EarSteth: Phonocardiogram Reconstruction using Earbuds

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Motivation

Physicians **auscultate** the heart with a stethoscope to evaluate general health and diagnose irregularities like heart murmurs.

In telehealth, however, physicians cannot easily perform auscultation.

38x
increase in telehealth utilization during COVID

By wiring out the **in-ear microphone** in common consumer active noise-cancelling earbuds, we can record sounds from the ear canal without additional hardware.

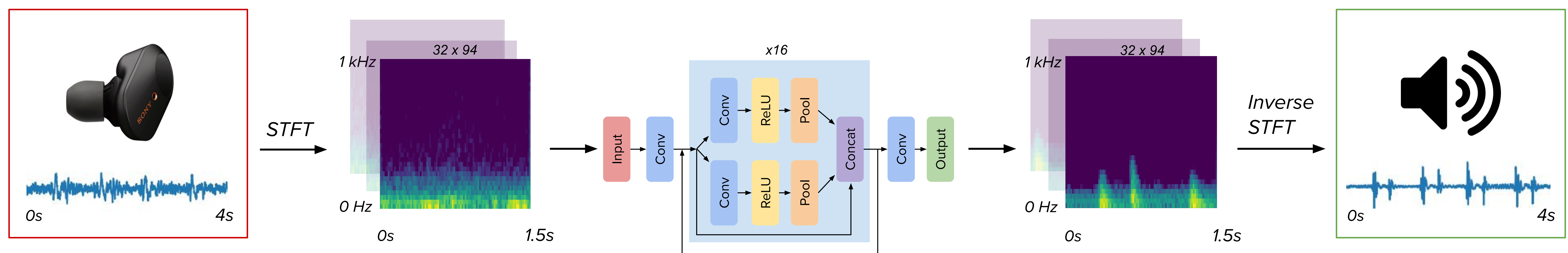Outer Microphone · Inner Microphone · Speaker · Ground
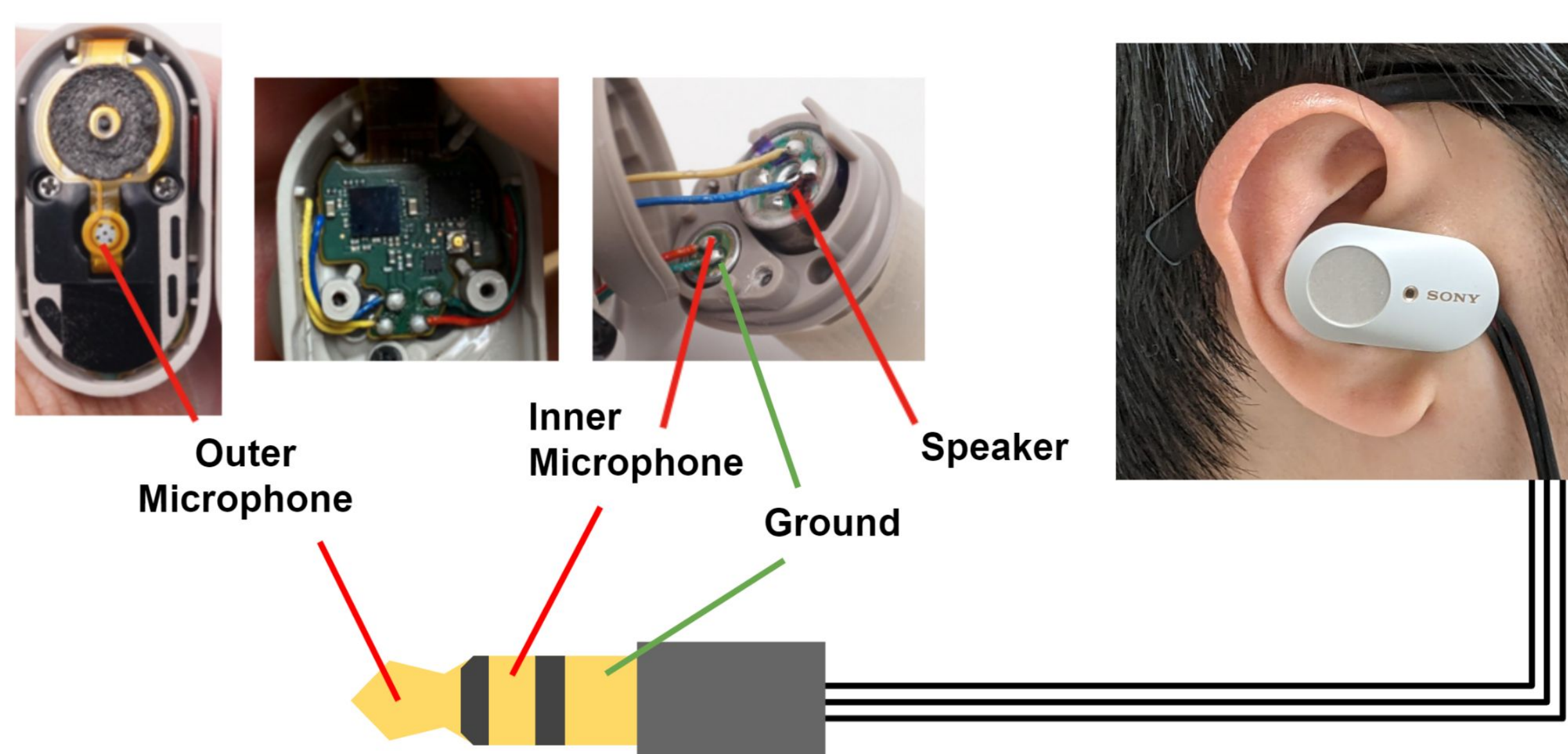
These recordings can be used to **reconstruct stethoscope-like sounds**, potentially enabling:

- Remote heart auscultation for telehealth
- Sporadic heart monitoring without special sensors

13-17%
of all medical visits are via telehealth

Phonocardiogram Reconstruction

Raw Earbud Sounds
Recorded from in-ear mic.

Input Spectrograms
After preprocessing, 1D audio data is windowed and translated into the 2D log-frequency domain.

EarStethNet
A 2D CNN residual network with two receptive fields for preserving both inter- and intra- heartbeat timing. Optimizes for **perceptual similarity** to a digital stethoscope.
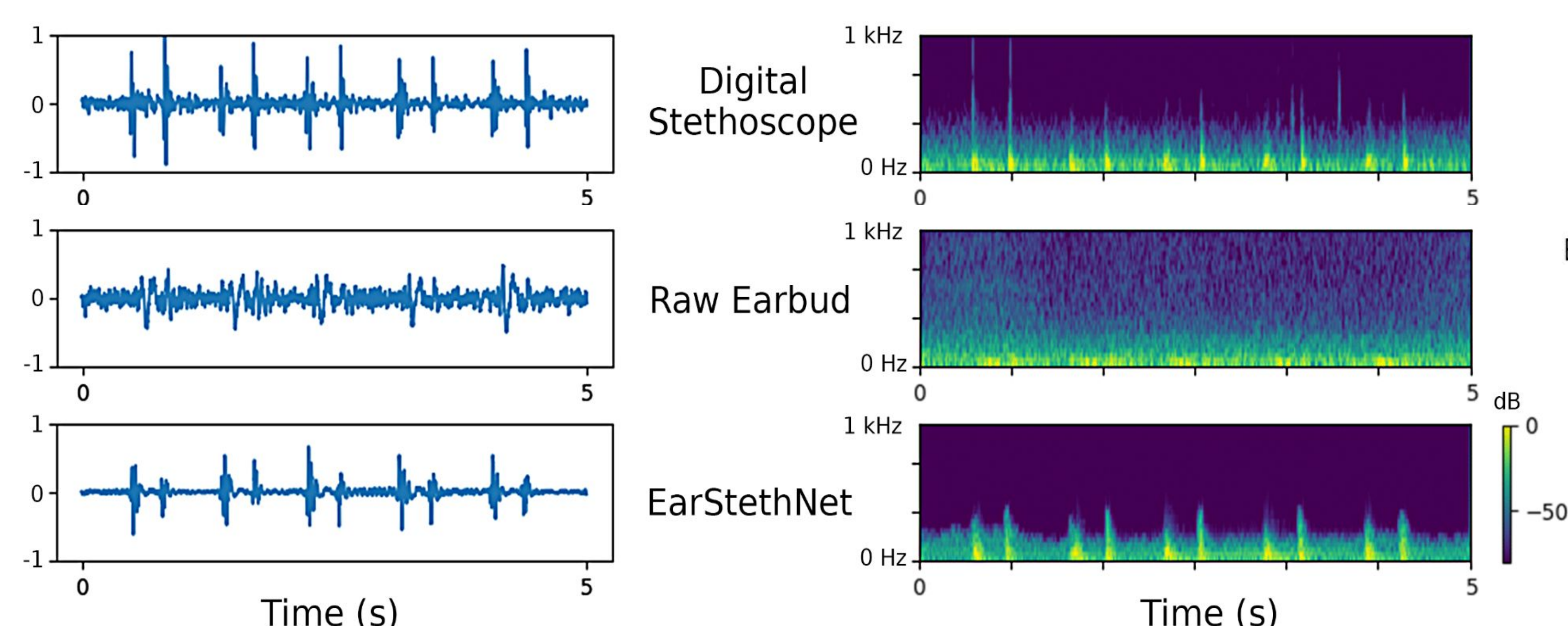
Reconstructed Spectrograms
Inverse preprocessing transforms are applied and windows are stitched back together.

Reconstructed Phonocardiogram
Stethoscope-like sounds are reproduced for interpretation by a clinician.
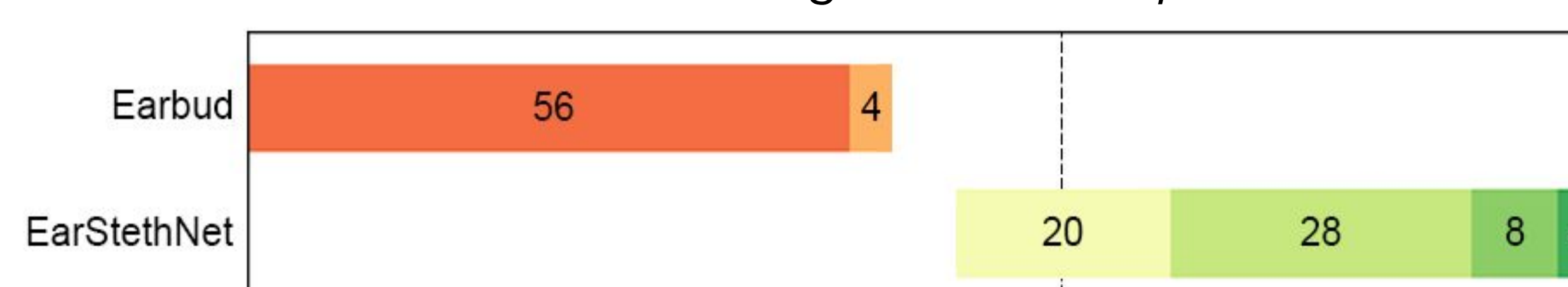
Pilot Study Results

Samples from 15 user pilot study

Digital Stethoscope · Raw Earbud · EarStethNet

Survey of 15 clinicians

"The audio from (recording variant) is _____ suitable for auscultation than the digital stethoscope"

- 1 - Significantly Less
- 2 - Moderately Less
- 3 - Slightly Less
- 4 - Equally
- 5 - Slightly More
- 6 - Moderately More
- 7 - Significantly More

Earbud: 56, 4
EarStethNet: 20, 28, 8, 4

Next Steps - Clinical Study

EarSteth is currently trained on mostly healthy heart sounds, but needs to be able to reconstruct irregularities to be clinically useful.