerlyzer
PiCO

Smokerlyzer
Micro

Current CO breathalyzers have several drawbacks

- No independent cessation verification mechanism

Smokerlyzer
iCo

Smokerlyzer
PiCO

Smokerlyzer
Micro

Current CO breathalyzers have several drawbacks

- No independent cessation verification mechanism
- No wireless data reporting
- Large and not mobile

Smokerlyzer
iCo

Smokerlyzer
PiCO

Smokerlyzer
Micro

Monoxalyze Smoking Cessation Compliance System

Key for scale

115mm

70mm

Smokerlyzer iCo

Monoxalyze

Monoxalyze Smoking Cessation Compliance System

115mm

Key for scale

70mm

Smokerlyzer
iCo

Monoxalyze

Monoxalyze Smoking Cessation Compliance System

Key for scale

115mm

70mm

Smokerlyzer
iCo

Monoxalyze

Monoxalyze Smoking Cessation Compliance System

Key for scale

115mm

70mm

Smokerlyzer
iCo
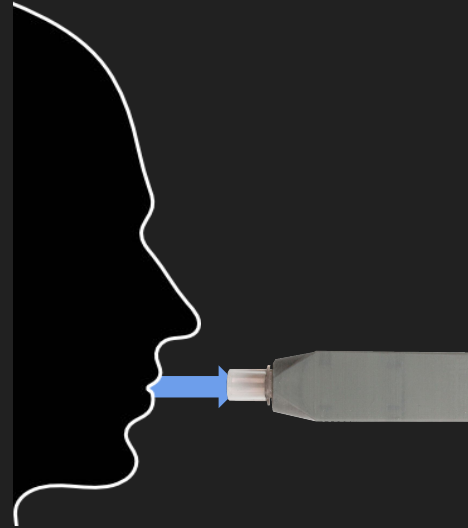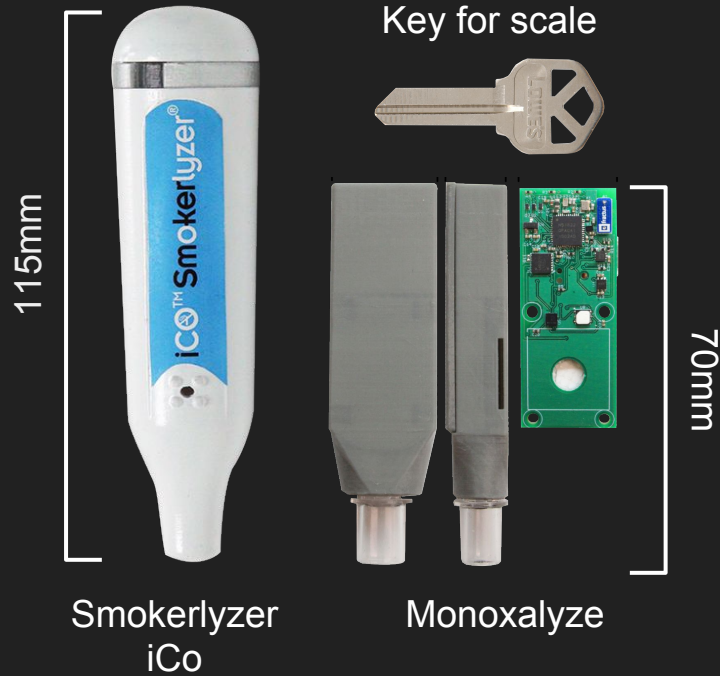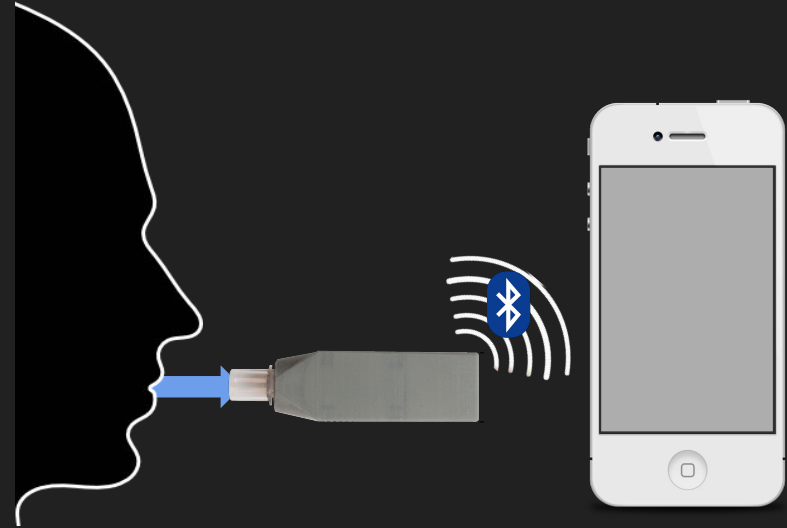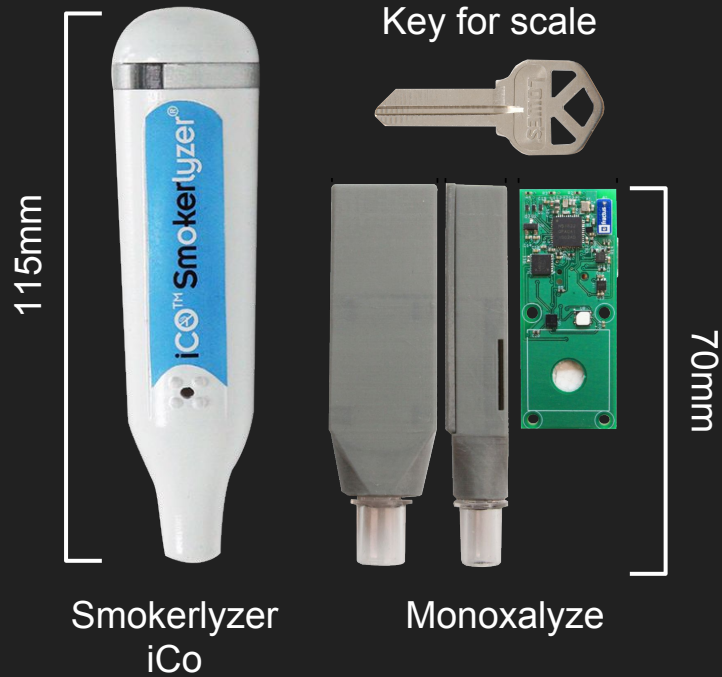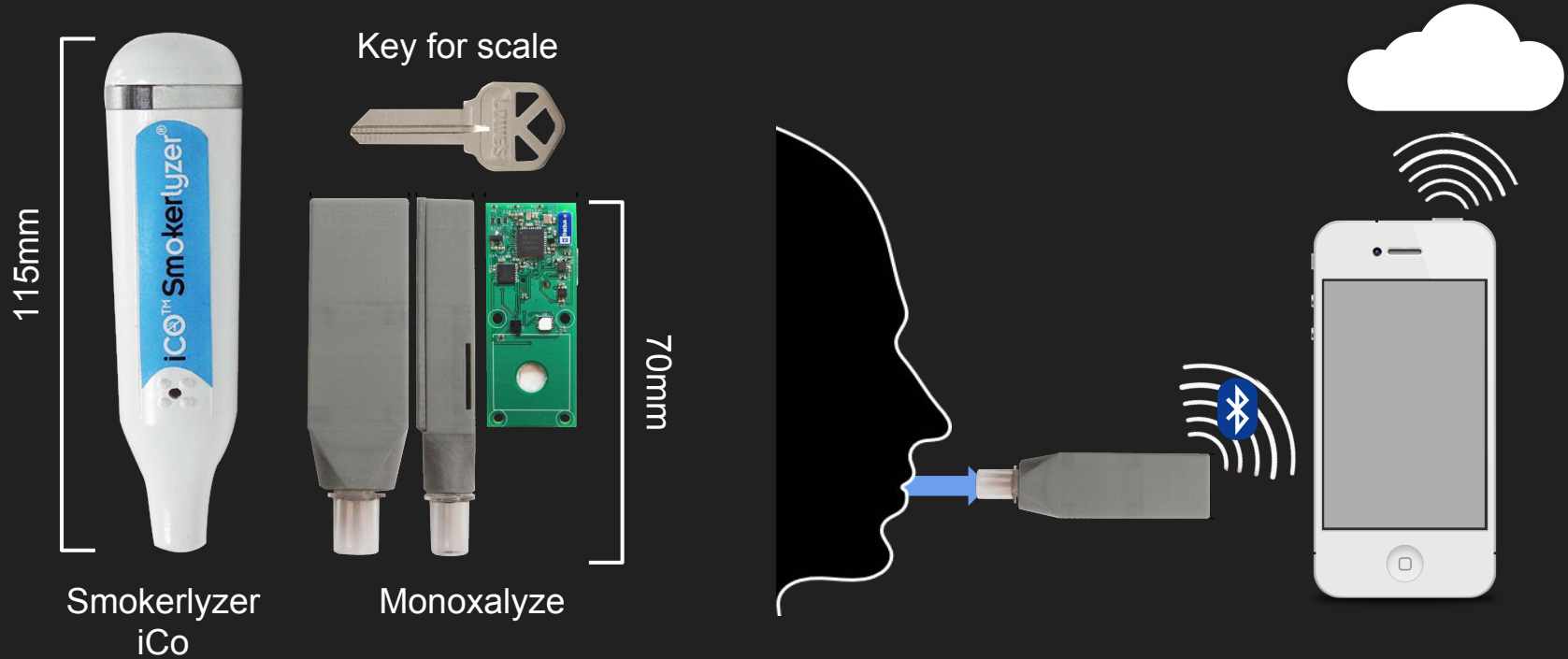
Monoxalyze

Monoxalyze Smoking Cessation Compliance System

- Wireless data reporting ✅
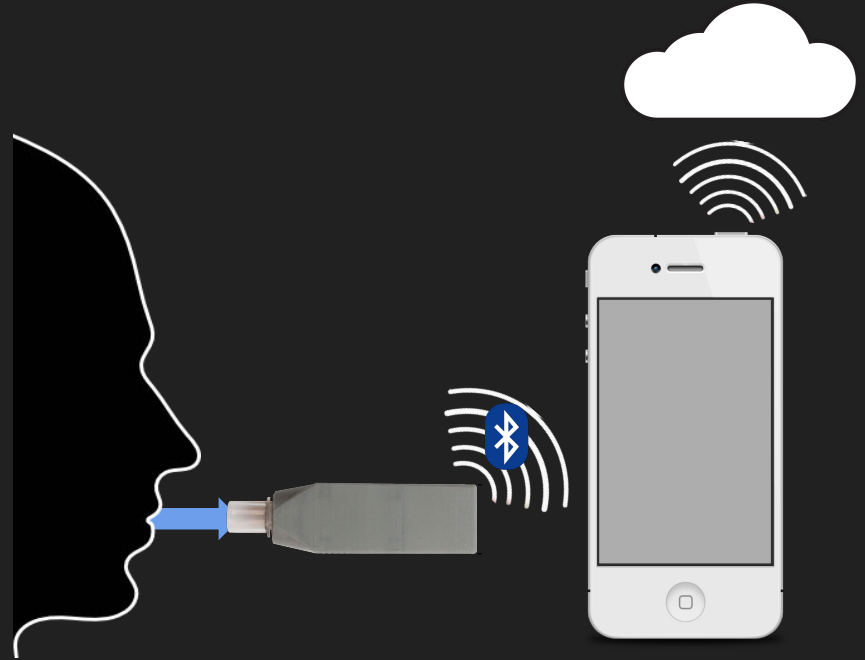
Monoxalyze Smoking Cessation Compliance System
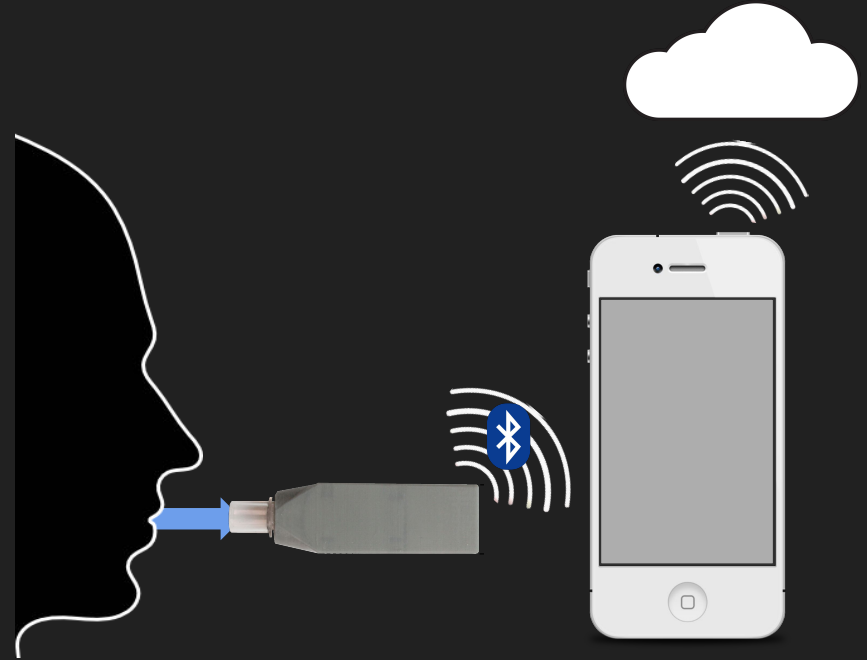
- Wireless data reporting ✔✔
- Small and more mobile ✔
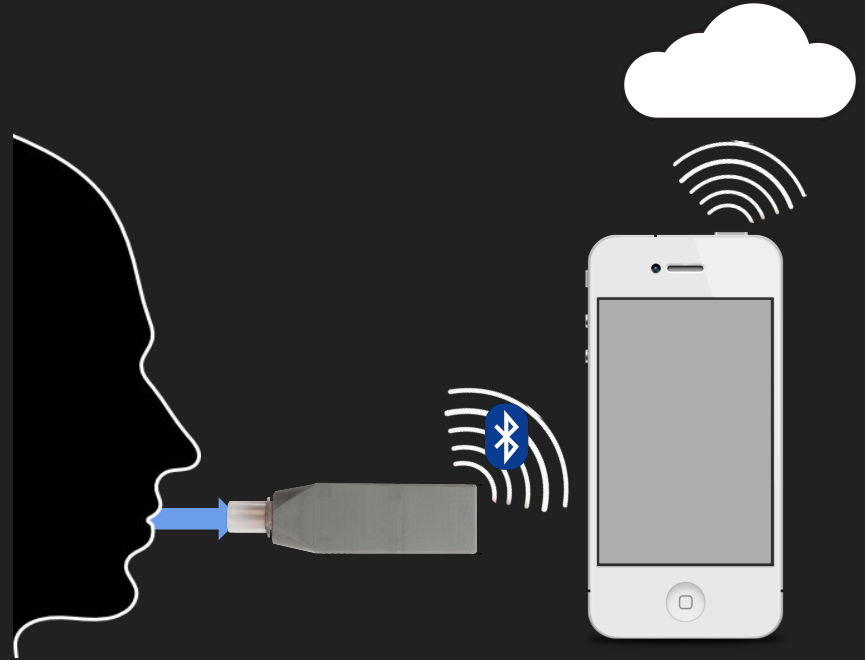
Monoxalyze Smoking Cessation Compliance System

- Wireless data reporting ✅
- Small and more mobile ✅
- Still no verification ❌

Monoxalyze Smoking Cessation Compliance System

- Wireless data reporting ✔
- Small and more mobile ✔
- Still no verification ✘
- Energy constrained ✘

Threat model: non-technical attacks

- Tampering with the sensor, spoofing bluetooth messages, publishing false reports to the cloud
  - Existing techniques can mostly mitigate these attacks

Threat model: non-technical attacks

- Tampering with the sensor, spoofing bluetooth messages, publishing false reports to the cloud
  - Existing techniques can mostly mitigate these attacks
- Not exhaling during a test

Threat model: non-technical attacks

- Tampering with the sensor, spoofing bluetooth messages, publishing false reports to the cloud
  - Existing techniques can mostly mitigate these attacks
- Not exhaling during a test
- Having a non-smoking friend exhale

Threat model: non-technical attacks

- Tampering with the sensor, spoofing bluetooth messages, publishing false reports to the cloud
  - Existing techniques can mostly mitigate these attacks
- Not exhaling during a test
- Having a non-smoking friend exhale
- Spoof with a second device
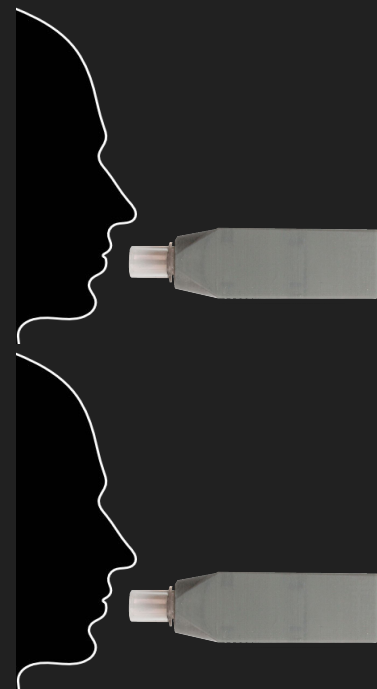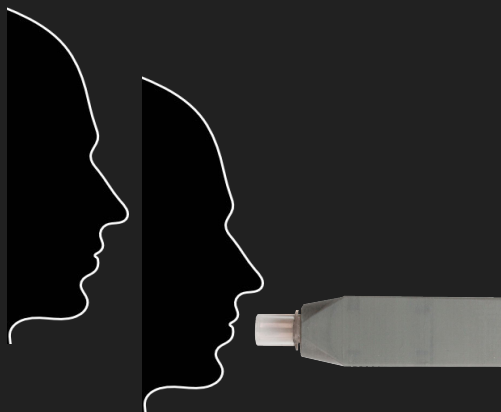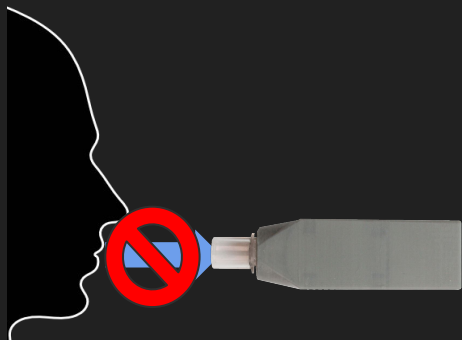
Verifying sufficient exhalation
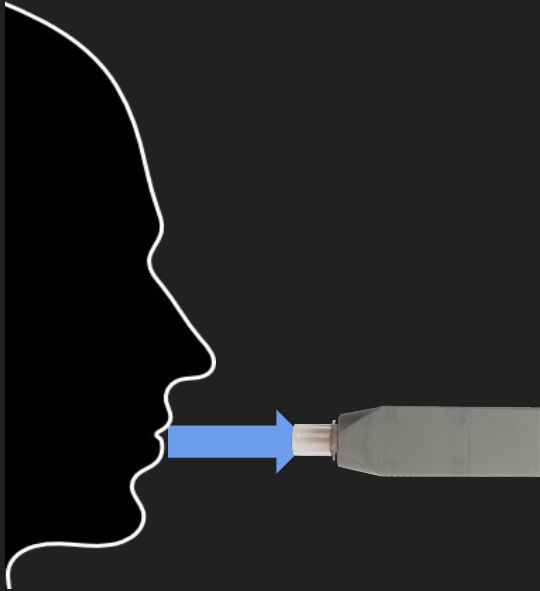
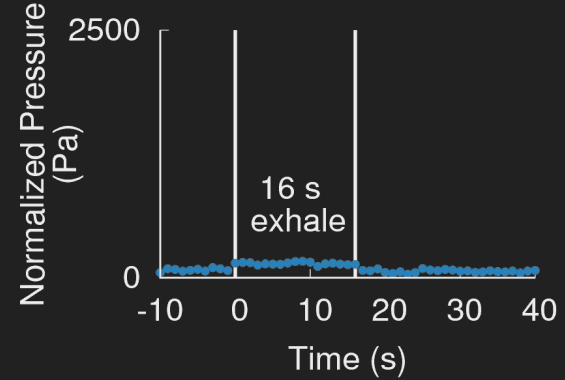# Verifying sufficient exhalation

Verifying sufficient exhalation

Verifying sufficient exhalation

- Exhaled breath increases gas chamber pressured due to humidity

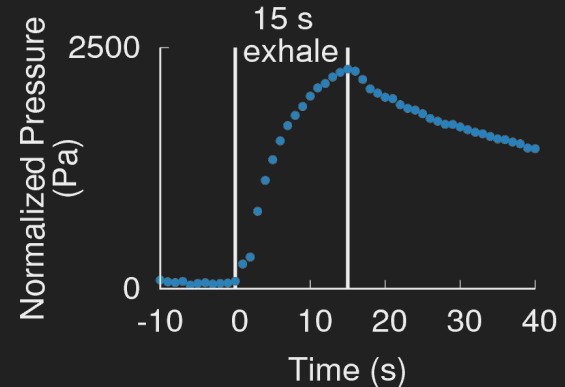No pressure increase during simulated, dry "exhalation"

16 s exhale

Normalized Pressure (Pa)

Time (s)

Verifying sufficient exhalation

- Exhaled breath increases gas chamber pressured due to humidity

No pressure increase during simulated, dry "exhalation"

16 s exhale

Normalized Pressure (Pa)

2500

0

-10   0   10   20   30   40

Time (s)
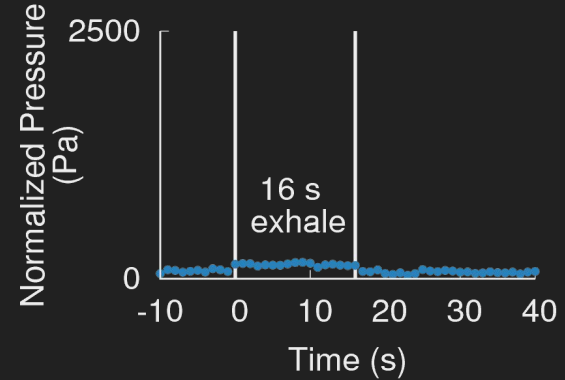
Pressure increase during real exhalation

15 s exhale

Normalized Pressure (Pa)

2500

0

-10   0   10   20   30   40

Time (s)

Verify the Monoxalyze user with facial recognition

Facial Recognition
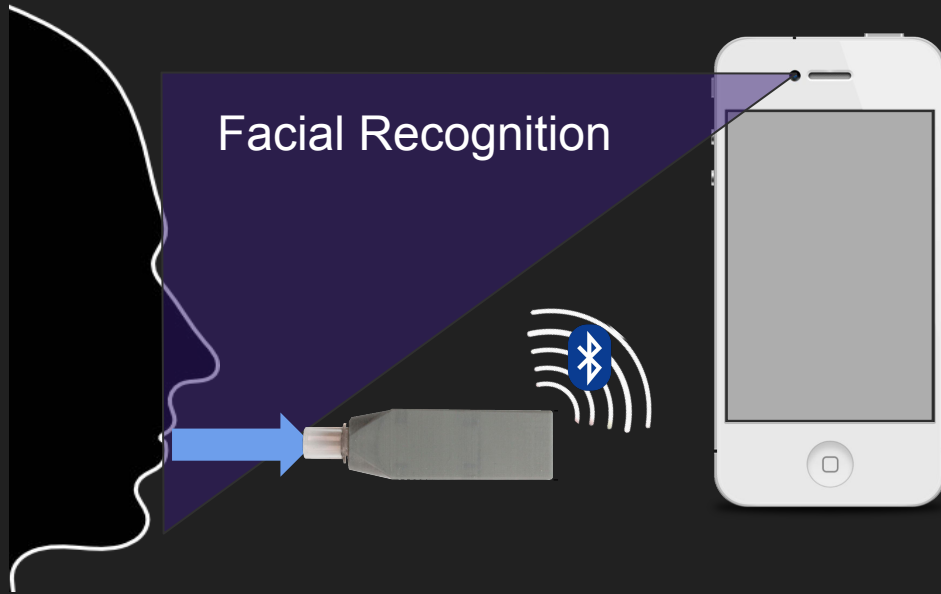
Facial recognition alone fails to verify the identified user is exhaling into the connected device
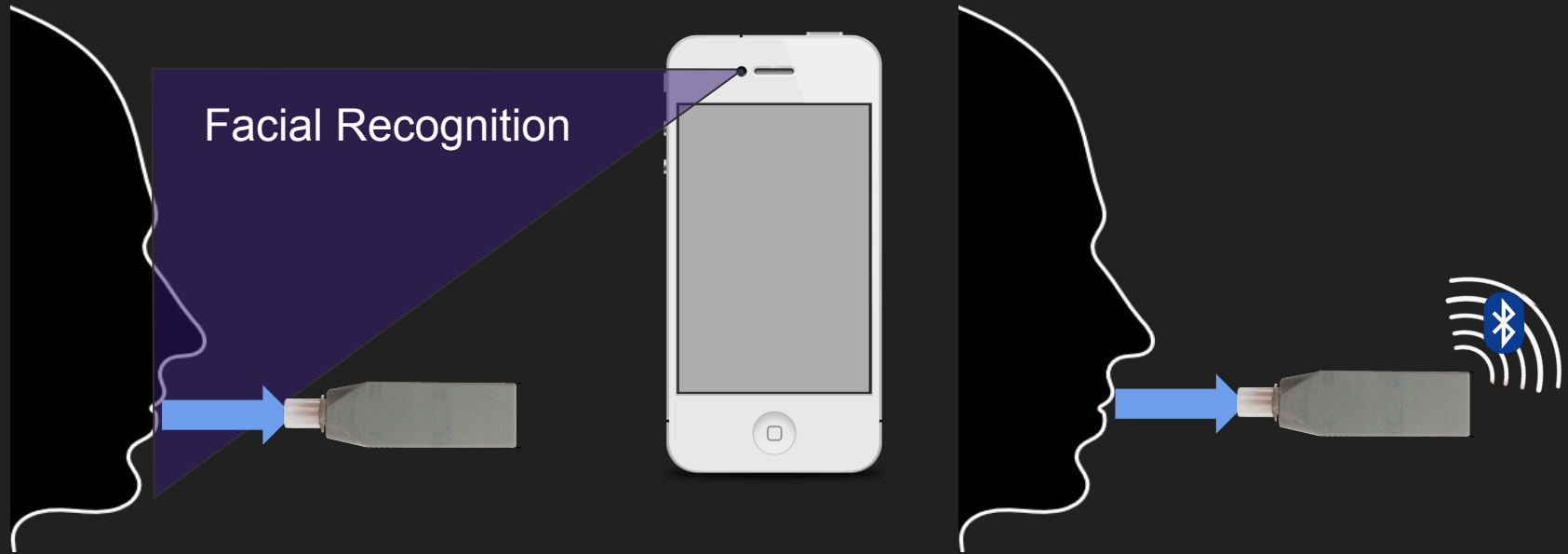
Facial Recognition

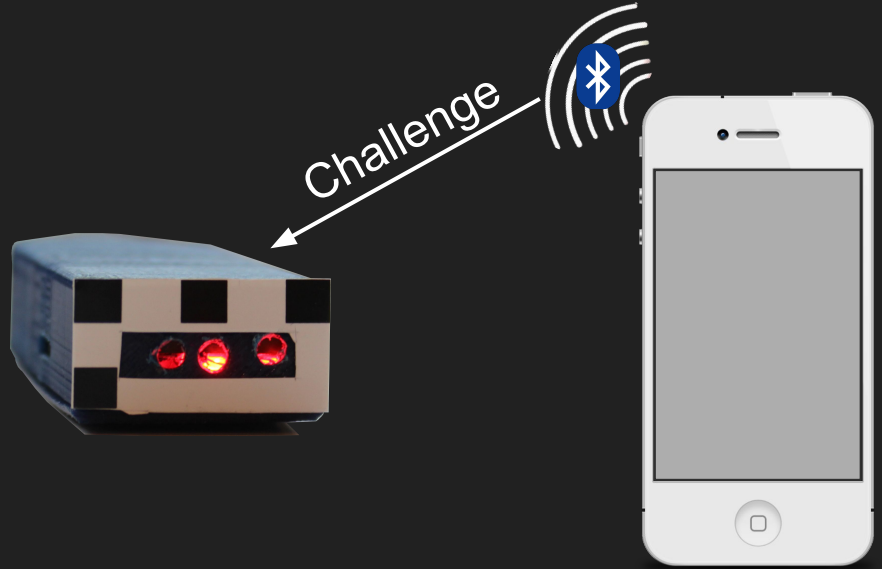# Visible light communication (VLC) ties the connected device to the identified user

Facial Recognition

VLC
fails

# Visible light communication (VLC) ties the connected device to the identified user

Facial Recognition

VLC
succeeds
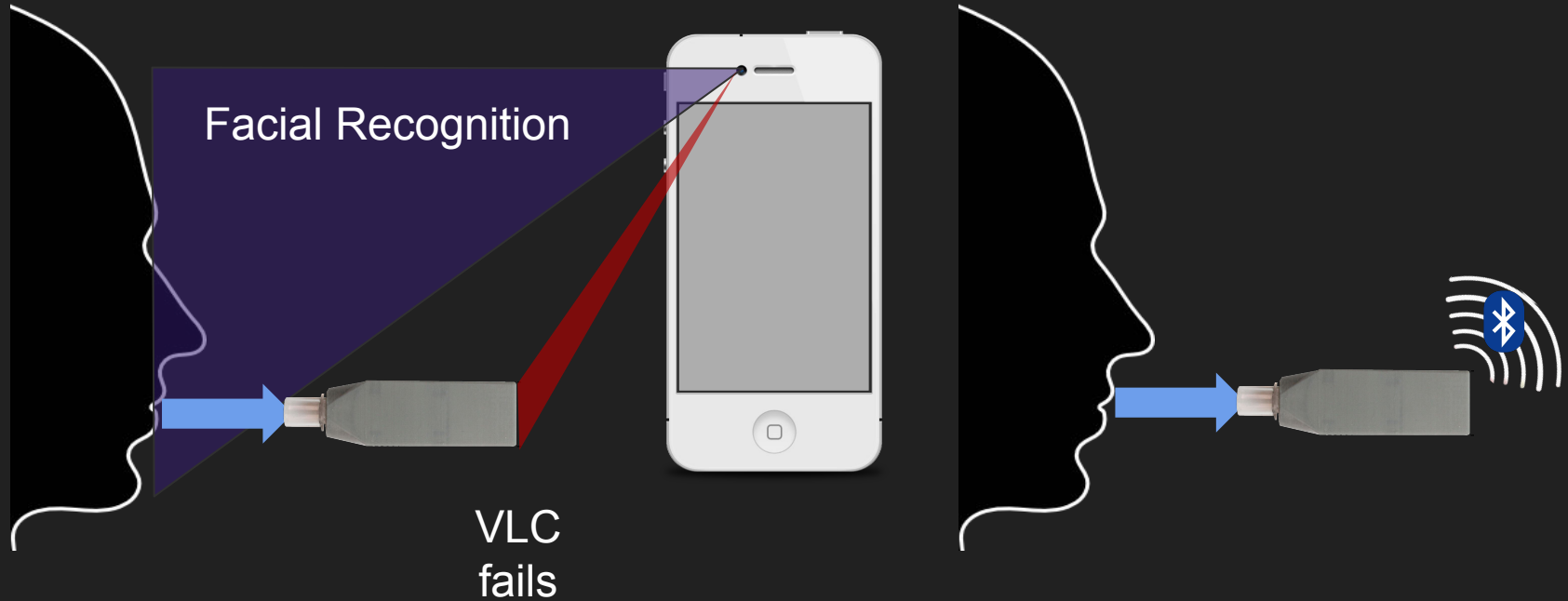
Low power visible light challenge-response

- The phone transmits a valid random challenge over Bluetooth

Challenge

Low power visible light challenge-response

- The phone transmits a valid random challenge over Bluetooth
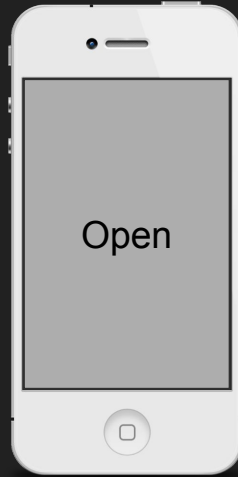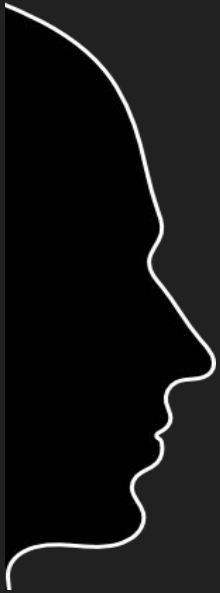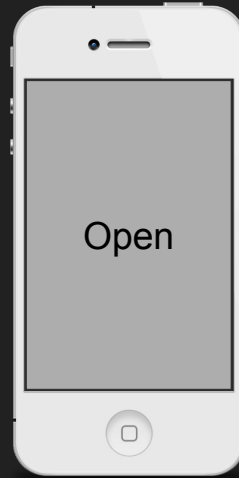- The challenge is transmitted back from the LEDs to the phone camera

Challenge

Response
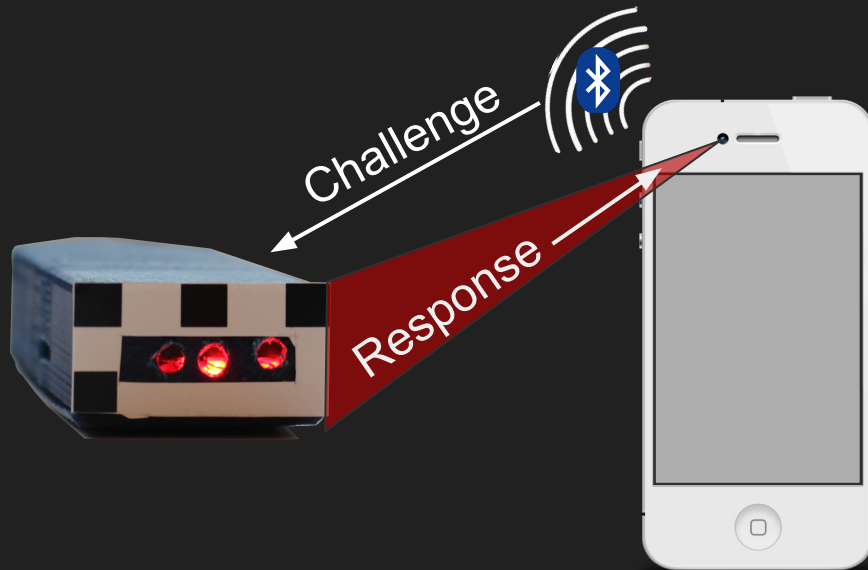
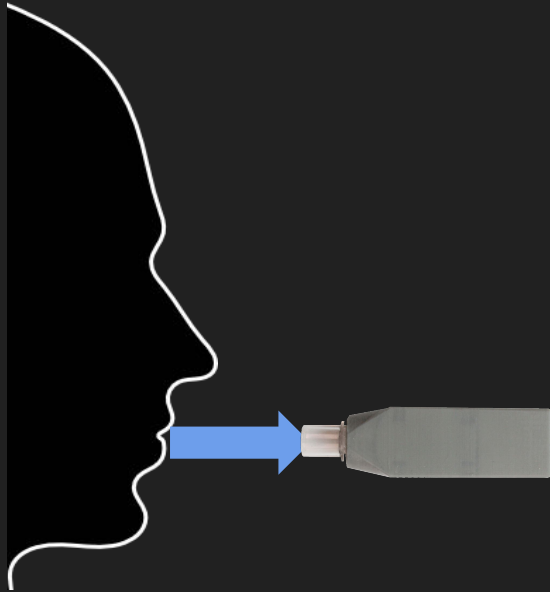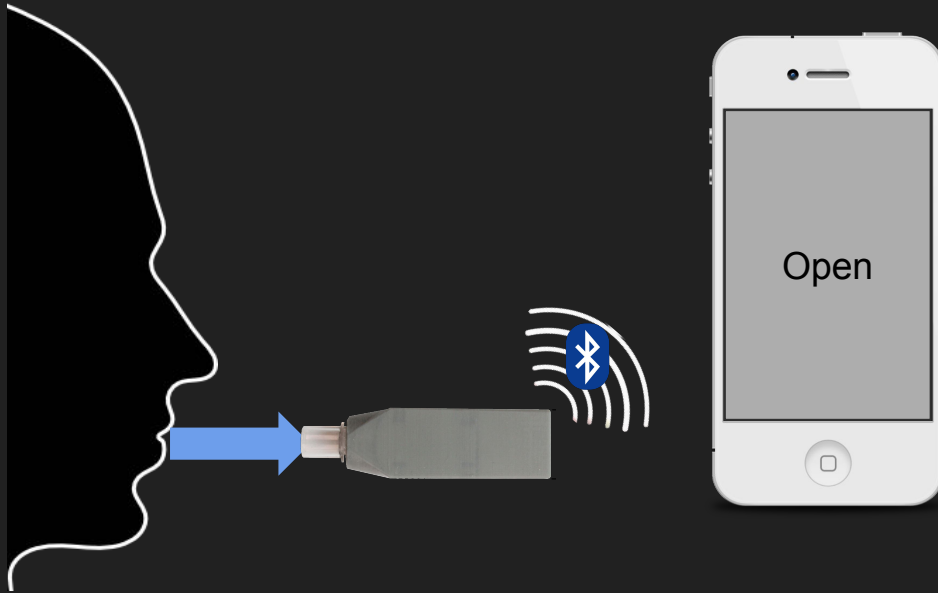# Monoxalyze step-by-step
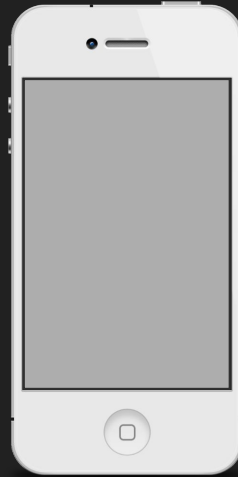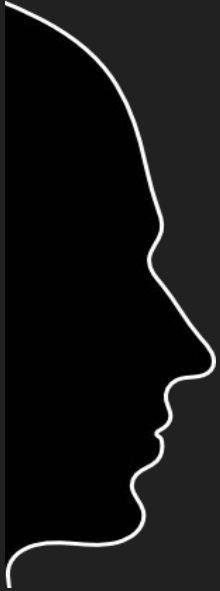
0)   Register

Monoxalyze step-by-step

Open
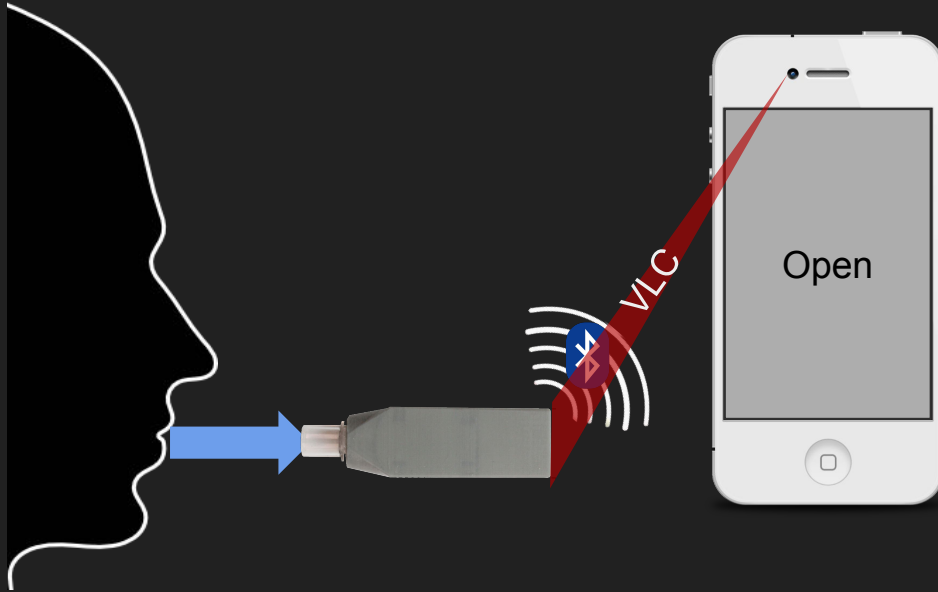
0) Register
1) Open the app

Monoxalyze step-by-step

Open

0) Register
1) Open the app
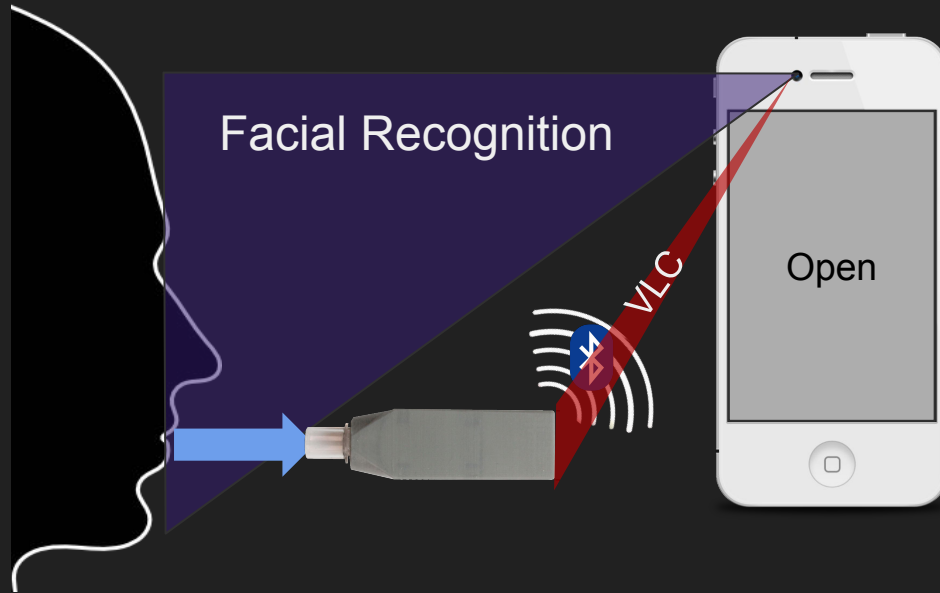2) Wakeup by exhaling

Monoxalyze step-by-step

Open

0) Register
1) Open the app
2) Wakeup by exhaling
3) Connect over Bluetooth
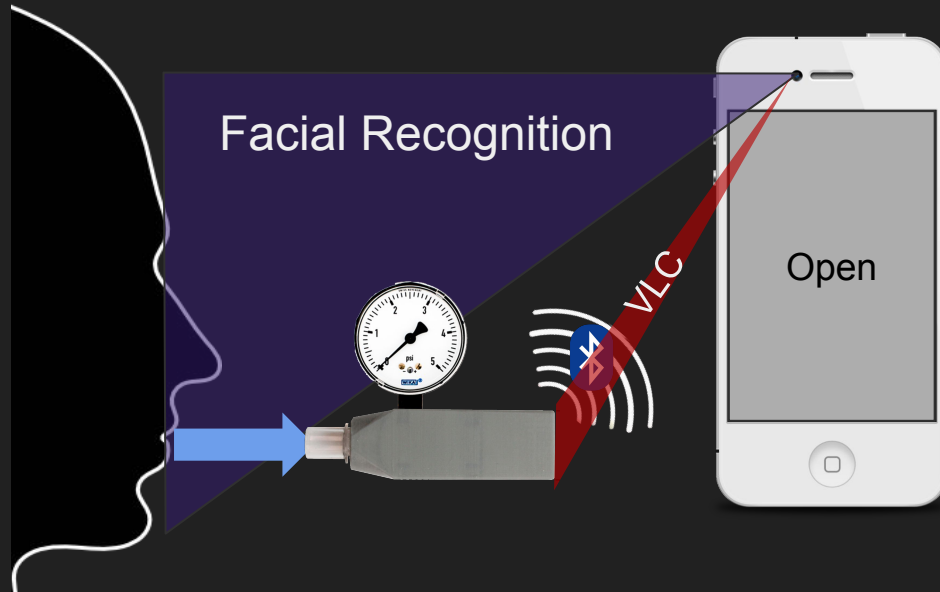
Monoxalyze step-by-step

VLC

Open

0) Register
1) Open the app
2) Wakeup by exhaling
3) Connect over Bluetooth
4) Authenticate the device with VLC

Monoxalyze step-by-step

Facial Recognition

VLC

Open
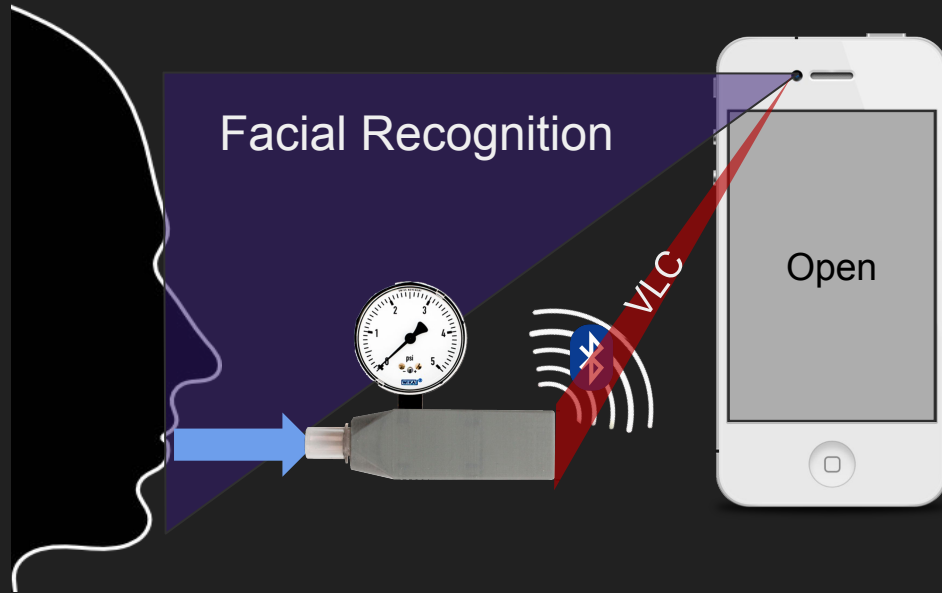
0) Register
1) Open the app
2) Wakeup by exhaling
3) Connect over Bluetooth
4) Authenticate the device with VLC
5) Identify the user

Monoxalyze step-by-step

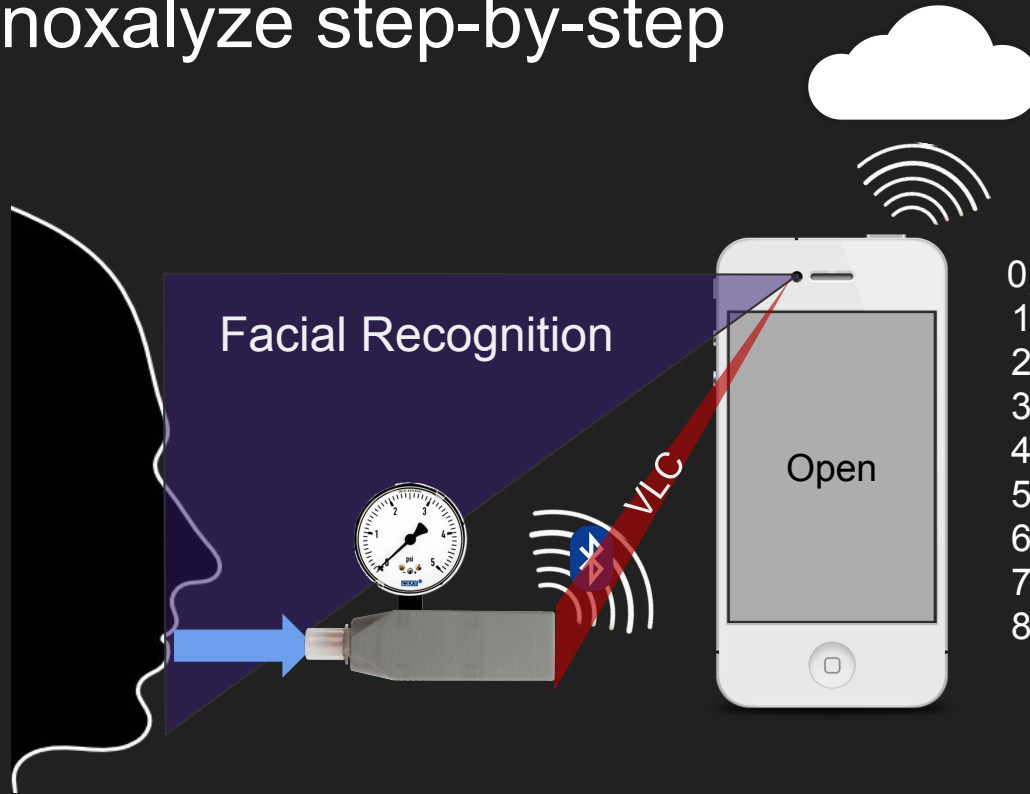Facial Recognition

VLC

Open

0) Register
1) Open the app
2) Wakeup by exhaling
3) Connect over Bluetooth
4) Authenticate the device with VLC
5) Identify the user
6) Verify sufficient exhalation

Monoxalyze step-by-step

Facial Recognition

VLC

Open

0) Register
1) Open the app
2) Wakeup by exhaling
3) Connect over Bluetooth
4) Authenticate the device with VLC
5) Identify the user
6) Verify sufficient exhalation
7) Collect CO reading

Monoxalyze step-by-step

Facial Recognition

VLC

Open

0) Register
1) Open the app
2) Wakeup by exhaling
3) Connect over Bluetooth
4) Authenticate the device with VLC
5) Identify the user
6) Verify sufficient exhalation
7) Collect CO reading
8) Report to intervention provider

Transitive Trust between User, Device, and Phone
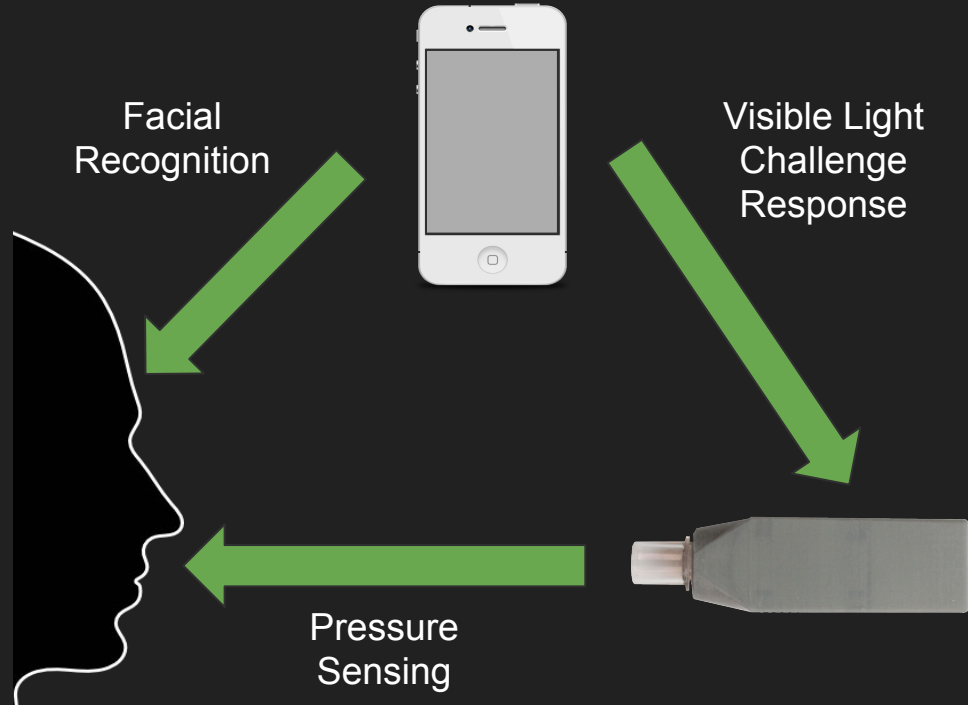
Facial Recognition

Visible Light Challenge Response

Pressure Sensing

Monoxalyze Smoking Cessation Compliance System

- Wireless data reporting ✅
- Small and more mobile ✅
- Mobile cessation verification ✅
- Energy constrained ❌

Facial Recognition
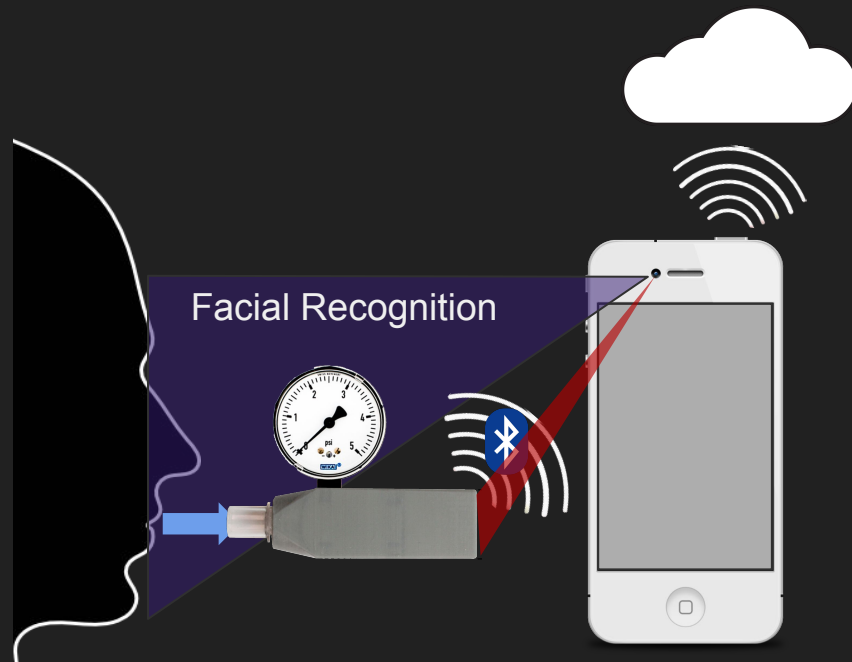
Low power device-to-phone VLC challenge-response

- Signal needs to be self clocking
- Challenges need to be random
  - Challenges do not need to be arbitrary

- On-Off keying in 3 bit frames
- Each frame must cause the LEDs to change state
  - provides a clock
- 0.61 LEDs active per bit on average
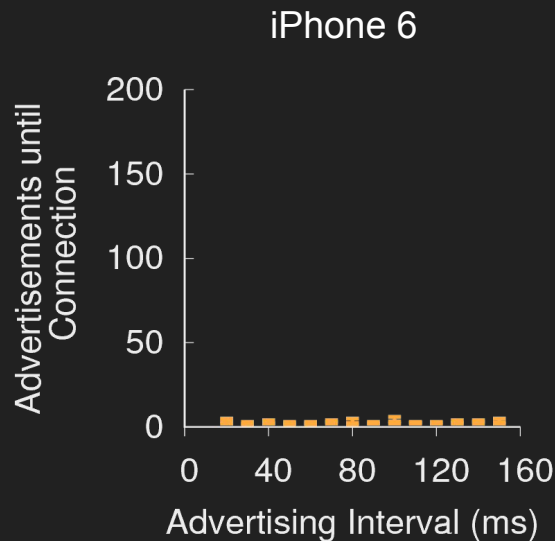- Manchester Encoding: 1 LEDs active per bit
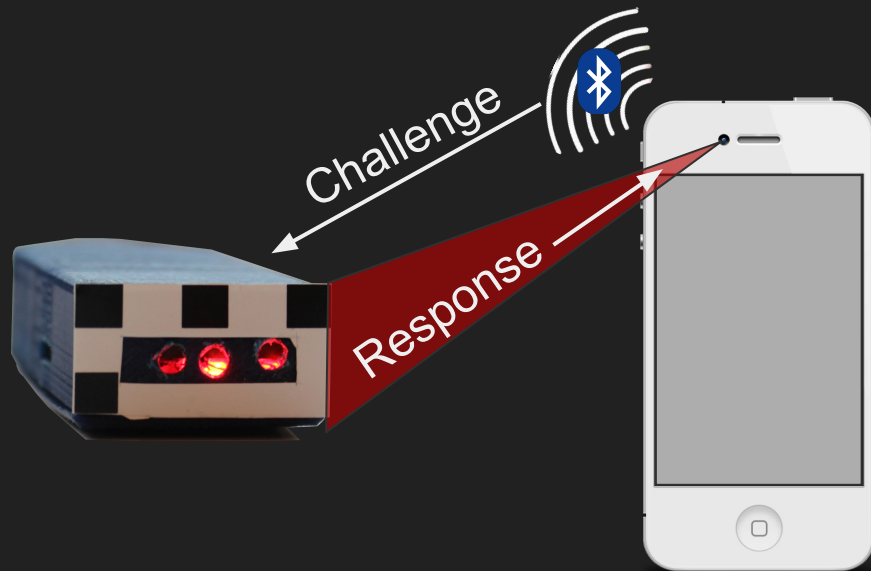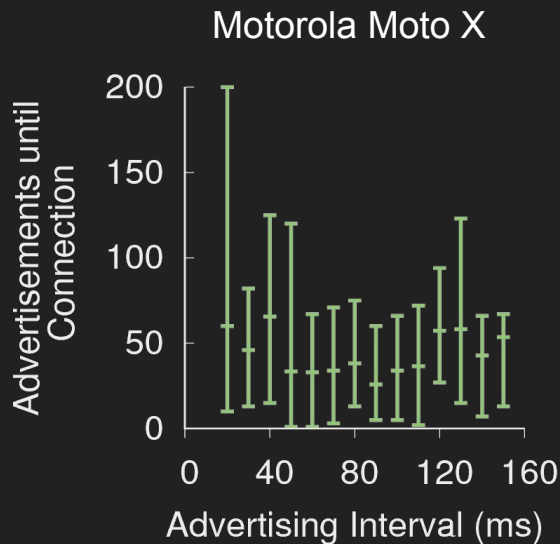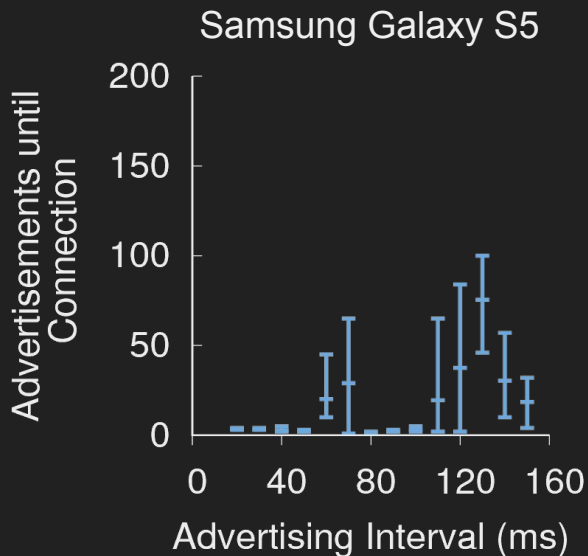
Challenge

Response

How many times should a device advertise?

- Bluetooth Low Energy (BLE) device send advertisements until phone connects

How many times should a device advertise?

- Bluetooth Low Energy (BLE) device send advertisements until phone connects
- Not all phones are created equal

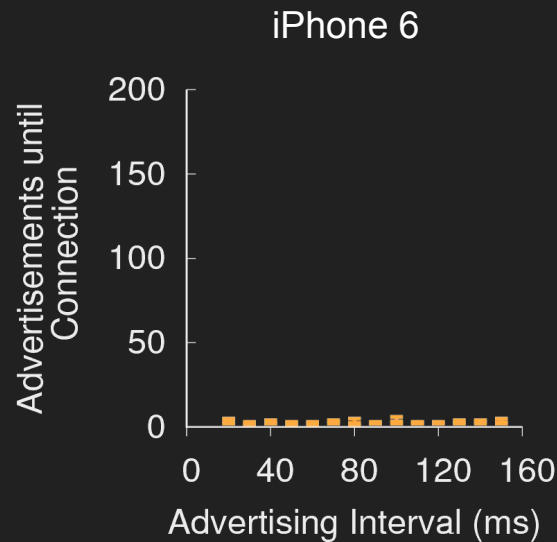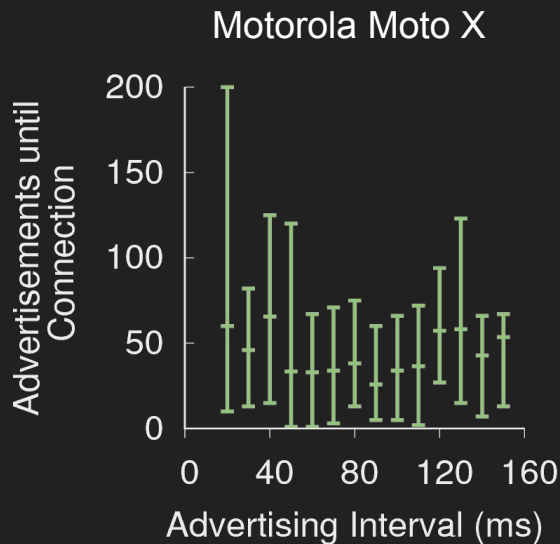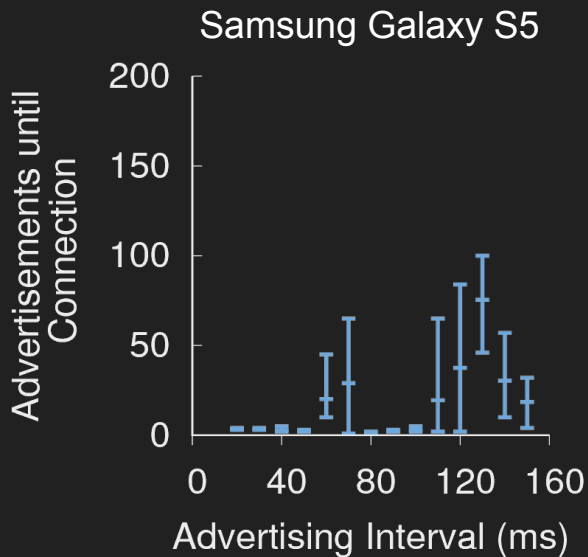Samsung Galaxy S5 — Motorola Moto X — iPhone 6

How many times should a device advertise?

- Bluetooth Low Energy (BLE) device send advertisements until phone connects
- Not all phones are created equal
- Most phones don't accept high connection interval requests

Samsung Galaxy S5

Motorola Moto X

iPhone 6

Battery lifetime with optimizations

- Energy Budget: 532 J
- 1000+ breath tests
- 110 days of sleep
- Expected combined battery life: 83-95 days

Breathalyzer test energy

Event	Percent of Energy
Bluetooth Advertising	9%
Bluetooth Connection	66%
Pressure Sensor	12%
Visible Light Auth	13%
Gas Sensor	<1%
Total	400.5mJ

Exhalation verification works with sufficient reset time between measurements

- 10 tests with 10 minutes between tests: 100% exhalation detection
- Correctly identifies insufficient volume
- Correctly identifies ending exhalation early
- Lower rates of exhalation detection with back-to-back testing
  - This is not the normal case
 - Failure is an inconvenience not a security flaw

Low error rates on VLC processing

- Testing performed at 10hz frames, 28bps
- Random 12 bit challenge-responses
- 5-8 inches: 29/30 succeeded
  - 0.1% bit error rate
- Longer distances rarely work
- Extreme lighting conditions reduce success rate
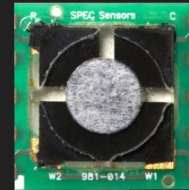- Failure is an inconvenience not a security flaw

Accurate gas sensing requires filtering

- Two sensors were used for testing
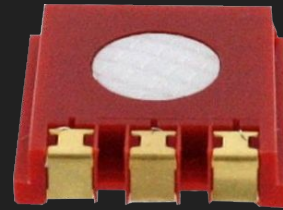 - SPEC CO Sensor ($10)
  - Citytech Microcel CF ($100)
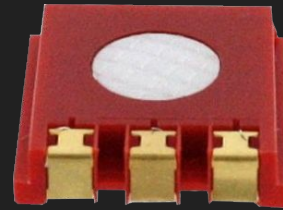
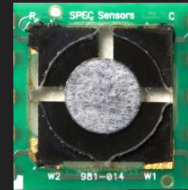Microcel CF   SPEC

Accurate gas sensing requires filtering

- Two sensors were used for testing
  - SPEC CO Sensor ($10)
  - Citytech Microcel CF ($100)
- CO sensors respond to water vapor
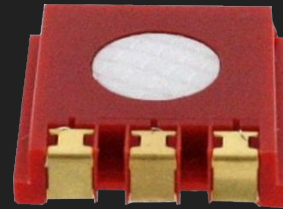
Microcel CF   SPEC
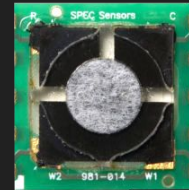
Accurate gas sensing requires filtering

- Two sensors were used for testing
  - SPEC CO Sensor ($10)
  - Citytech Microcel CF ($100)
- CO sensors respond to water vapor
- Tested multiple filter materials
  - Activated Charcoal and PTFE

PTFE Hydrophobic Filter

Activated Charcoal Filter

Microcel CF

SPEC

Accurate gas sensing requires filtering

- Two sensors were used for testing
  - ~~SPEC CO Sensor ($10)~~
  - Citytech Microcel CF ($100)
- CO sensors respond to water vapor
- Tested multiple filter materials
  - Activated Charcoal and PTFE

PTFE Hydrophobic Filter

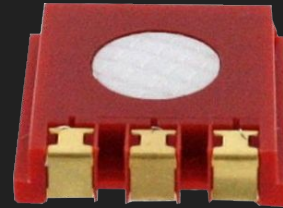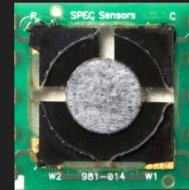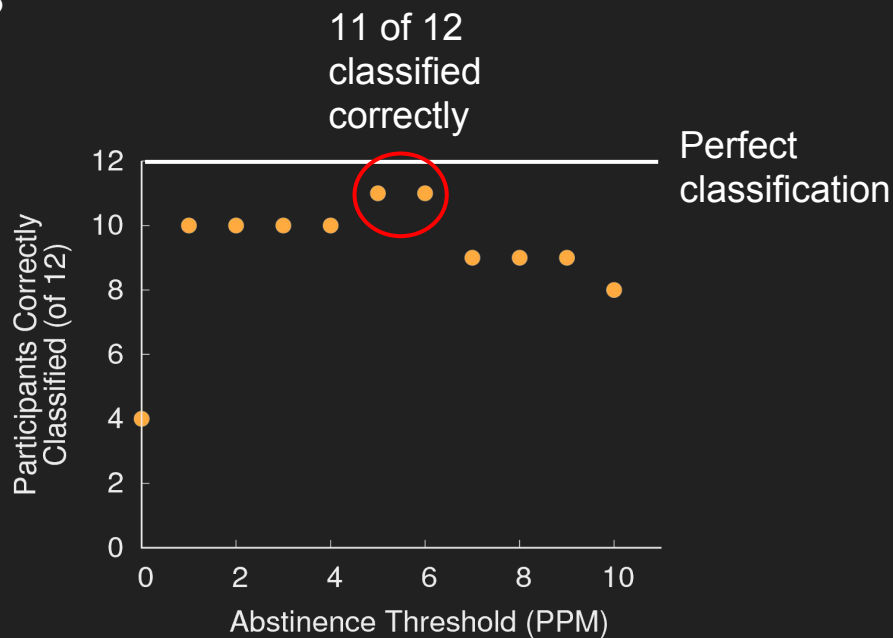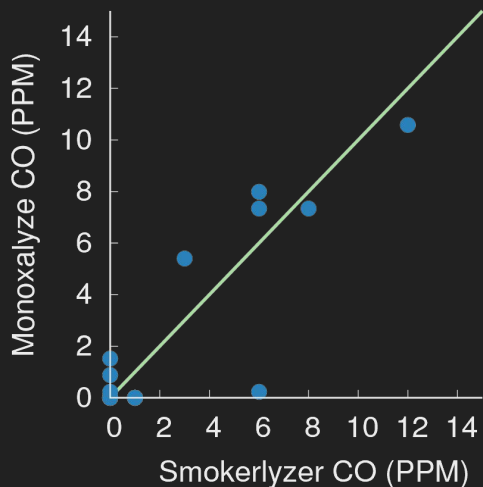Activated Charcoal Filter

Microcel CF

SPEC

Testing Monoxalyze at a smoking cessation clinic

- 12 participant study at smoking cessation clinic
- Can Monoxalyze classify smokers?

11 of 12 classified correctly

Perfect classification

What other applications could use this system?

- Other breathalyzer applications
  - Court mandated compliance
- Health insurance verifying physical exercise
- Medical devices attempting to provide more reliability

Monoxalyze

Verifying Smoking Cessation with a
Keychain-sized Carbon Monoxide Breathalyzer

Joshua Adkins and Prabal Dutta