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Technical challenges in health research and RADAR-Base



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Technical Challenges

- Device Integration.
- **Real-time data** collection and analysis.
- Data security, privacy, standardisation and storage.
- Ensuring **scalability** and **interoperability** of the platform is complicated.
- Data **monitoring** and participant **compliance**.
- **Ease of** study setup and configuration.
- Participant **acceptance and PPIE feedback**.
- Data from **external** sources.
- Technical feasibility of the Protocols.

Data Stream Integration Challenges

- Diverse devices generate various data streams.
- Integrating data seamlessly poses significant challenges.
- Real-time processing and analysis can be complex.
- Secure data management and sharing are crucial.



Platform Scalability Challenges

- Platform scalability and interoperability are complex.
- Scaling beyond single server has limitations.
- Distributed deployments enable horizontal scaling.
- Kubernetes improves platform scalability and management.
- Docker Compose suitable for limited scalability needs.



Data Compliance & Monitoring

- Securely monitor and ensure data compliance
- Implement robust data governance frameworks
- Maintain data quality and integrity
- Adhere to regulatory standards and policies

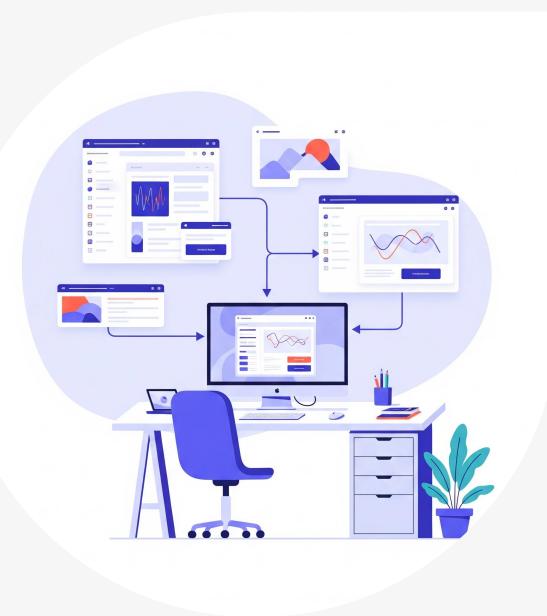




Participant Compliance Challenges

- Ensure participants comply with study protocols.
- Implement robust monitoring mechanisms.
- Maintain participant engagement and adherence.
- Address challenges in remote data collection.

Study Setup & Config



- 01 Simplify study setup with intuitive tools
- 02 Streamline the research workflow
- 03 Configure studies with flexible options
- 04 Efficiently manage various study parameters

Participant Acceptance Challenges

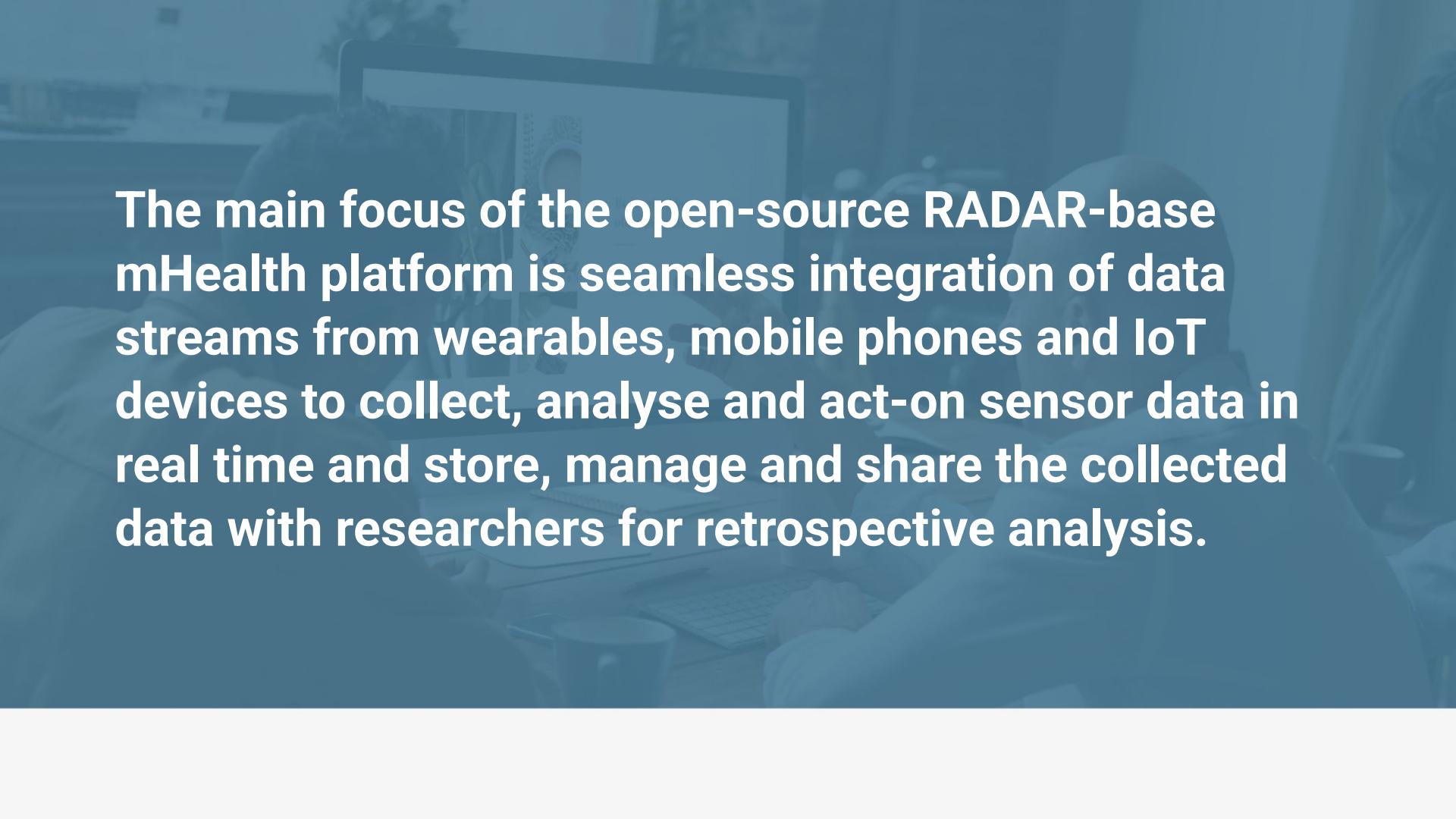
- Participants must accept technical apparatus.
- Explain the device to the participants.
- Provide training on device usage.
- Address concerns for comfort and privacy.



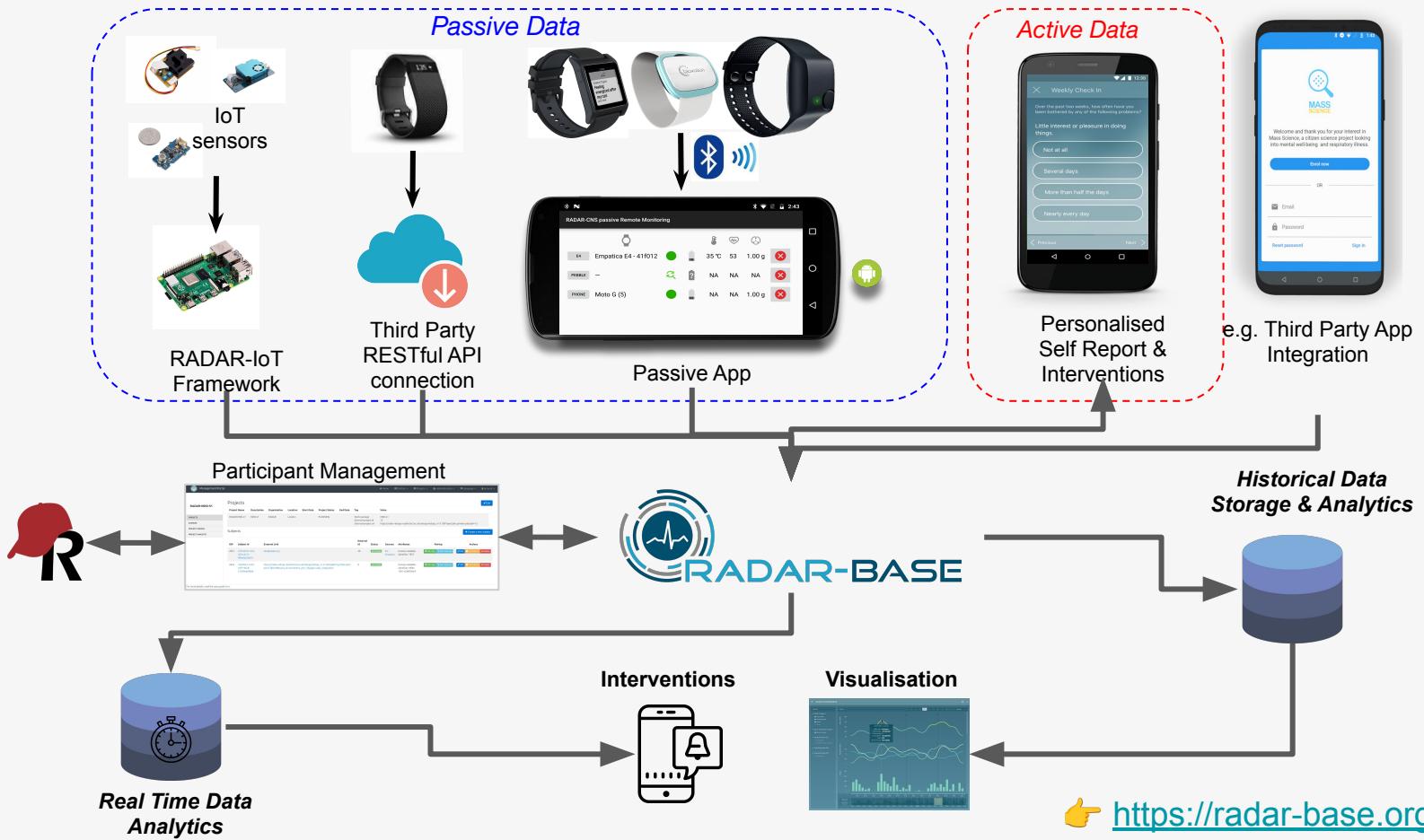


External Data Challenges

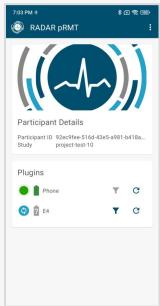
- Integrating external data sources presents hurdles.
- Data from unknown origins lacks platform integration.
- This results in fragmented and inconsistent data.
- Addressing this is crucial for comprehensive analysis.



The main focus of the open-source RADAR-base mHealth platform is seamless integration of data streams from wearables, mobile phones and IoT devices to collect, analyse and act-on sensor data in real time and store, manage and share the collected data with researchers for retrospective analysis.



Devices and Apps Integrated with RADAR-base



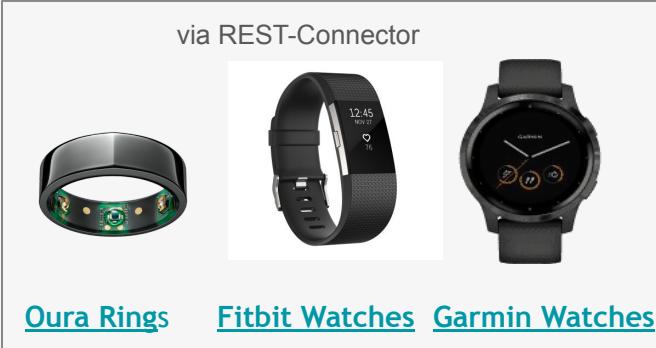
[Polar](#)



[Empatica E4](#)



[Bittium Faros 180](#)



[Dreem 2](#)

RADAR-base Passive App



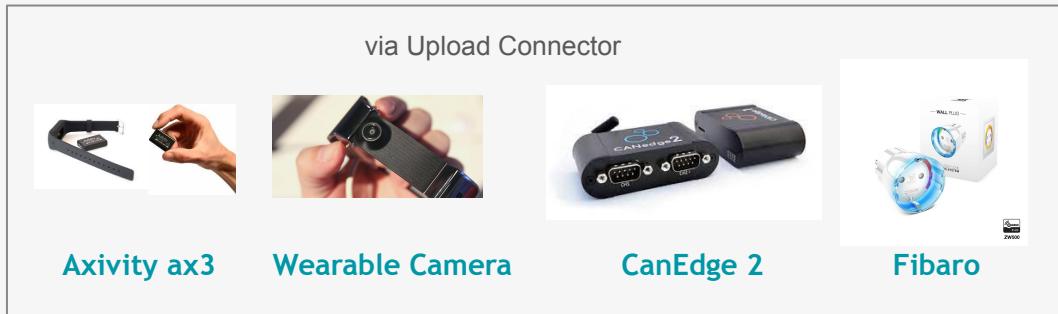
[Apple Healthkit](#)



[Altoida App](#)

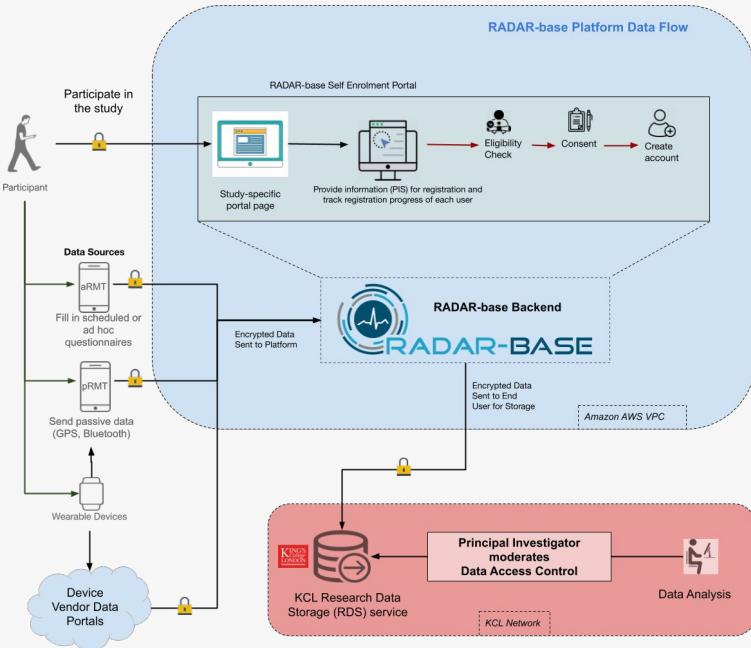


[Banking App](#)



RADAR-base Active App

Self Enrolment Portals



PAPrKA: How Active are People After Knee Surgery?

The Physical Activity Patterns after Knee Arthroplasty (PAPrKA) study will discover how long it takes to recover from knee surgery and how quickly people can expect to get their mobility back.

Led by the University of Manchester, we will ask people who have had surgery via the NHS or through a private healthcare provider, to share past data from their fitness tracker and smartphone applications and link it to their National Joint Registry record, so we can find answers to these questions.



Who Can Take Part?

- A. People living with knee osteoarthritis who had a total or partial knee replacement by the NHS or a private healthcare provider:
 - between January 2017 and December 2023
 - are over 18 years old and live in England, Wales, Northern Ireland, Isle of Man or Guernsey at the time of the surgery
- B. People must have used a smartphone or fitness tracker to track their activity before and after the knee replacement surgery.
- C. The device used can be: iPhone, Fitbit, Apple Watch, Garmin and Oura Ring.
- D. People who can read and understand English or have support from someone who can.
- E. People must be willing to give us permission to access their physical activity data and link to their knee replacement information in the National Joint Registry.

As a thank you for taking part, you can opt into the study's prize draw when you fill in our consent form. This will give you a chance to win one of the Amazon gift cards.

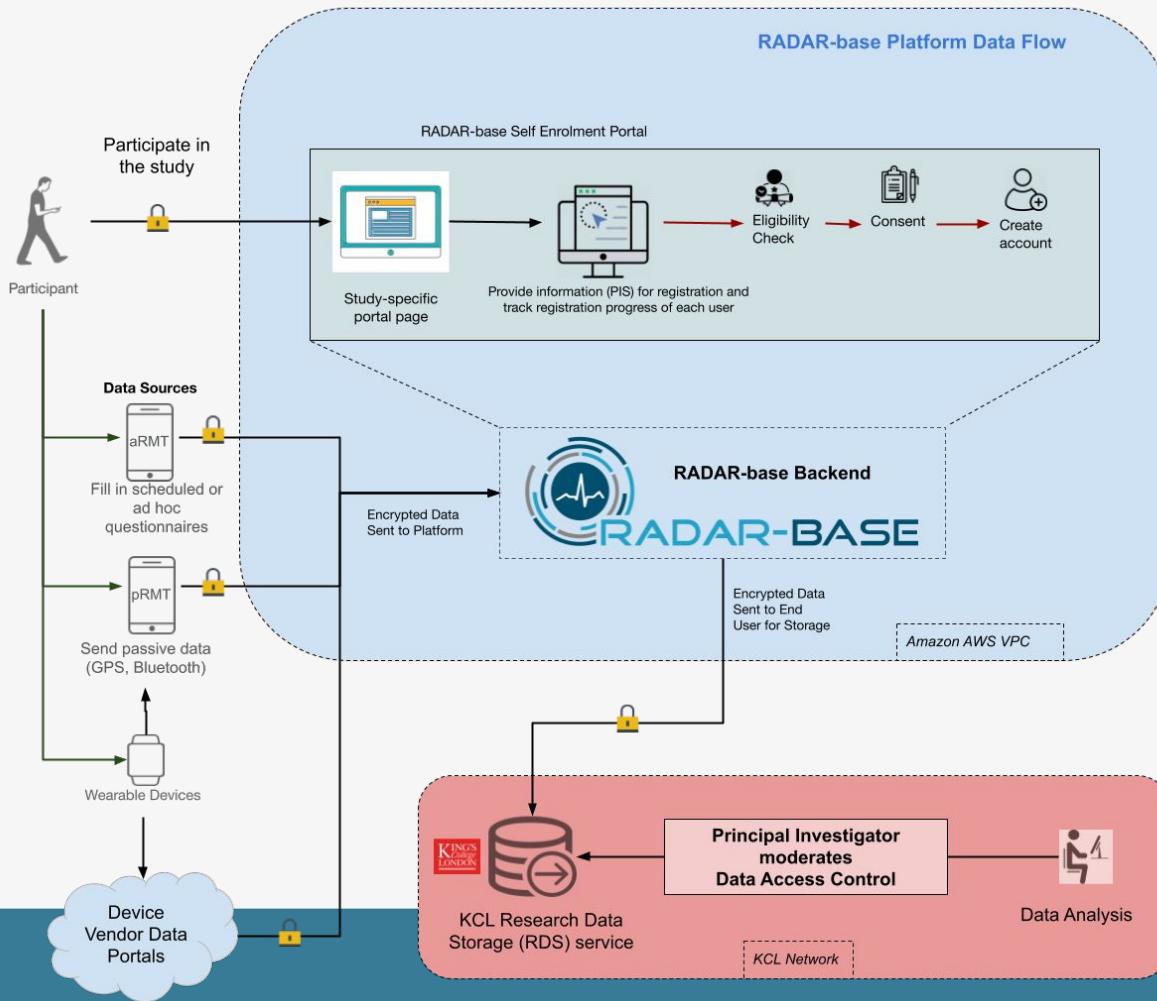
Connecting Your Fitness Tracker

We will collect past activity data from participants fitness trackers or smartphone apps and analyse it to understand recovery and mobility after knee replacement surgery.

We're looking for people who tracked activity levels before and after surgery using an iPhone, Fitbit, Apple Watch, Garmin and Oura Ring.

Connecting your device couldn't be simpler. With help from real patients, we have designed a step-by-step process that will support





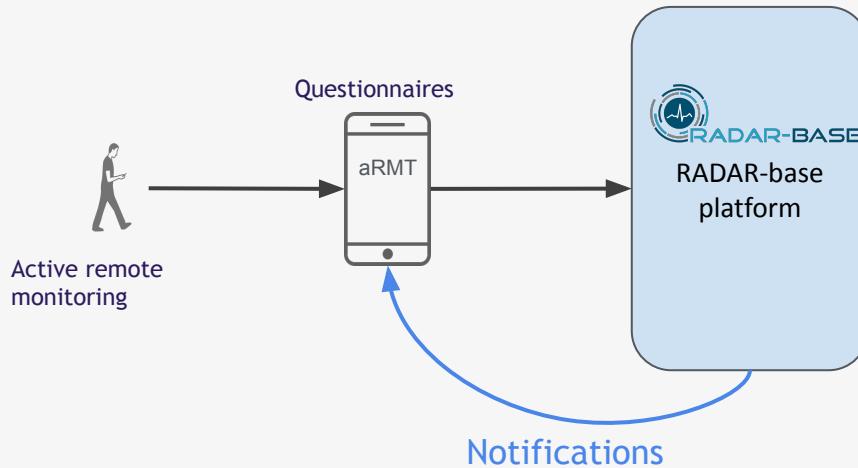
RADAR-base Active Remote App

The image displays four screenshots of the RADAR-base Active Remote App interface:

- Registration:** A dark teal screen with the word "Registration" in white. Below it, text reads: "Before you can start using the app, we need to register it first. Click the 'Scan' button and point the camera onto the QR code, given by your doctor. An example QR code is below." Below the text is a QR code.
- Today:** A teal screen showing the date "Today" at the top. In the center is a large circle with the number "0" and the word "Completed" below it. At the bottom, it says "Your next task starts in 7hrs." and shows a timer "7x 7min". A yellow triangle icon with the text "Requires a quiet space" is present. At the bottom is a large blue "Start" button.
- Questionnaire:** A teal screen asking, "Over the past two weeks, how often have you been bothered by any of the following problems?" Below is a list of symptoms with corresponding response options:
 - Little interest or pleasure in doing things.
 - Not at all
 - Several days
 - More than half the days
 - Nearly every day
- Settings:** A teal screen titled "Settings" with a back arrow. It includes sections for "User Info" (User ID: 1814), "Project Name: RADAR-MDD-KCL-s1", "Enrolment Date: Last Thursday at 1:00 AM", "Language" (set to English), "Notifications" (Sound: on, Vibration: off, Night Mode: on), and a red "Reset" button at the bottom.

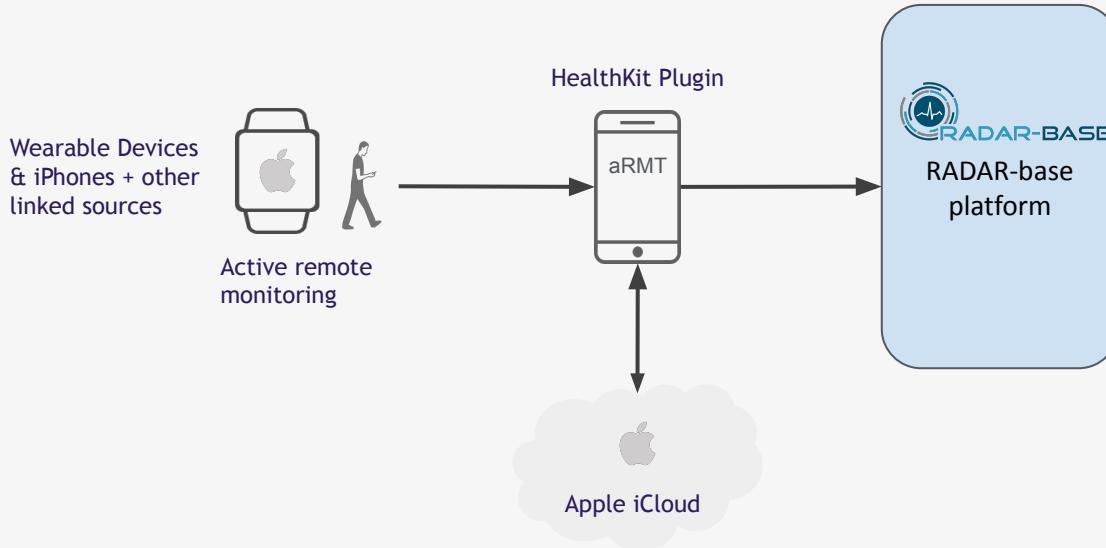
Patient reported data e.g. Questionnaires, Speech or Pictures/Video

Active (aRMT) app: Patient Reported Outcome Measures:



- aRMT app for electronic patient reported outcome (ePRO)
 - Data generation requires conscious effort from the participant
 - Customizable surveys and schedule by researchers
 - Configurable time window to complete tasks
 - Notifications to remind users to complete surveys or tasks
 - Easy onboarding via QR code scanning
 - Other tasks e.g. Audio or speech sampling & Apple HealthKit
 - Network partition tolerance
 - Cross platform

Apple HealthKit Integration



- **HealthKit Plugin for Collecting Apple ecosystem data**
 - Integrated via the aRMT
 - Provides access to a wide variety of HealthKit data types
 - Live and historic data collection
 - Unlike REST-Connectors data flows via the phone

iOS HealthKit Integration

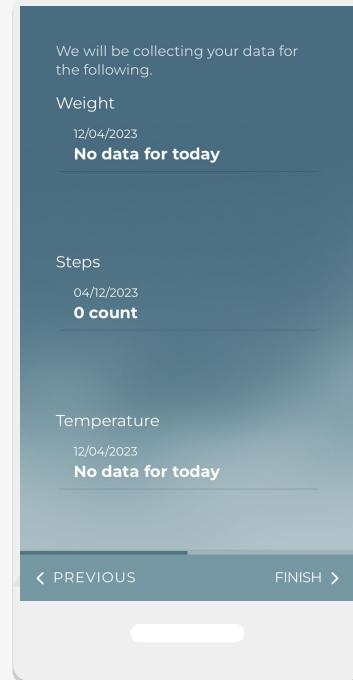
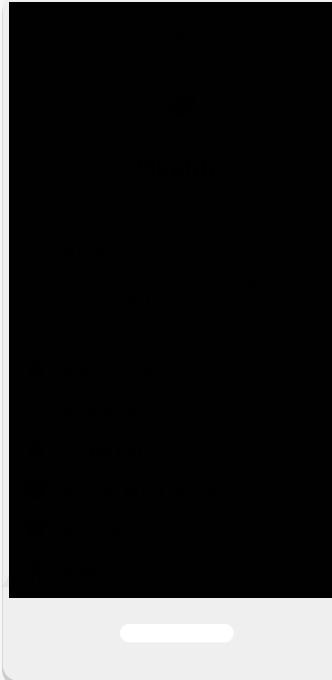


The HealthKit framework is designed to share data between apps in a meaningful way. Integration is via the RADAR-base Active App.

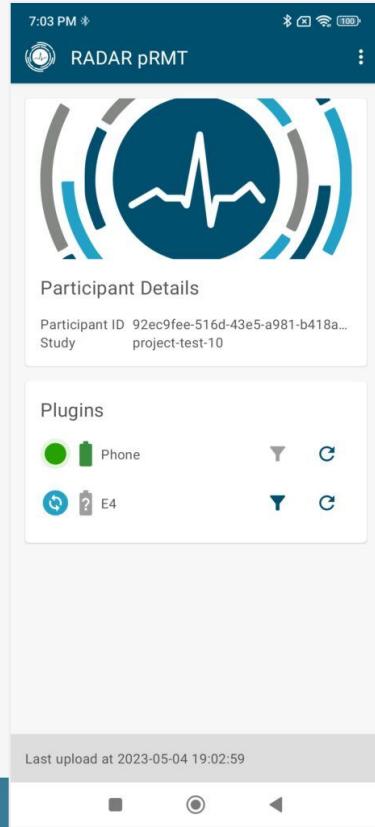
https://developer.apple.com/documentation/healthkit/about_the_healthkit_framework

User Flow

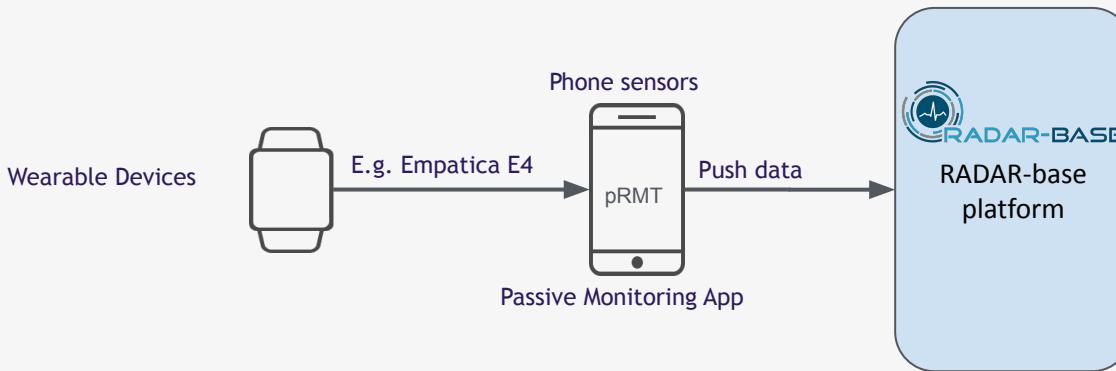
1. Open the app
2. Start a task to collect HealthKit data
3. Allow HealthKit Permissions
4. View HealthKit Data
5. Finish the task and data will be sent to the server



RADAR-base Passive App

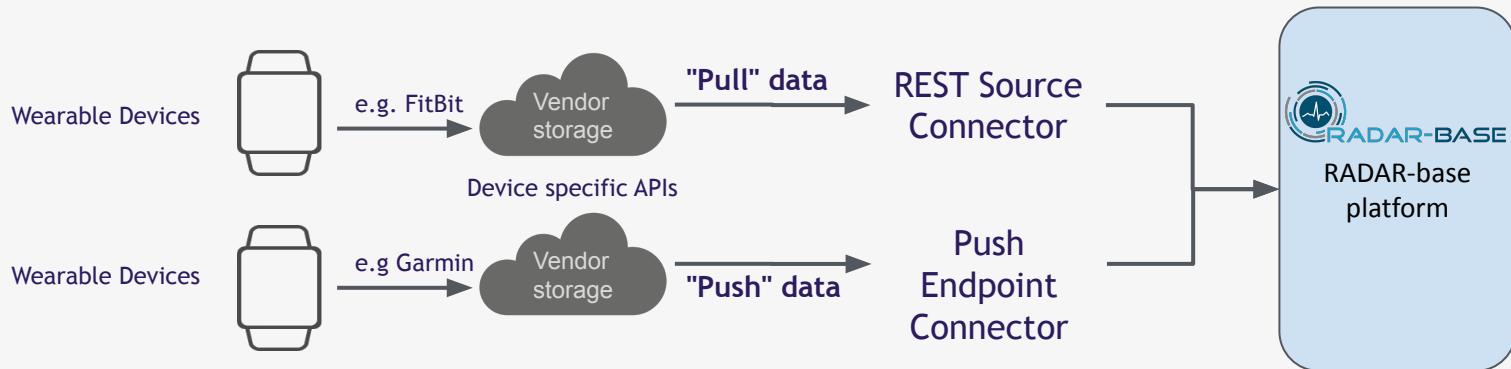


Passive (pRMT) app: Phone Sensors and Wearables



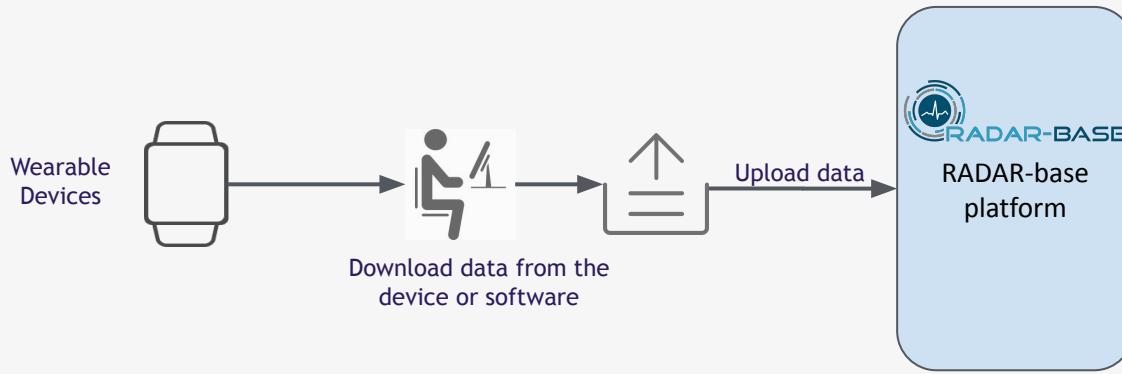
- **pRMT app for passive data collection**
 - Collect data from native phone sensors
 - SDK Plugin architecture for integration of wearable devices over Bluetooth
 - e.g. Empatica E4, Faros, etc
 - Easy onboarding via QR code scanning
 - Real-time streaming
 - Customizable plugins per study
 - Network partition tolerance
 - Presently Android (alpha on iOS)

REST-API Sources: Data collection from 3rd party data portals



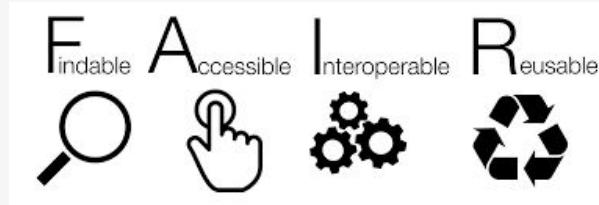
- Passive data collection via wearable devices without Bluetooth SDK
 - Plugin integrations of 3rd party APIs.
 - e.g. Fitbit (Pull) and Garmin (Push)
 - Easy device authorization and integration to a study participant via Authentication portal
 - Server-to-Server data transfer
 - Collect data in vendor-determined latency or retrospectively

Manual data collection of data



- Data collection from devices without any integration methods
 - Allows integration of devices and sensors without integration methods (i.e. no bluetooth SDK, APIs or other automated data sharing methods)
 - Home embedded sensors
 - Devices with proprietary software
 - Upload data using a web application to the platform backend

Data harmonization and standardization in RADAR-base



- Open and harmonized data schemas
- Inspired by Open mHealth
- Automatically transformed and structured with pseudonymised identifiers

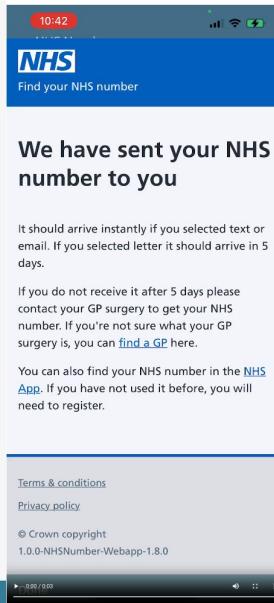
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  "namespace": "org.radarcns.passive.empatica",
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  "name": "EmpaticaE4Acceleration",
  "doc": "Data from 3-axis accelerometer sensor with gravitational constant g as unit.",
  "fields": [
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    { "name": "timeReceived", "type": "double", "doc": "Device receiver timestamp in UTC (s)."},
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    { "name": "z", "type": "float", "doc": "Acceleration in the z-axis (g)."}
  ]
}
```

NHS ID Capture and Consent



see blog [NHS ID Integration](#)



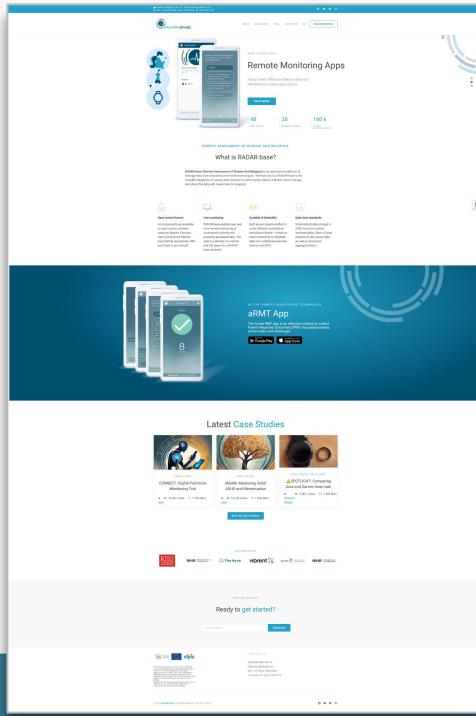
- Linkage of **mHealth** data collected with RADAR-base to **Clinical Records and Registries**
- Provides an instrument for Consent and NHS Number recovery within the **Active App**
- Wide range of applications from existing cohorts to citizen science projects

How can I use RADAR-base?



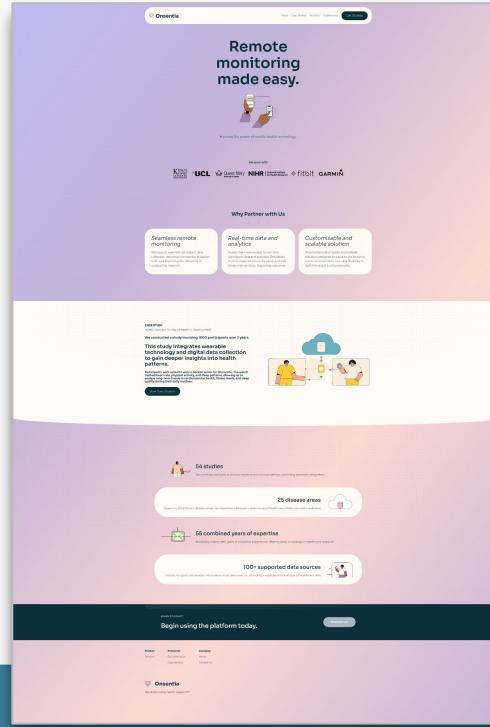
Self deploy open source RADAR-base

<https://radar-base.org>



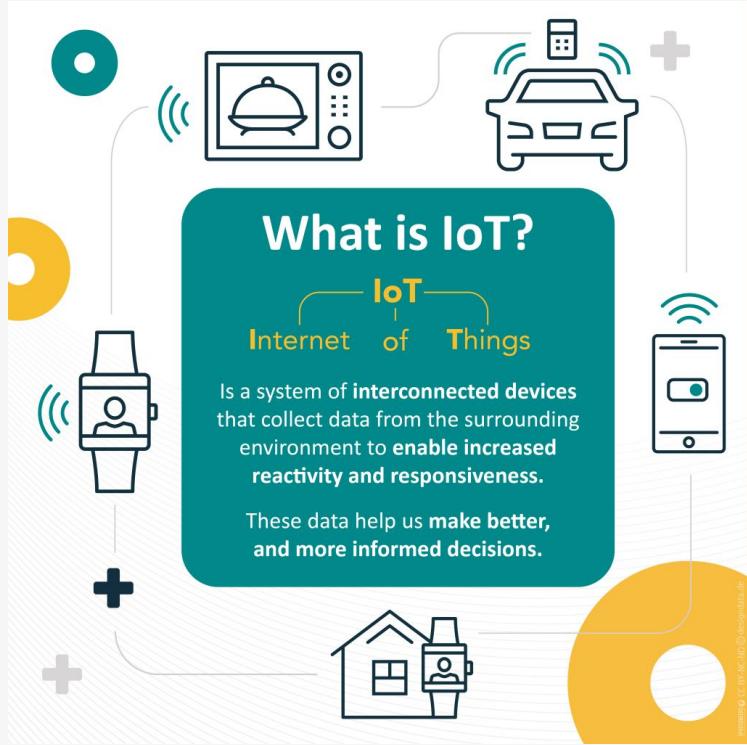
Onsentia managed RADAR-base service and consultancy

<https://onsentia.com>



Internet of Things (IoT)

The Internet of Things describes the **network of physical objects**—“things”—that are embedded with sensors, software, and other technologies for the purpose of **connecting and exchanging data** with other devices and systems over the **internet**.



RADAR-IoT Framework



- A flexible and extensible **Internet of Things** edge gateway framework for plugging in a wide variety of different sensors and using those as inputs for processing the data in different ways.
- Supports **uploading IoT sensor data to RADAR-base** platform.
- Has support for uploading to InfluxDb so can be easily visualised in **real-time on Grafana dashboards**.
- Can easily add more data processing variants and more sensors.
- It is language and platform agnostic.

RADAR-IoT Real-time Dashboard

<https://radar-iot-dashboard.rosalind.kcl.ac.uk/grafana/d/3BdzY0MGk/yatharths-raspi-3b?orgId=1&from=1593815705598&to=1601533581962>



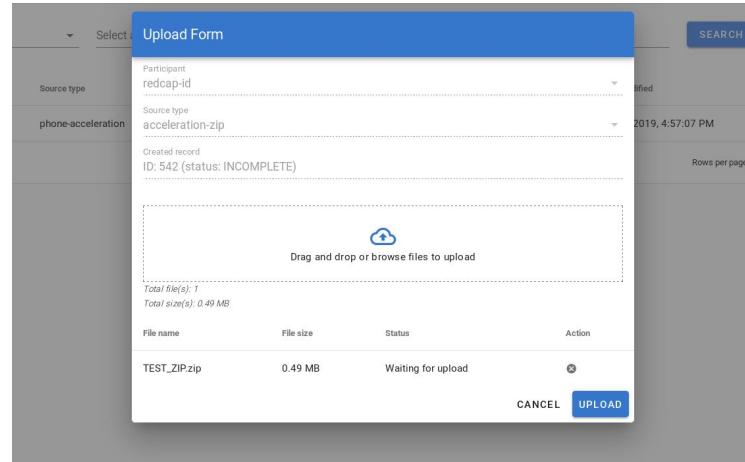
Holistic View of a User's health and environment

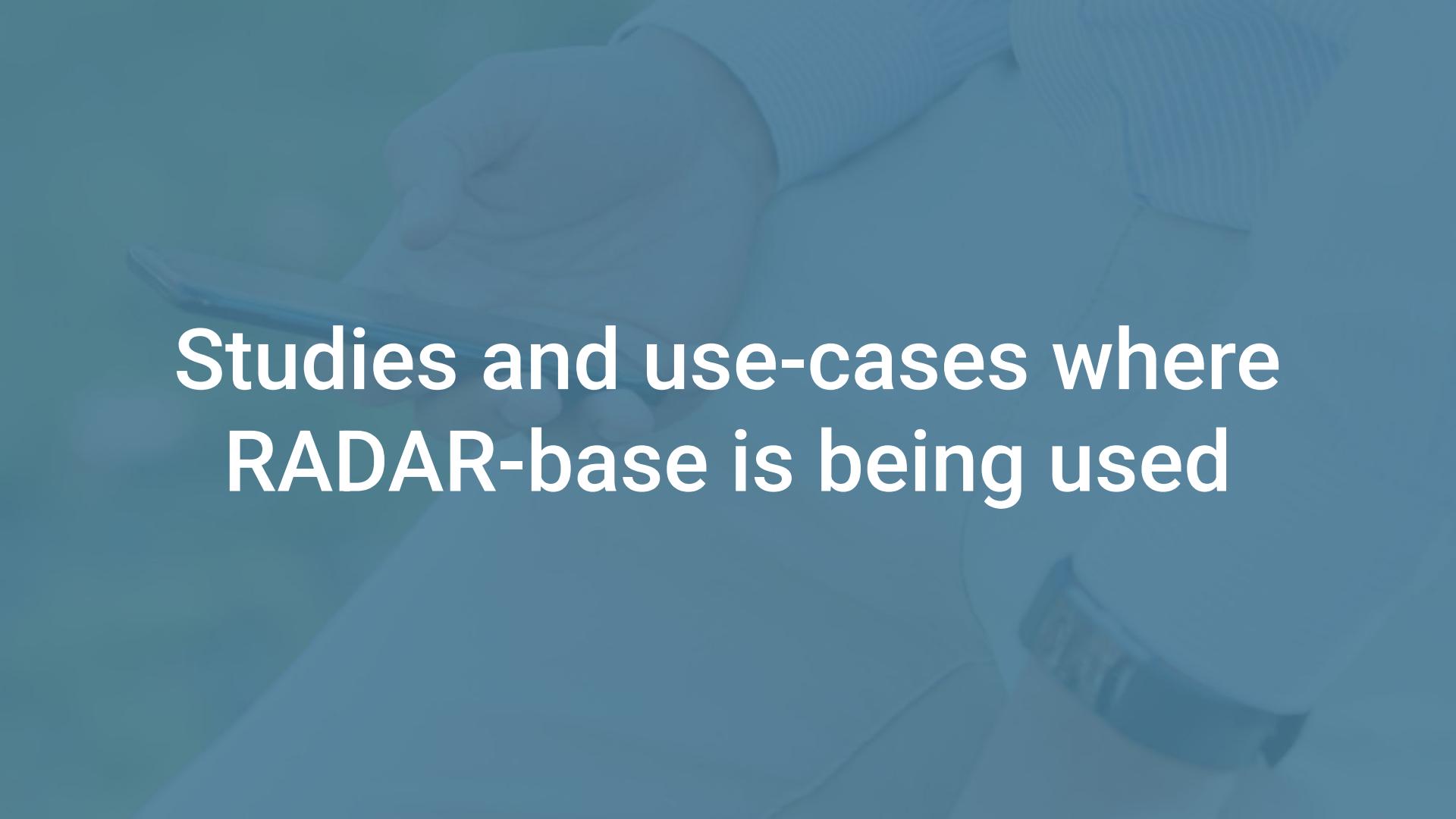
Using the RADAR-IoT framework with the RADAR-Base platform provides a **360° view into a user's health and environment** including data from -

- Wearable devices
- Mobile phone sensors and interactions
- Questionnaires and tasks
- Audio
- Environmental sensors like indoor air quality, temperature, humidity and toxic gas levels.
- Offline medical device data connected via serial interface to the RADAR-IoT edge device

Upload Connector

- A new upload mechanism/application has been developed to allow users to manually upload data/files to RADAR Base.
- Some study devices don't have an SDK or are difficult to integrate into the platform.
- Thus, the upload application can be used to manually upload files for participants into the server.



A photograph of a medical professional, likely a doctor or nurse, wearing a white lab coat and a stethoscope. They are holding a smartphone in their right hand, which is resting on their chest. The background is slightly blurred.

Studies and use-cases where RADAR-base is being used

CoViD Collab

- Research study to investigate the ongoing COVID-19 pandemic
- Key feature is the use of a **Fitbit** plus **MASS SCIENCE app** which will be used to investigate changes in measurements such as heart rate during infection with coronavirus.
- Will help understand the psychological impact, symptoms and disease trajectory associated with covid-19 and potential to generate digital **biomarkers** from wearable data.
- Now has more than 15,000 users enrolled in the study with more than 10,000 users donating Fitbit data.

Studies

All RADAR-CNS
studies
(except Epilepsy)

IMI - AIMS-2-Trials:
Autism study, Funded
n=300
Network of 37
countries, 100 sites

SUBER-Epilepsy:
Forecasting of
Epileptical Seizure in
KCL, Ongoing
N=10

EEG-at-Home,
Ongoing

ART - Attention-Deficit/
Hyperactivity disorder study (ADHD) -
Pilot study, Completed
N=45
Integration of three **cognitive tests** and
clinical assessments in **aRMT**.
Use of **pRMT** app with **FitBit**
Funded by KCL

RALPMH - Remote
Assessment of Lung
disease and impact on
Physical and Mental
Health, Ongoing

RADAR-Engage -
Depression and
User Engagement
Study, Ongoing

RALPMH - Lung Disorders

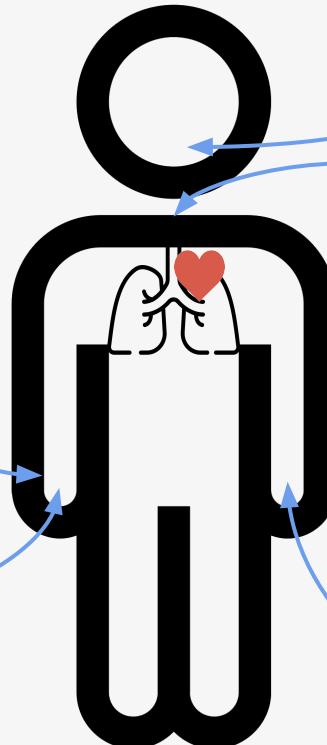
- Evaluate remote monitoring (mHealth) in **3 Lung Diseases** - COPD, IPF and Post Hospitalisation Covid. Total n=60.
- Evaluate wearable data against (Spirometry & Self-report) in the detection of clinically important events such as **exacerbations**.
- Monitor disease trajectory, symptom variability and disease progression
- Will use the Realtime ML pipeline to **detect exacerbations in realtime** in the COPD arm and prompt feedback from the user using aRMT app.
- Planned to start in May 2021.

RALPMH - Lung Disorders

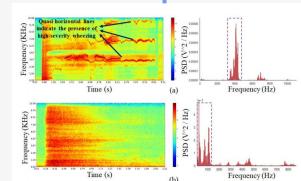
Garmin Vivoactive 4 PPG, HR, SpO₂, Activity, Sleep, Fatigue (body battery)



Finger Pulse Oximetry
HR, SpO₂



Nuvoair Bluetooth Spirometer: lung function test
FVC, FEV-1, Spirogram, Duration



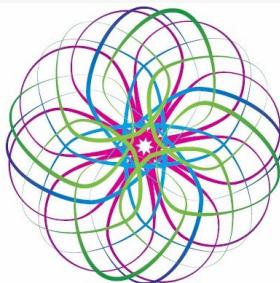
Speech & vocalisation sampling
e.g.
Vocal dynamics, wheezing, symptoms signals



RADAR-base aRMT App (active monitoring):
Questionnaires
Clinical Tests (Symptoms, Severity).
Triggered Exacerbation Rating Scale

RADAR-Base for CRO

- CHDR MORE® for CHDR
 - The Center for Human Drug Research (**CHDR**) is one of early adopters of customized and **white labeled version** of RADAR-base platform called **CHDR MORE®**.
 - The platform is used in multiple trials to **validate** remote monitoring methods and to demonstrate the added value of time-consuming and less invasive studies in a home-based setting.
 - 21 CFR Part 11, GCP and GDPR compliance validation under GAMP5 framework.



CHDR
Centre for Human Drug Research

Research areas:

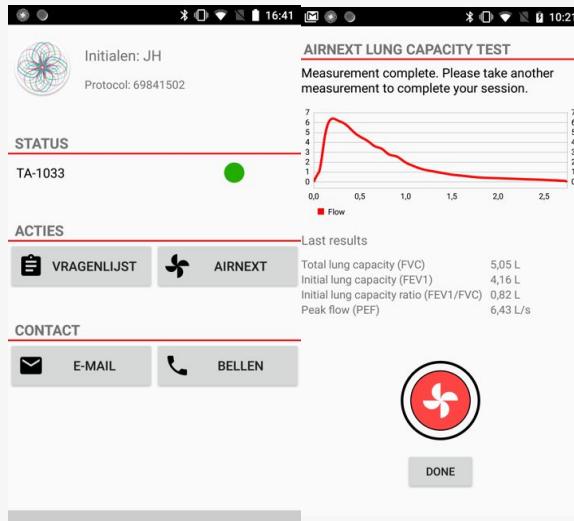
- Respiratory diseases (Asthma)
- Depression

User group:

- Pediatric patients.

RADAR-Base for CRO

- CHDR MORE® for CHDR
 - Customized Android application for study participants
 - Integration with Withings app 'Healthmate'
 - Alerts when app is closed or missing data
 - Support for multiple wearable devices



AirNext Spirometer



RADAR-Base for RATE-AF Trial

- Study patients with Atrial Fibrillation
 - RATE-AF Trial: RAtE control Therapy Evaluation in permanent **Atrial Fibrillation**
 - RATE-AF Stage II for BD@H: BigData@Heart aims to improve patient outcomes and reduce the societal burden of atrial fibrillation and other heart failure diseases
 - RADAR-base data collection to supplement clinical measurements to determine the added value of having data on day-to-day physical activity.



Research areas:

Cardiology - atrial fibrillation

User group:

- Elderly (average age ~ 65 years)
- 50 patients for follow up out of 160 patients in original trial
- typical recording period: 12 months

RATE-AF Trial

Study patients with Atrial Fibrillation

- Combination of pRMT app and Fitbit Charge 2
- PPG plugin integrated to pRMT App
 - PPG Measurement using phone camera and light emitting
 - Developed by UMC Utrecht
 - Evaluated in the trial



RADAR-AD



- Detection of early symptoms of **Alzheimer's Disease**
- Multi-tier studies with different set-up
 - a. Remote monitoring of participants with **wearables** and apps (Tier 1)
 - b. **Smart-home** studies (Tier 2) with inbuilt-sensors

Research areas:

Alzheimer's Disease

User group:

- Elderly (average age ~ 65 years)
- 220 participants with different stages of AD

•

RADAR-AD

- a goal of ~200 participants in **14 sites**
- Currently in **Tier 1** of the study (8 weeks) with devices:
 - a. **Physilog** - monitors user's gait
 - b. **Axiety** - monitors physical activity
 - c. **Oxford Wearable Camera**
- Mobile phone apps:
 - a. **pRMT**
 - b. **Altoida**
 - c. **Mezurio** (Questionnaire and tasks app)
 - d. **Banking App**
- New features: *Upload connector, Kubernetes deployment, Grafana real-time dashboard*

Dynamore

- **DynaMORE (Dynamic Modelling of Resilience)**
 - Stress resilience and mental health study
 - Monitors healthy at-risk adults during stressful life phases (e.g. transition into adulthood or higher education or abruptly changed life situations)
 - has their own deployment of the platform and uses the public version of the aRMT and pRMT app
 - **~500 subjects so far in 5 sites:** Berlin, Mainz, Nijmegen, Warsaw, Tel Aviv



UCL Health-On-The-Move (HOME) Study

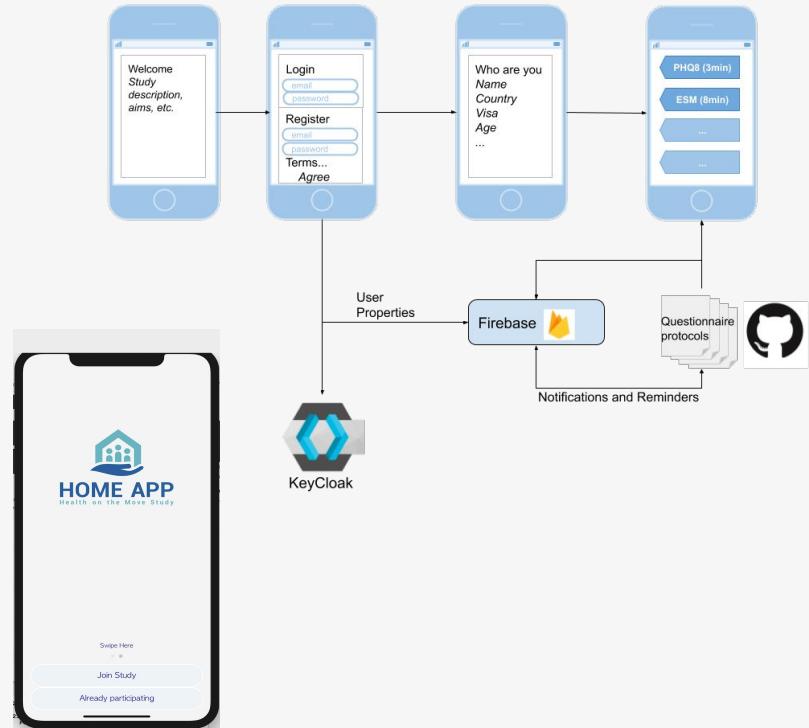
- Customized aRMT app to do **self-registration** and deliver questionnaires
- Micro randomised process evaluations based on selected conditions A/B testing
- **Reminders and completion window**
- Future ideas: Enable pRMT to do self registration Integrate with external API such as HealthKit, ResearchKit

Research areas:

Health of migrants and how these change over time since migration to the United Kingdom

User group:

Migrants who opt-in to participate in the study



Other Studies

ART-CARMA (a part of the IMI TIMESPAN project):
ADHD project, scale up from ART project.
n=300 participants split across UK and Spain (Barcelona VHIR),
Funded

Cognition project:
Look at cognitive dimensions for MDD (from GLAD) and Schizophrenia (from Slam/CRIS) to inform drug development by mapping the cognition tasks to impaired circuits in the scanner.
Considering Adding wearable data to this,
Putative

NHIR LONG COVID:
Research into the longer term effects of COVID-19 in non-hospitalised individuals. Characterisation, determinants, mechanisms and consequences of the long-term effects of COVID-19: providing the evidence base for health care services,
Ongoing

Other Studies

H20

IMI Health Observatory

Outcomes:

brings together the public and private sectors to create an unprecedented, standardised data governance and infrastructure system across Europe to incorporate patients' opinions and preferences in decisions affecting their individual health care and those of the entire patient community, Ongoing

Health Data Research UK

(HDR UK):

Capacity RMT in the Actionable Analytics theme
Ongoing
UK, multiple organisations

NIH PASC Long Covid Call (NICCH):

The solicited research will improve understanding of and develop strategies to prevent and treat post-acute manifestations of SARS-CoV-2 infection across the lifespan.

Putative

N=500-2000

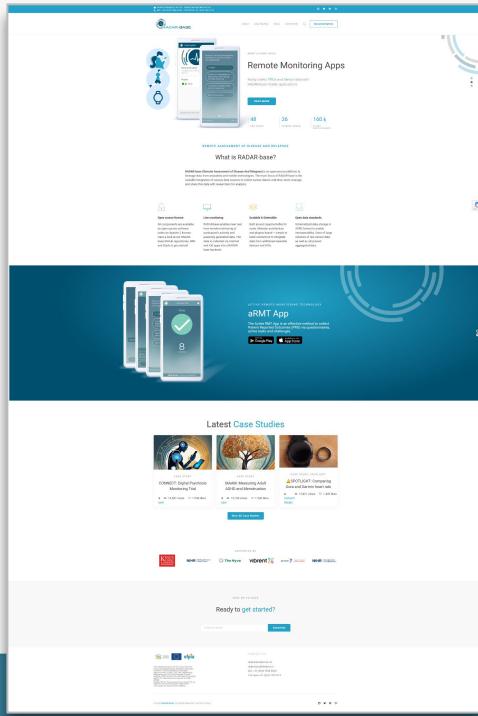
Collaboration b/w Vibrent, KCL
Probably Covid-Collab
infrastructure too if funded.

How can I use RADAR-base?



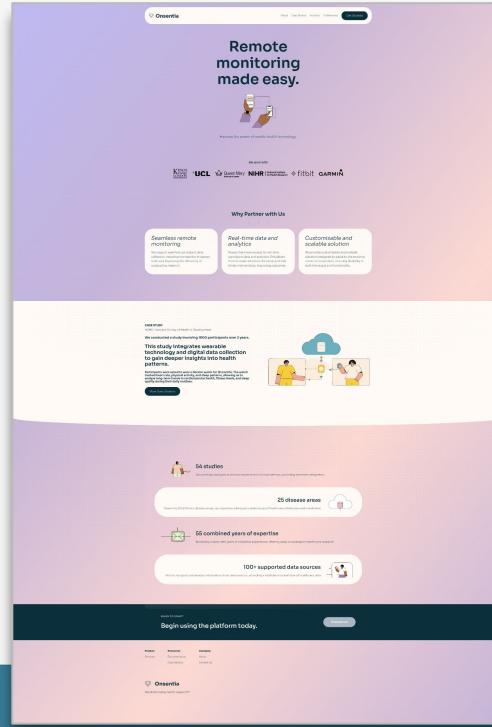
Self deploy open source RADAR-base

<https://radar-base.org>

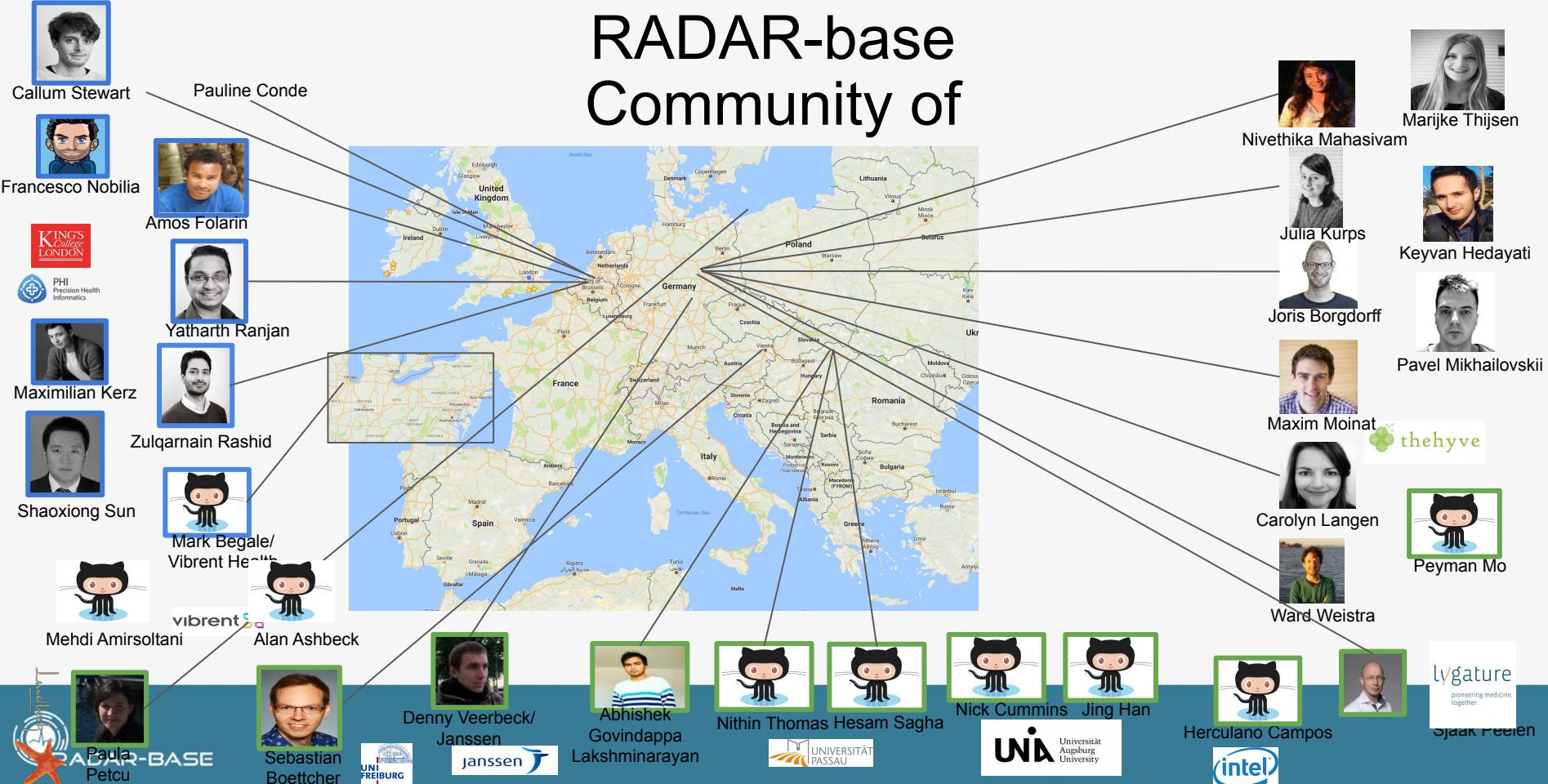


Onsentia managed RADAR-base service and consultancy

<https://onsentia.com>



RADAR-base Community of



Many thanks to the efforts of the KCL Mobile Health Team

and the many supporters and contributors to the RADAR-base project



Software Developer

PAULINE CONDE



Senior Software Development Group Leader

DR AMOS FOLARIN



Software Developer and PhD student

YATHARTH RANJAN



PhD Student

CALLUM STEWART



PhD Student

YUEZHOU ZHANG



Head of Bioinformatics

PROFESSOR RICHARD DOBSON



Lead Research Software Engineer

DR ZULQARNAIN RASHID



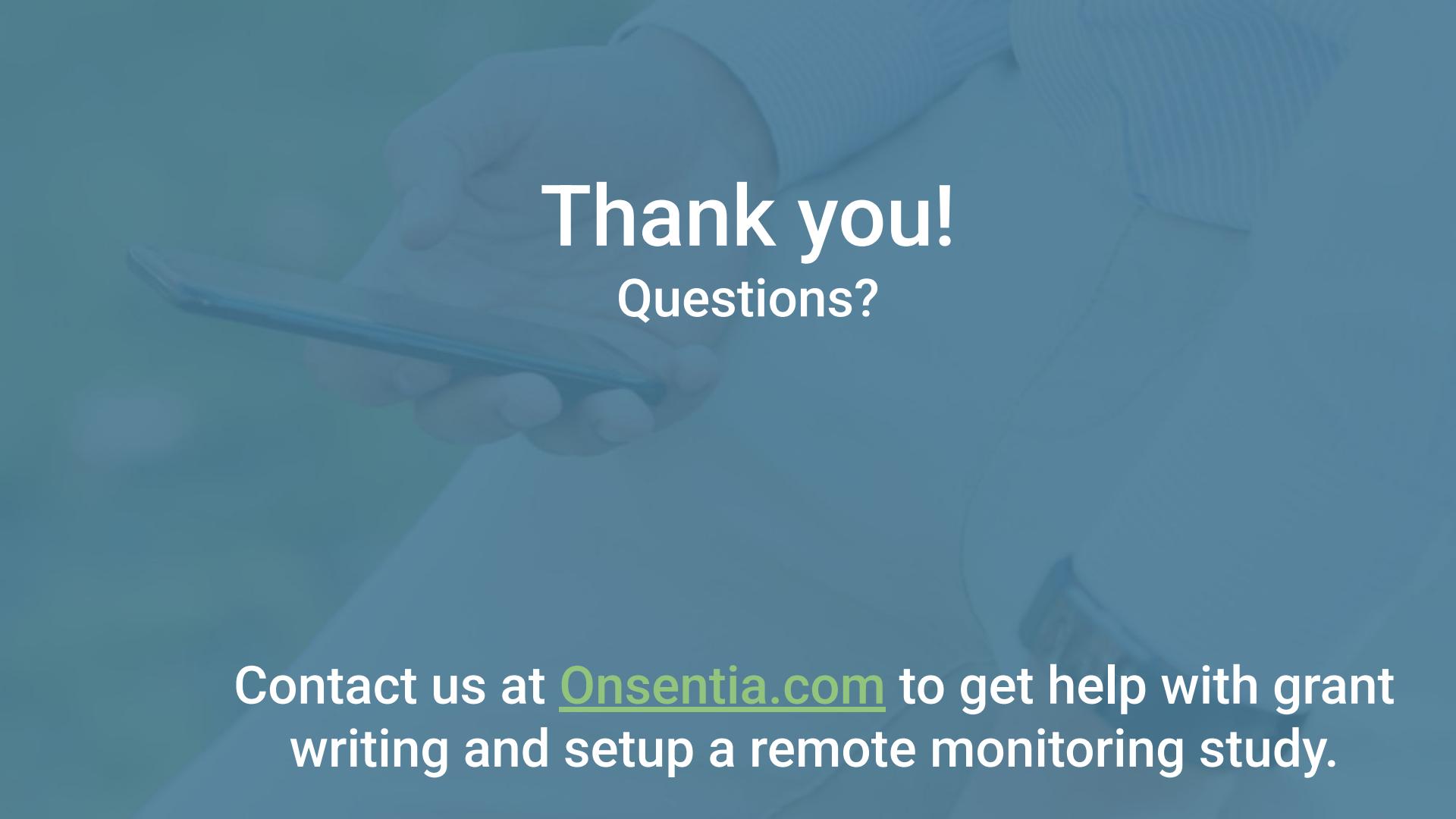
Software Developer

HEET SANKESARA



Senior Research Associate

DR SHAOXIONG SUN

A person's hands are visible, holding a smartphone horizontally. The background is a soft-focus teal color.

Thank you!

Questions?

Contact us at Onsentia.com to get help with grant writing and setup a remote monitoring study.