



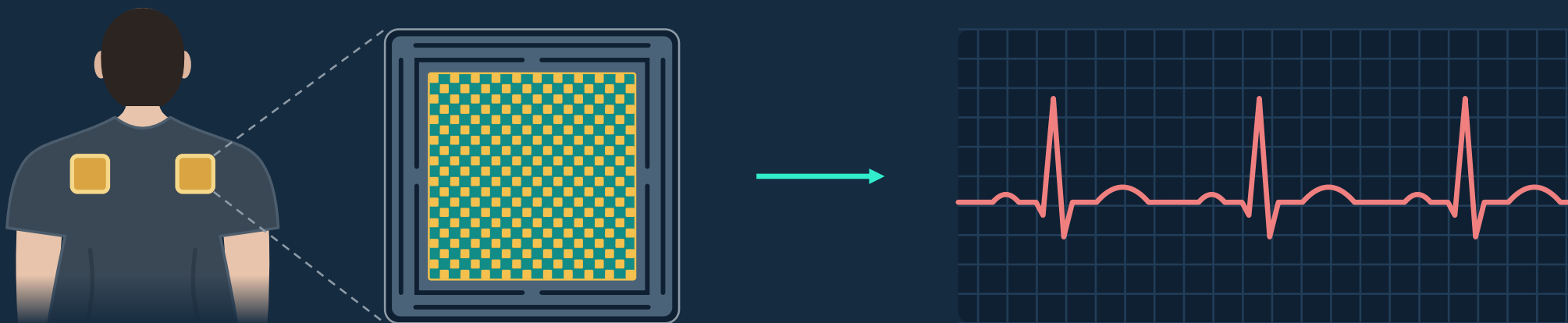
MOBIDX '26 · AUSTIN, TX · OCT 26-30



Continuous Electrocardiogram Monitoring with a Loose T-Shirt

Ho Man Colman Leung · Kyle Tong · Ming Gong · †Nam Bui · Xia Zhou

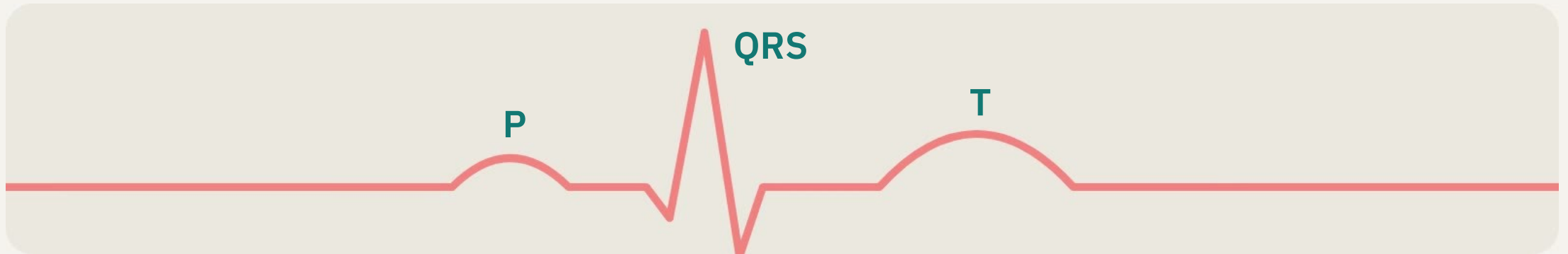
Columbia University · †University of Colorado Denver



MOTIVATION

Why continuous Electrocardiogram (ECG)?

ECG waveform



P - QRS - T shape is what clinicians need to diagnose heart diseases such as atrial fibrillation and flutter

MOTIVATION

Why continuous Electrocardiogram (ECG)?



EXISTING METHODS

Current ECG wearables

Smartwatches



Touch the crown with the other hand

**Snapshots,
not continuous**

Adhesive patches



Adhesive and gel bond electrodes to skin

**Skin irritation,
needs replacing**

Chest straps



Tension presses electrodes onto the chest

**Not suited to
everyday wear**

OUR GOAL

What about a regular loose T-shirt?

Smartwatches



Adhesive patches



Chest straps



Regular loose T-shirt



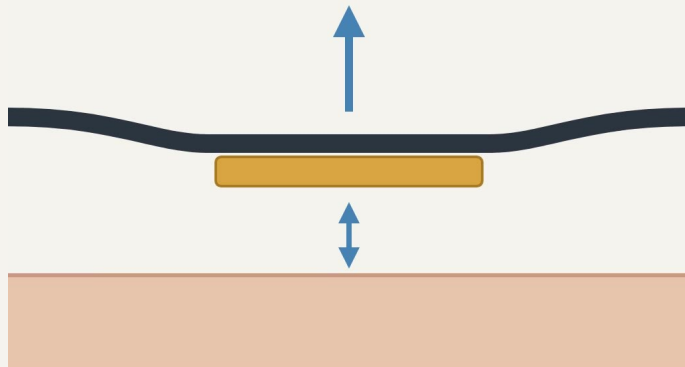
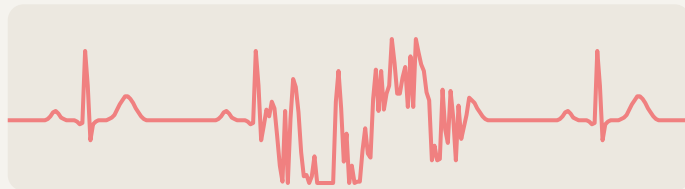
Continuous, suitable for
everyday wear

THE PROBLEM

Three kinds of motion

1 • Lift-off

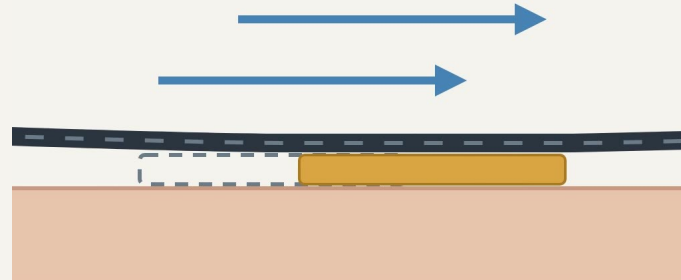
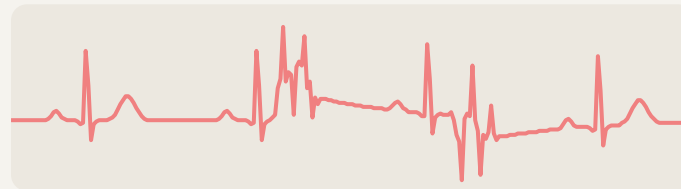
perpendicular macro-motion



Contact breaks: the signal drops out

2 • Shear

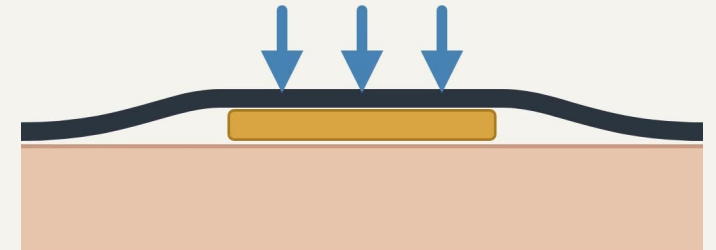
lateral macro-motion



Drag across skin: sharp motion artifacts

3 • Micro-shifts

breathing, posture-change
micro-motion



Changing pressure: the baseline wanders

OUR APPROACH

Decouple the sensor from the shirt's motion

MOTION

1 • Lift-off

2 • Shear

3 • Micro-shifts

HOW WE DECOUPLE IT

PHYSICAL

Gravity + suction seal

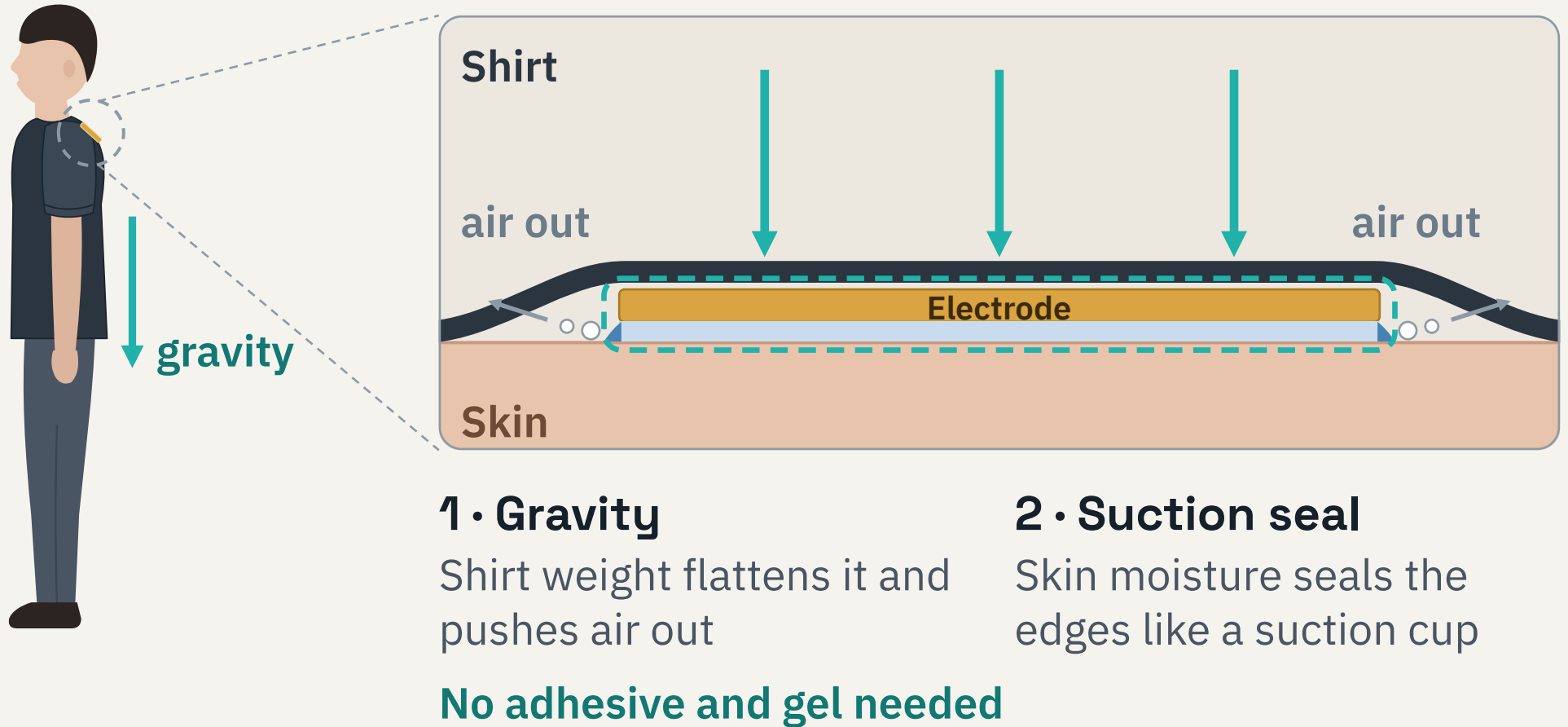
MECHANICAL

Kirigami pattern

COMPUTATIONAL

Hybrid electrode + adaptive filtering

Gravity and a suction seal hold the electrode



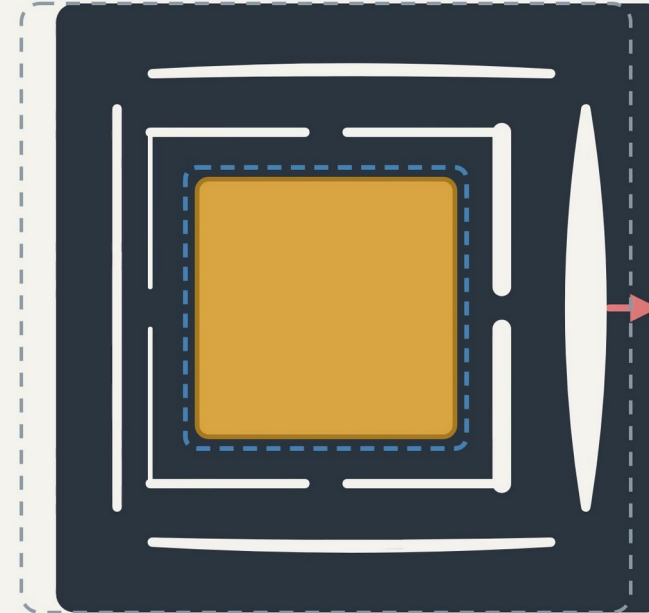
Kirigami pattern absorbs shear force

At rest



two rings of slits around the electrode

Fabric pulls the outer edge



slits open, outer edge moves,
center stays put

Handling micro-motion

Heart + motion noise



motion signal



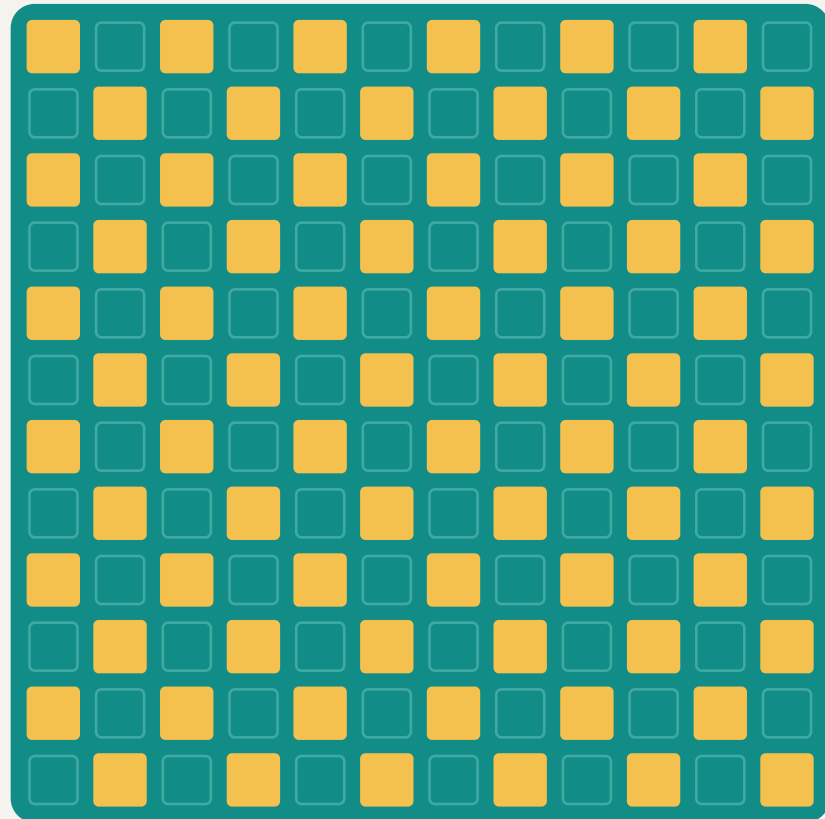
motion removed



-

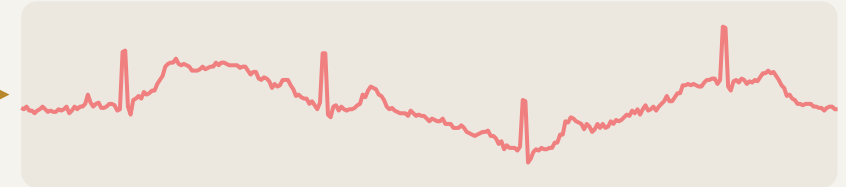
=

One electrode, two signals

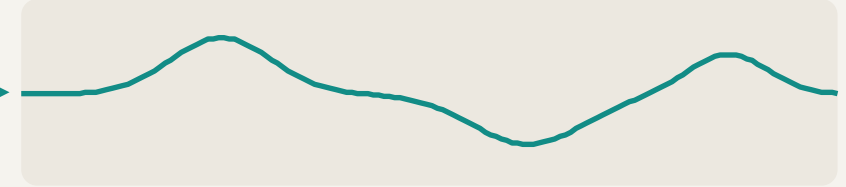


■ biopotential (exposed) ■ capacitive (insulated)

ECG · heart + motion noise

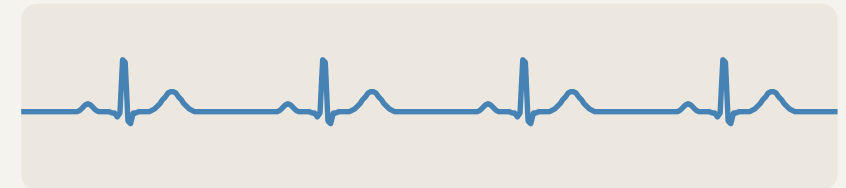


Capacitive · motion only



↓ adaptive filter subtracts motion ↓

Recovered ECG · motion removed



PROTOTYPE

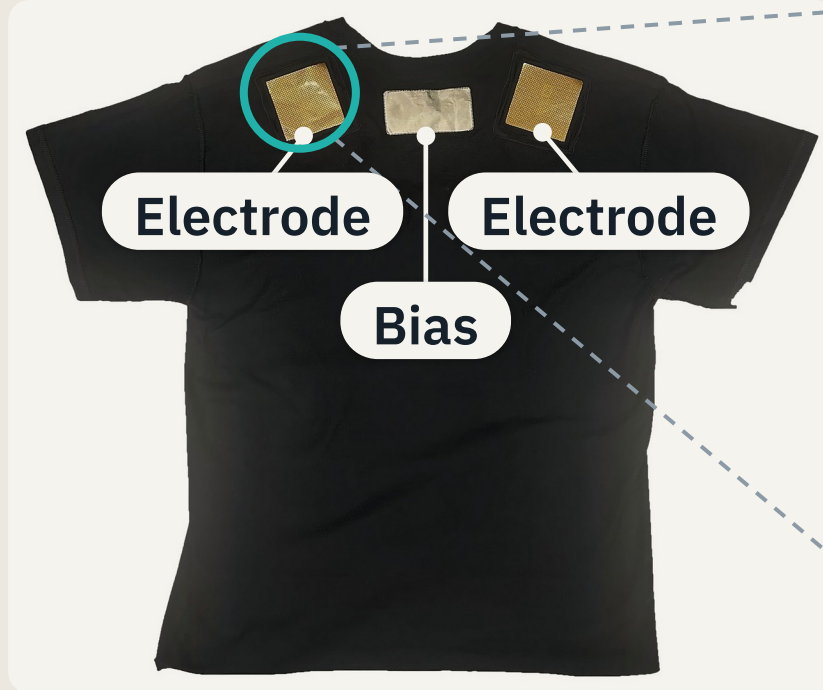
Integrated on a large size T-shirt



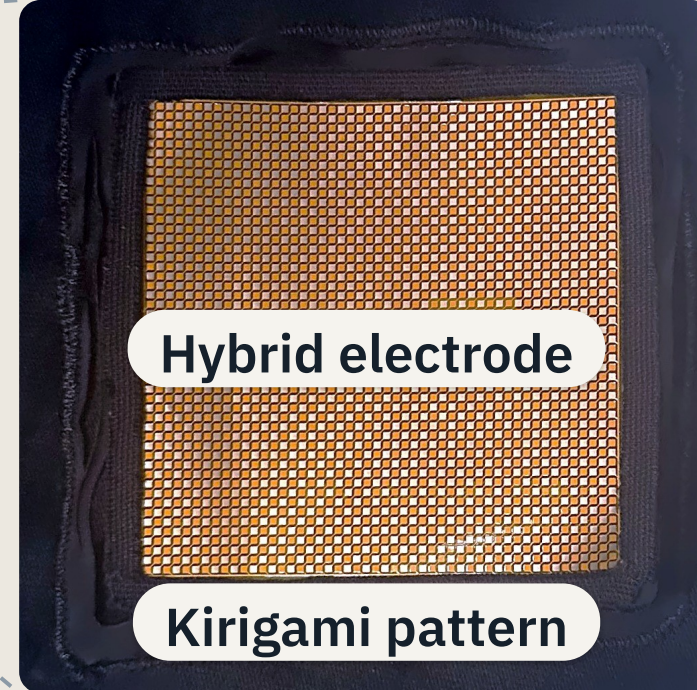
Looks like a regular loose T-shirt (size L, cotton)

PROTOTYPE

Integrated on a large size T-shirt



Two sensing electrodes 18 cm apart,
bias in the middle



7 × 7 cm flexible PCB in a 9.5 cm
kirigami pattern on spandex

PROTOTYPE

Integrated on a large size T-shirt



Back: an OpenBCI board streams both channels wirelessly at 250 Hz

RESULTS

Pilot Study

Protocol · 2 min each

4.83 / 5

comfort, convenience, ease of use



Sitting



Using device
(sitting)



Chatting
(standing)



Walking



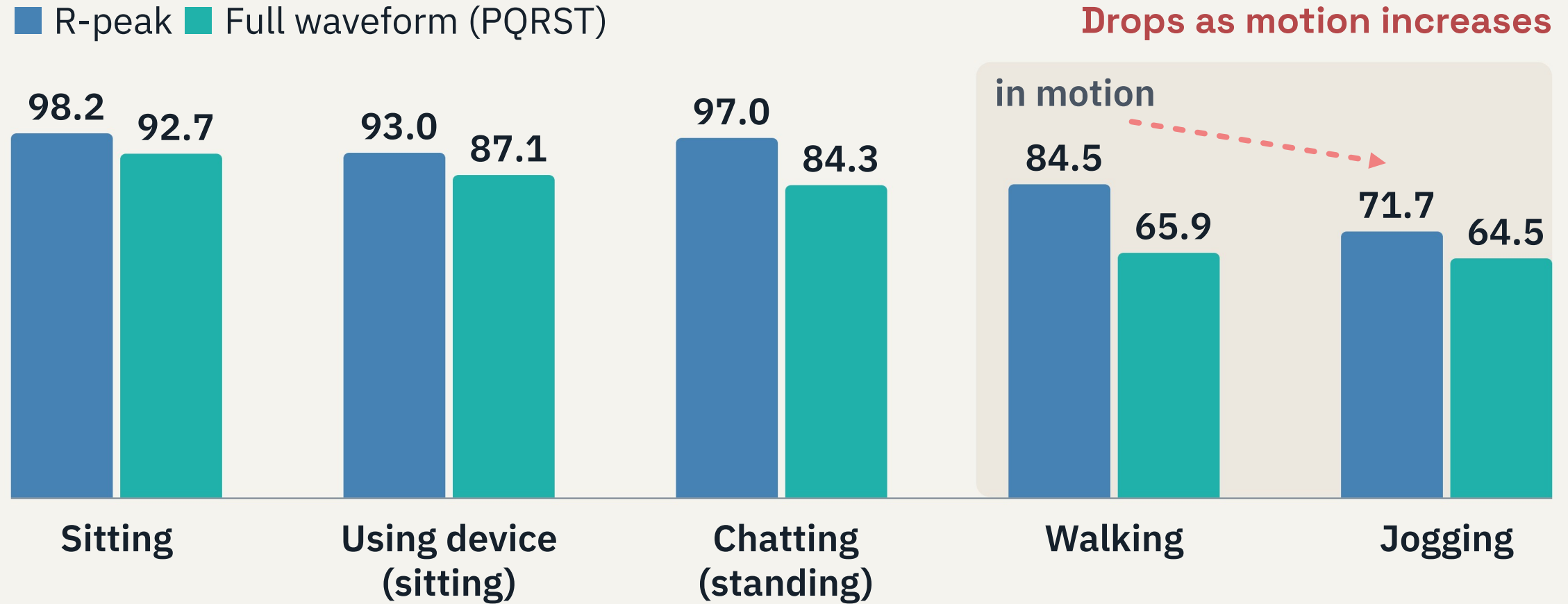
Jogging

Compared beat by beat against Lead I from wet Ag/AgCl electrodes on the forearms

RESULTS

Pilot Study

■ R-peak ■ Full waveform (PQRST)

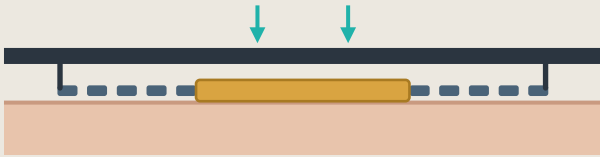


% of heartbeats matched to the wet-electrode ground truth

DISCUSSION

One shirt size doesn't fit every body

Too loose lower BMI



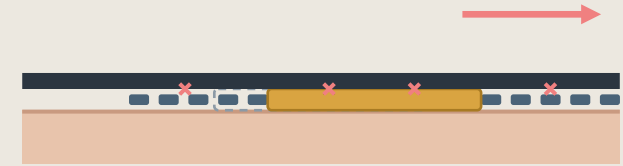
Light contact pressure
at rest, weaker contact

Just right **designed fit**



Kirigami is free to deform
the shirt moves and the
electrode stays

Too tight higher BMI



Layers pressed together
in motion, friction locks
the kirigami and the shirt
drags the electrode

FUTURE WORK

What we'll try next

1 Multiple shirt sizes

2 Low-friction linings

3 Multi-electrode clusters

4 Wider BMI study

TAKEAWAY

Motion decoupling is the key



| Gravity holds

| Kirigami absorbs

| Filtering subtracts

84.5% of heartbeats while walking · no glue or gel · 4.83 / 5 comfort



Thank you · Questions?

colman.leung@columbia.edu · colmanleung.com

On the job market · Industry research scientist roles · from summer 2027

