Enable Digital Phenotyping with Garmin Devices in Your Longitudinal Research Studies

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CTBH
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UbiWell Lab
Ubiquitous Computing for Health & Well-being

Northeastern University

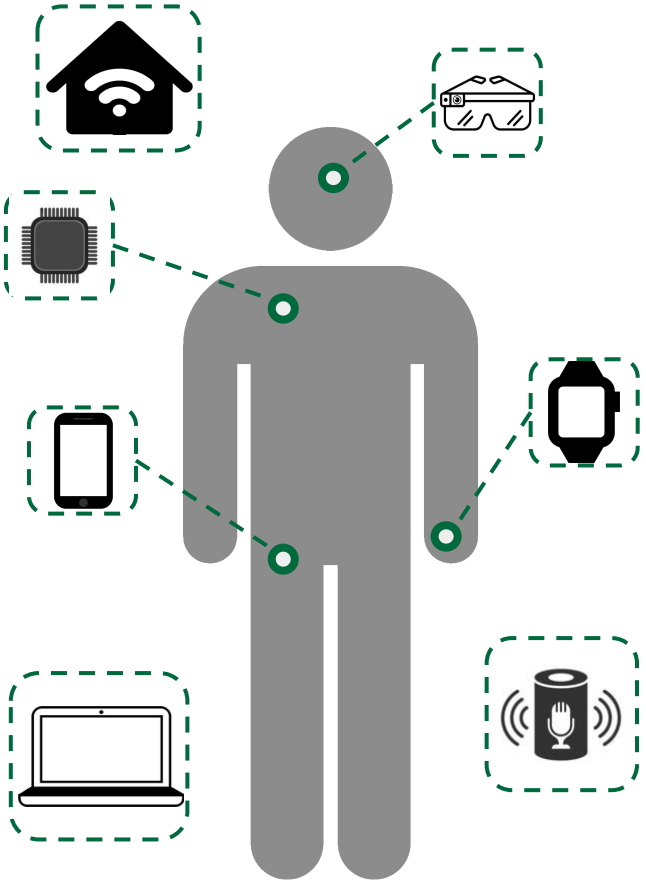
Center for Technology and Behavioral Health
Innovate · Evaluate · Disseminate

DARTMOUTH

AIM HIGH LAB
AI and Mental Health:
Innovation in Technology-Guided Healthcare

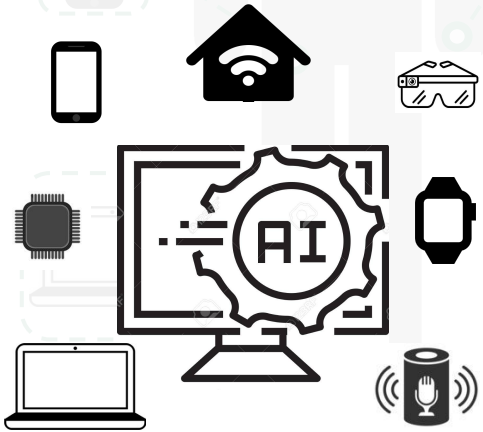
Agenda

- The promise of Digital Phenotyping
- Why consider wearables for your research?
- Which wearables to use and why?
- Garmin Health API
- Garmin Health Companion SDK
- Options for “low-burden” access
- Hearing from Garmin representative about latest updates
- Open discussion and QnA



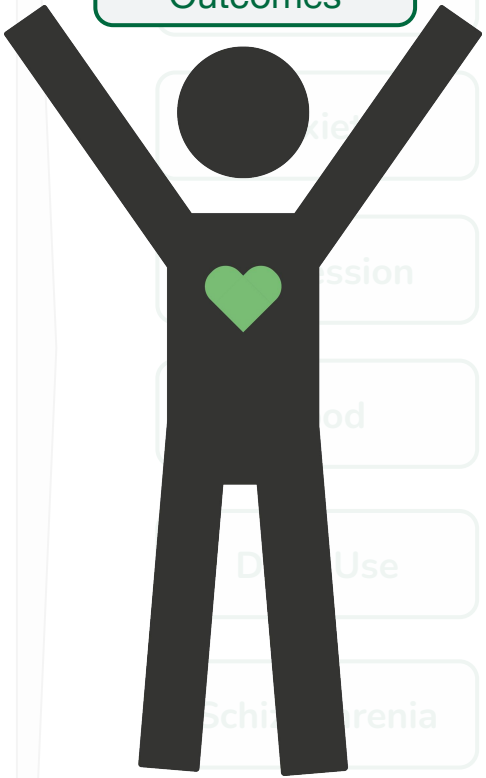
- Alcohol Abuse
- Anxiety
- Depression
- Mood Disorders
- Drug Use
- Schizophrenia

Providers



Support/
Intervention

Positive
Outcomes



Evolution of “smart-” phones

1994

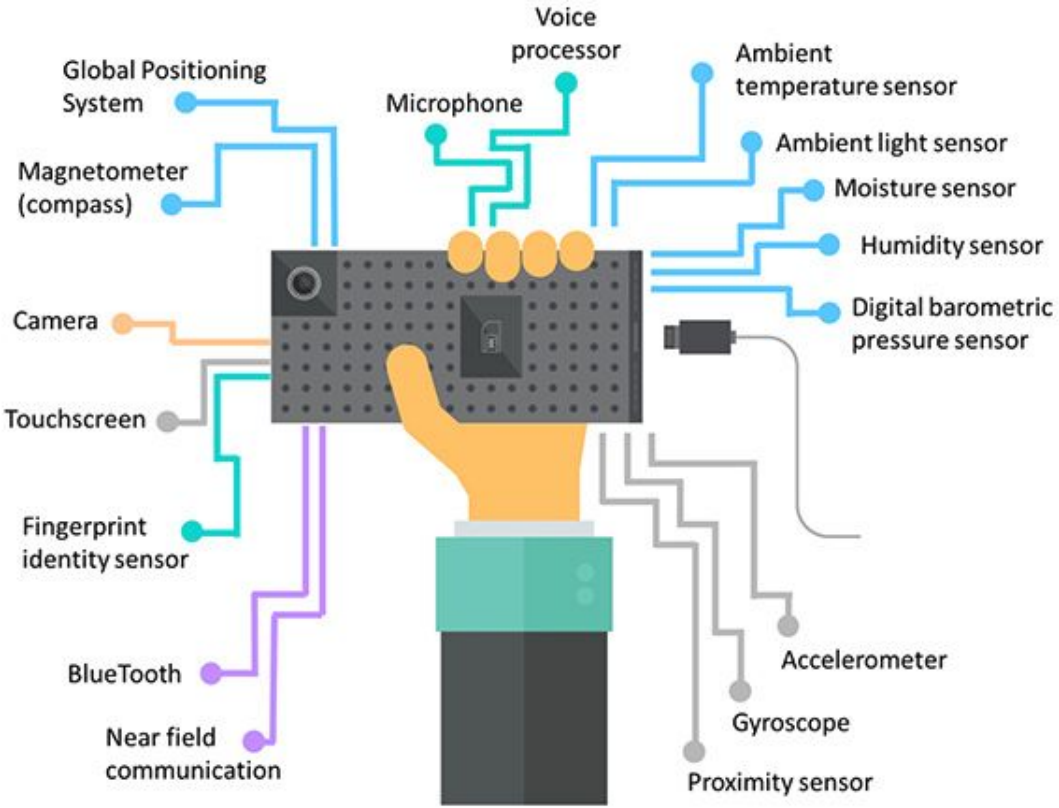
2001

2007

Now

...

Sensors everywhere!

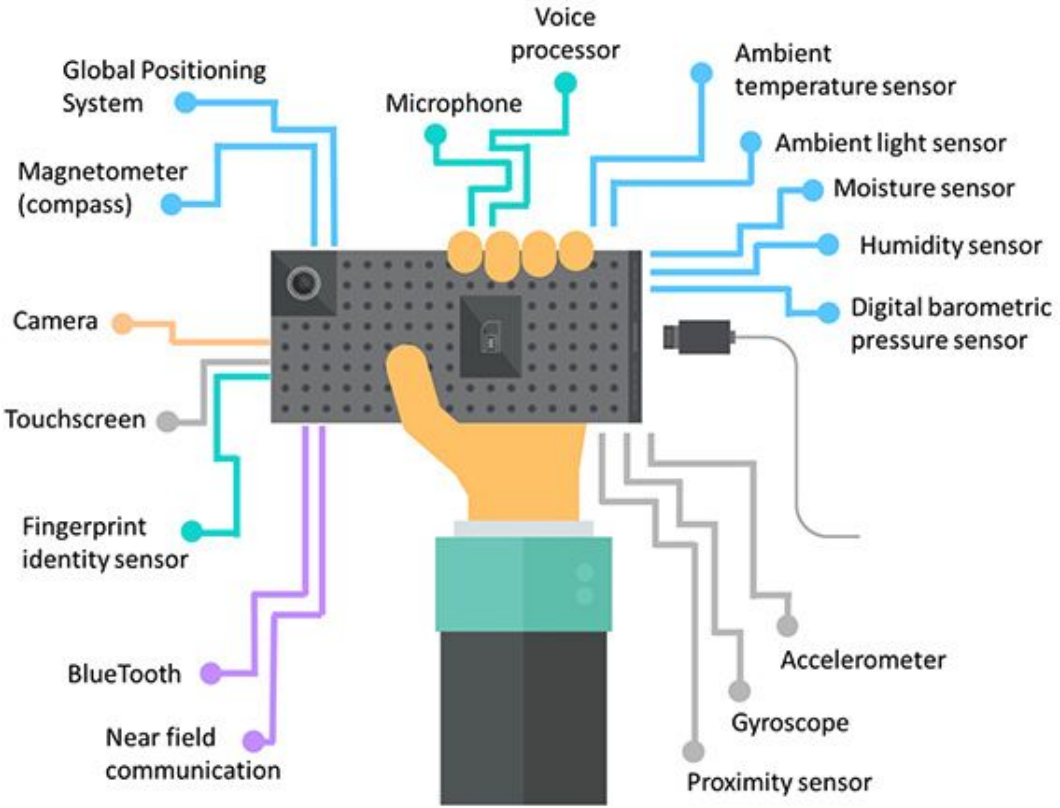


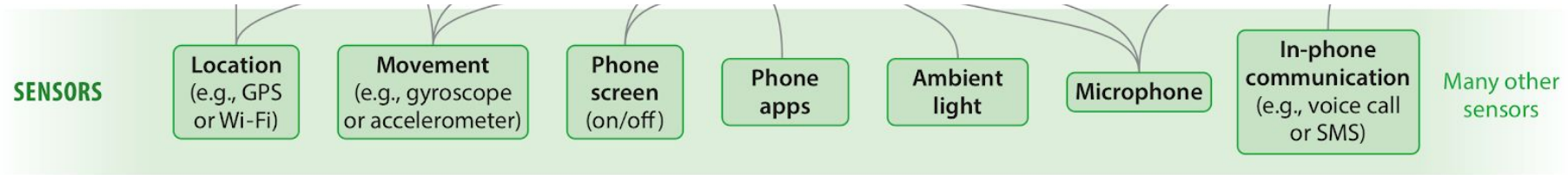
Sensors everywhere!

>90%

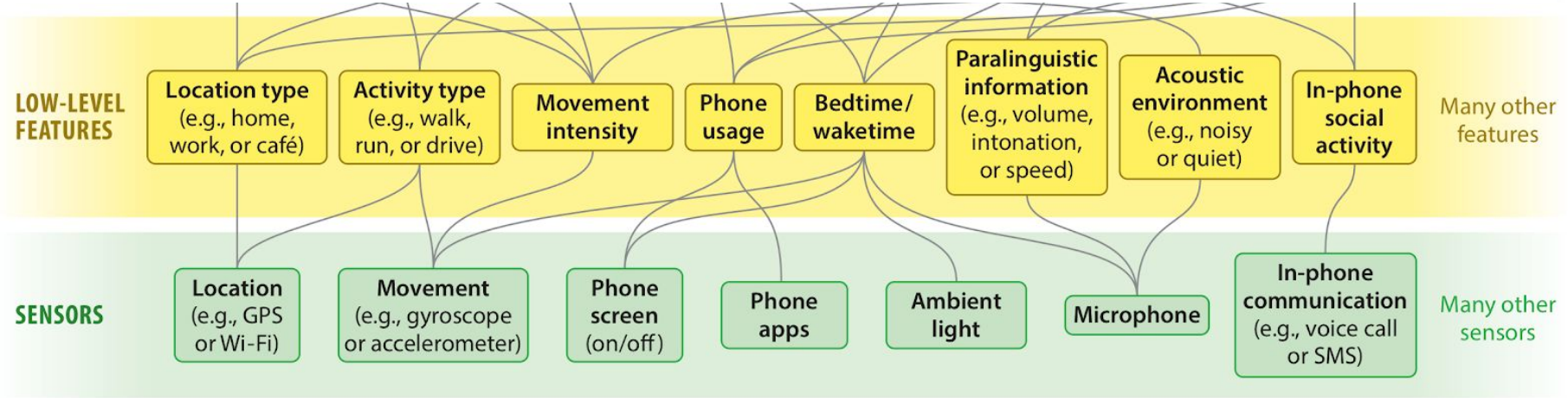
Americans own a smartphone

(Pew Research)

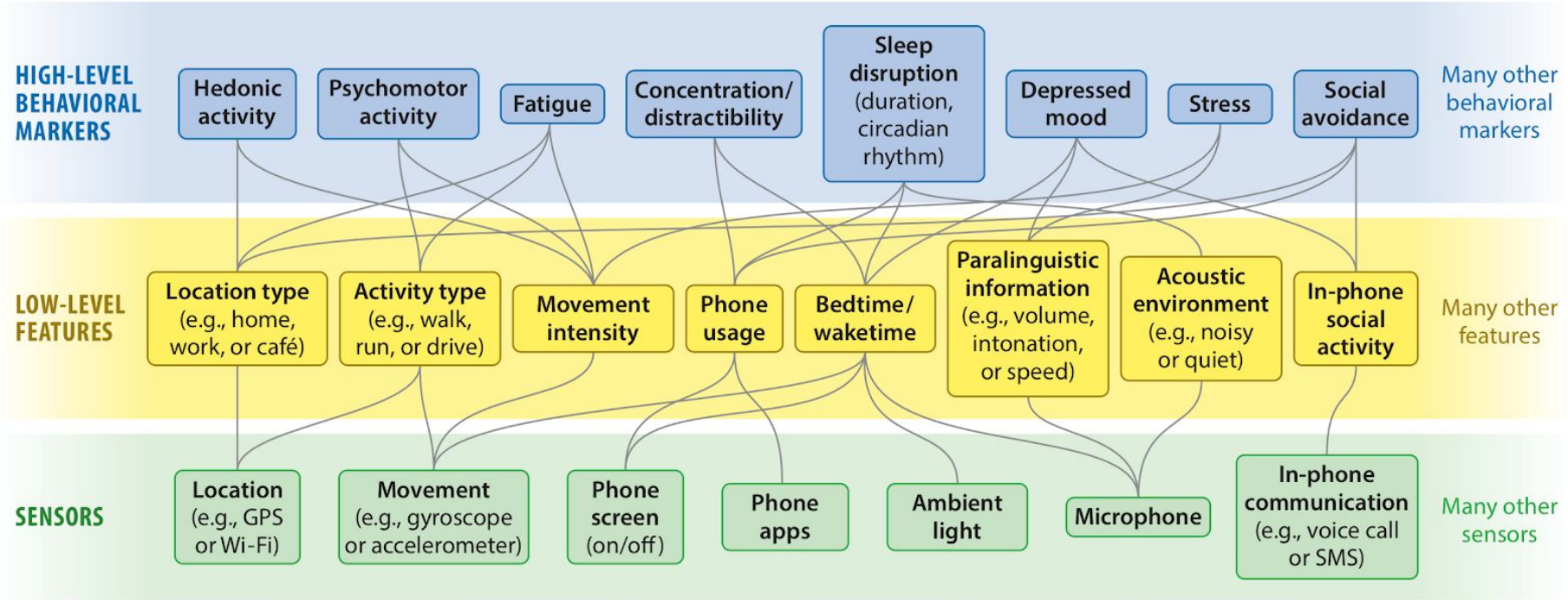




Mohr, David C., Mi Zhang, and Stephen M. Schueller. "Personal sensing: understanding mental health using ubiquitous sensors and machine learning." Annual review of clinical psychology 13 (2017): 23-47.



Mohr, David C., Mi Zhang, and Stephen M. Schueller. "Personal sensing: understanding mental health using ubiquitous sensors and machine learning." Annual review of clinical psychology 13 (2017): 23-47.



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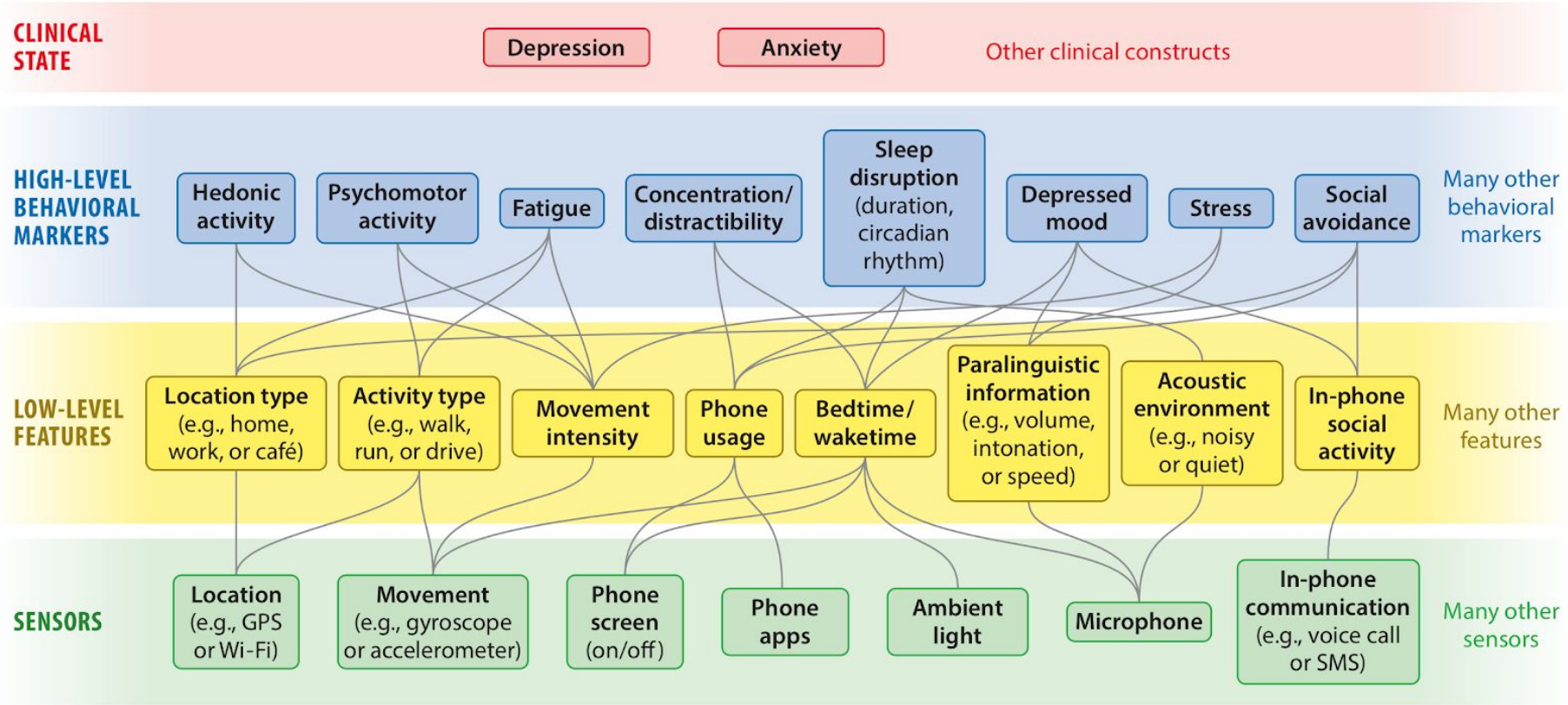


Mohr, David C., Mi Zhang, and Stephen M. Schueller. "Personal sensing: understanding mental health using ubiquitous sensors and machine learning." Annual review of clinical psychology 13 (2017): 23-47.

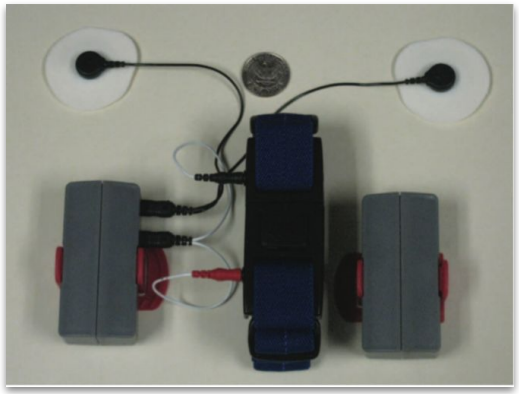
The rise of wearables

- Fine-grained movement
- Better sleep classification
- Physiological signals
  - Heart rate
  - Heart-rate variability
  - Electrodermal Activity
  - Respiration
  - Skin temperature

20-30%

Americans regularly use a smartwatch

“Research-grade” wearables



AutoSense Custom Sensing System

Zephyr Bioharness

Empatica E4

Empatica EmbracePlus

“Research-grade” wearables

Ventral EDA sensor (Electrodermal activity)
Detects subtle changes in electrical conductance at the surface of the skin

Advanced optical PPG (Photoplethysmogram)
Clinically validated PR and PRV measurements through a custom-made sensor

Digital skin temperature
Reads peripheral skin temperature

Accelerometer and Gyroscope
Raw accelerometry data and motion intensity detection

Empatica
EmbracePlus

https://www.empatica.com/embraceplus/

Consumer Wearables

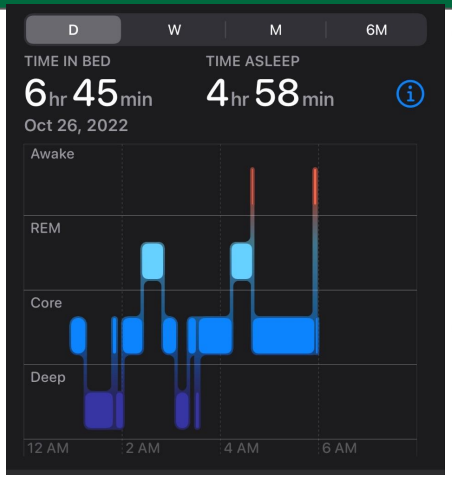
Apple Watch

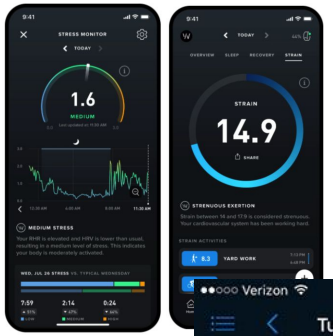
Fitbit

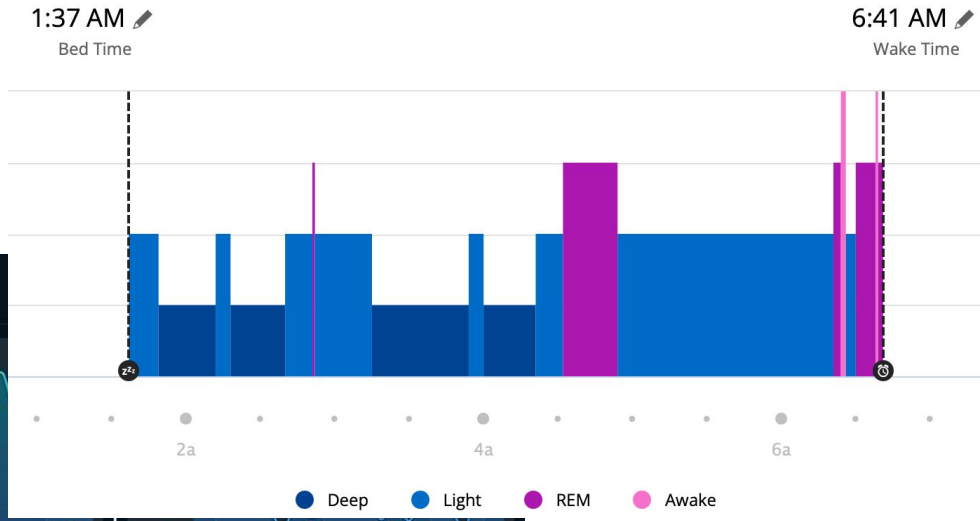
Garmin

Google

Whoop







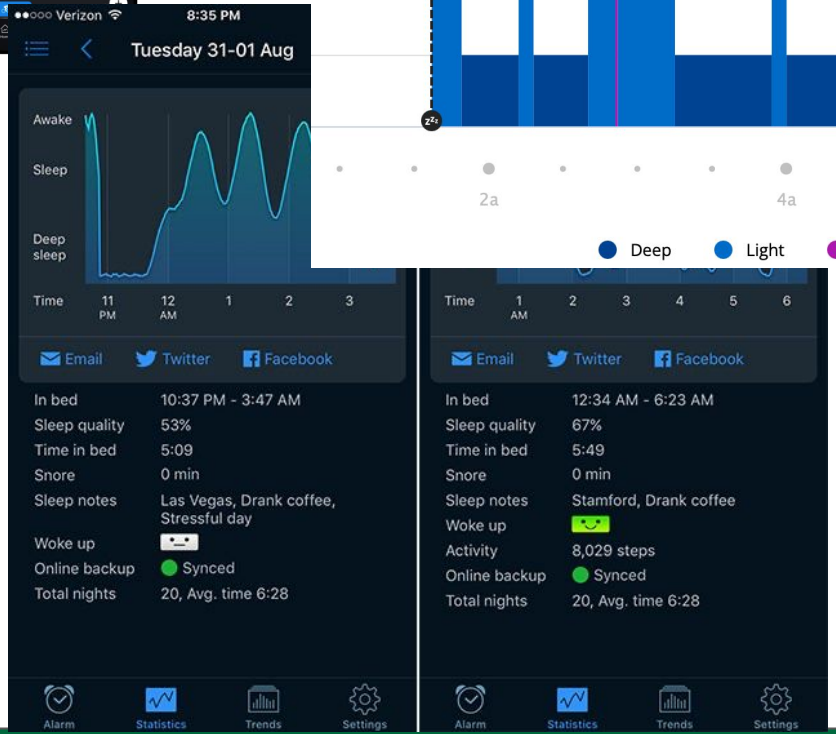
BODY BATTERY™ ENERGY MONITORING

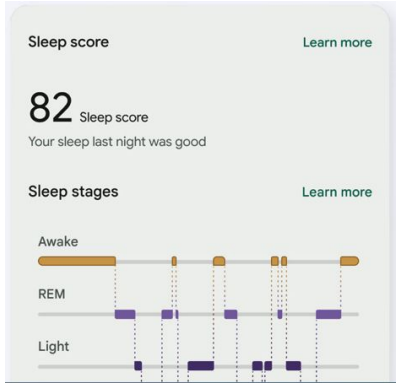
SLEEP COACH

BUILT-IN SPORTS APPS

MORNING REPORT

HRV STATUS





Consumer Wearables

Apple Watch

- Sleep Stage detection
- Heart-rate & HRV
- User-initiated ECG
- Activity metrics: steps, distance, intensity
- Respiration rate

Fitbit

- Sleep Stage detection
- Heart-rate & HRV
- User-initiated ECG
- Activity metrics: steps, distance, intensity
- Respiration rate

Garmin

- Sleep Stage detection
- Heart-rate & HRV
- User-initiated ECG
- Activity metrics: steps, distance, intensity
- Respiration rate
- Pulse ox

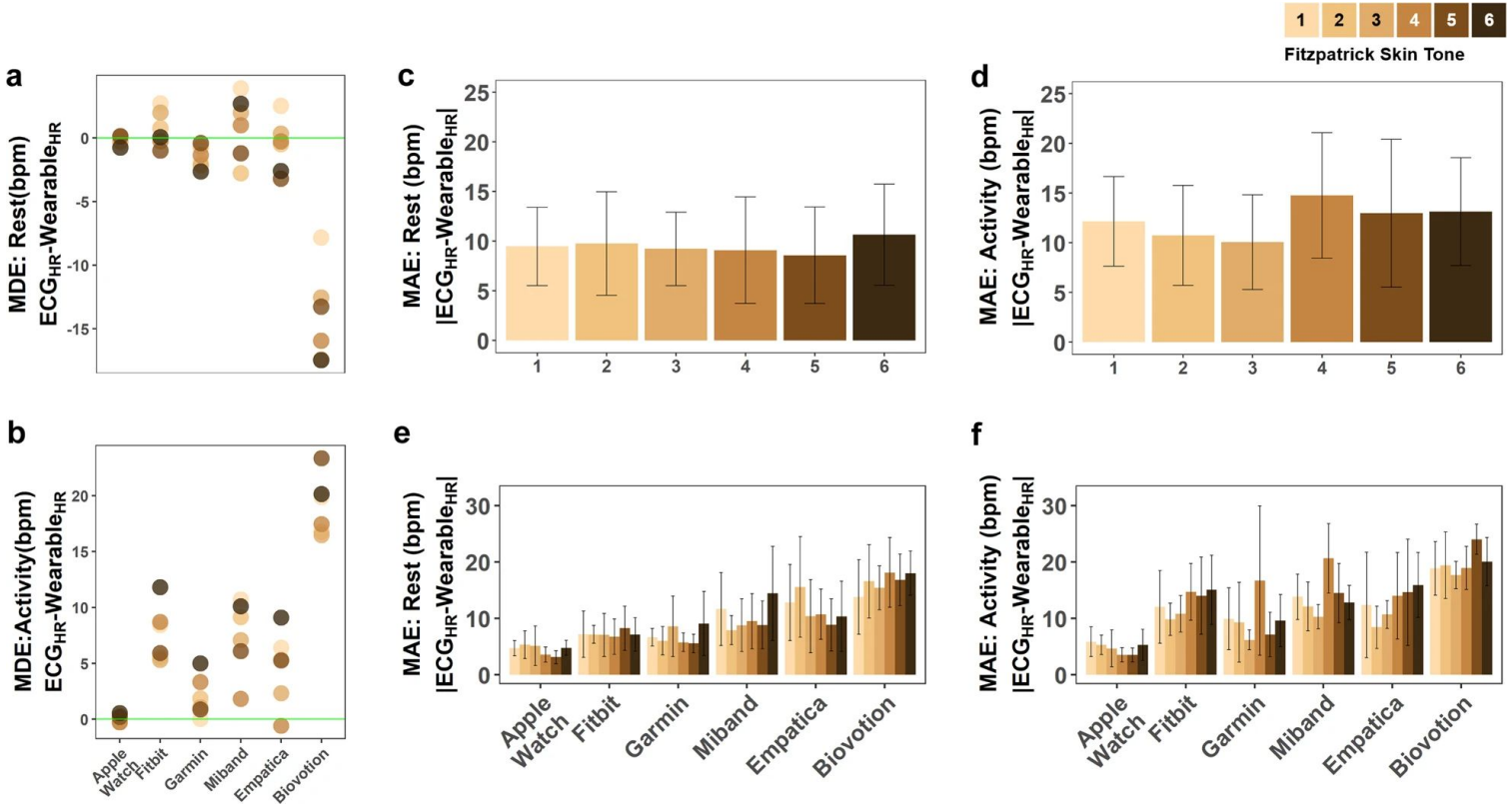
Google/Android

- Sleep Stage detection
- Heart-rate & HRV
- User-initiated ECG
- Activity metrics: steps, distance, intensity
- Respiration rate
- Electrodermal Activity (EDA)

Whoop

- Sleep Stage detection
- Heart-rate & HRV
- User-initiated ECG
- Activity metrics: steps, distance, intensity
- Respiration rate

Differences in Signal Quality



Bent B, Goldstein BA, Kibbe WA, Dunn JP. Investigating sources of inaccuracy in wearable optical heart rate sensors. NPJ digital medicine. 2020 Feb 10;3(1):18.

Data Access

Apple Watch

- Aggregated summaries
- Some raw signals, continuously
- iPhone only
- Programming heavy

Fitbit

- Aggregated summaries (minute, hour, day)
- Heart-rate every 15 seconds
- API Available

Garmin

- Aggregated summaries (minute, hour, day)
- Also provides access to real-time raw signals
- API for aggregations
- SDK for raw signals

Google/Android

- Aggregated summaries, through fitbit API
- Raw signals available
- Android only
- Programming heavy

Whoop

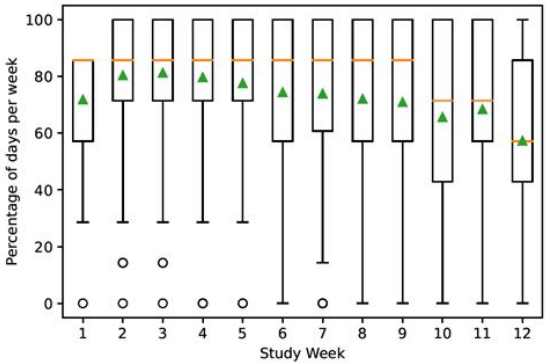
- Aggregated summaries through API

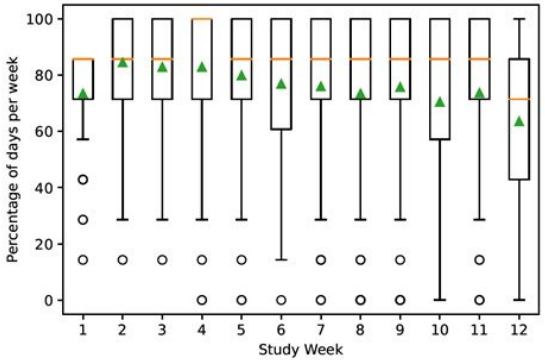
Current best choice: Garmin

- Different form factors
- Price starting from $150 to over $800
- Outstanding battery life!
- Access to biomarkers calculated by Garmin
- Access to raw data to develop new algorithms
- Garmin seems to be committed to Digital Health
- Third-party vendors for data collection: LabFront, Fitabase, Fitrockr

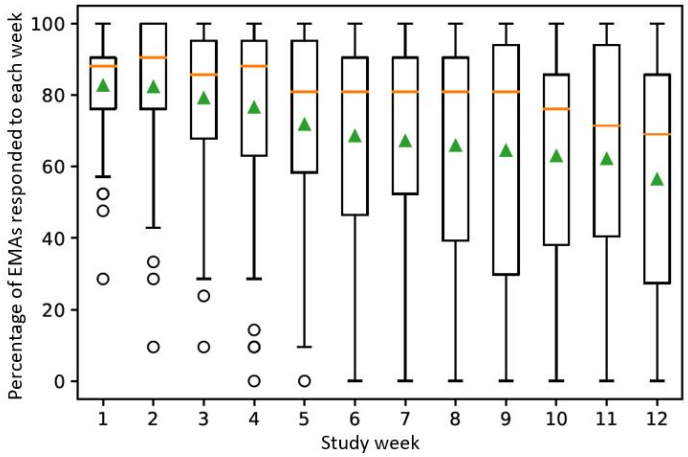
Compliance with Garmin Watch from OUD Study

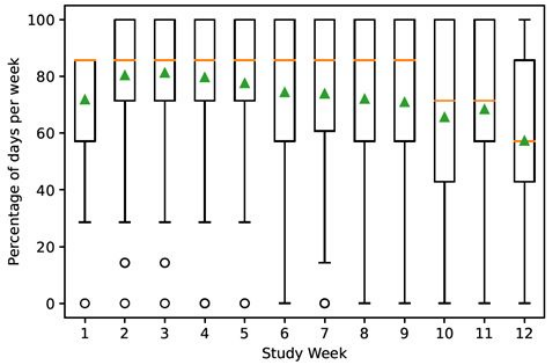
- Phone carry criteria met 94% of the days
- Watch wear criteria met 74% of the days.
- Wore watch to sleep 77% of the days.

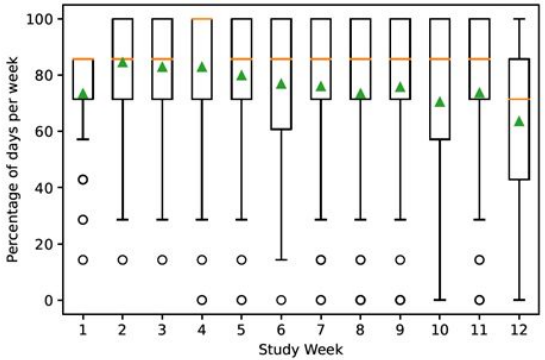




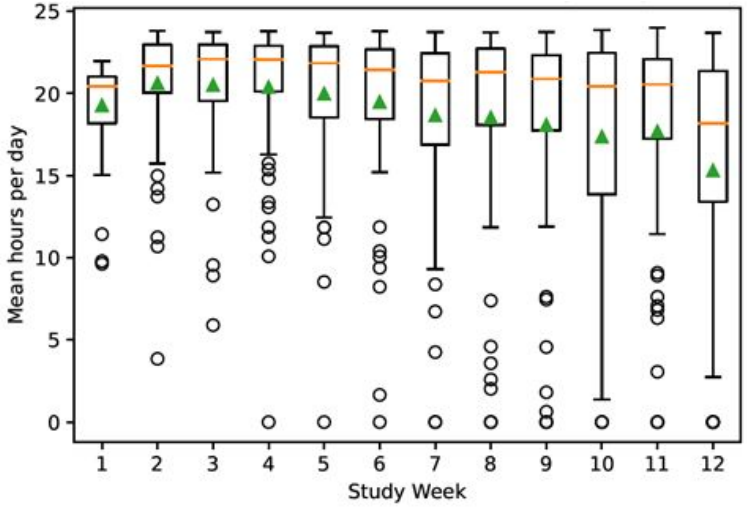
EMA vs Garmin from OUD Study

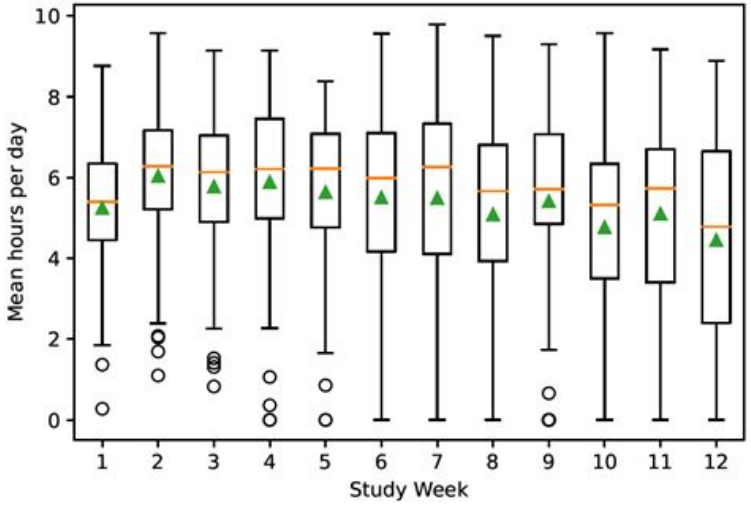






Hours of Garmin data from OUD Study





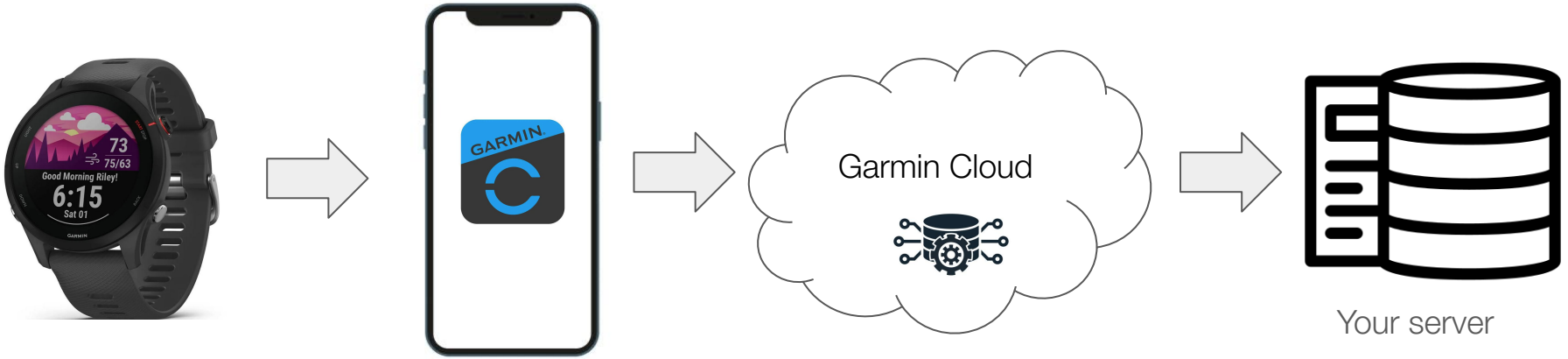
We have observed similar compliance in other studies too

Accessing Garmin Data

- Garmin Health API:
  - Access to all-day metrics, such as sleep stages, heart-rate, steps, etc.
  - Doesn't require any phone programming
  - Uses Garmin's standard/proprietary algorithms for various biomarkers: stress prediction, step count, sleep stage detection, calories burnt, etc.
- Garmin Companion SDK
  - Access to raw sensor streams: accelerometer, IBI (inter-beat interval), respiration rate, etc.
  - Does require phone programming
  - Some metrics are through Garmin's algorithms, but you can use the raw data to develop your own algorithms.

Garmin Health API

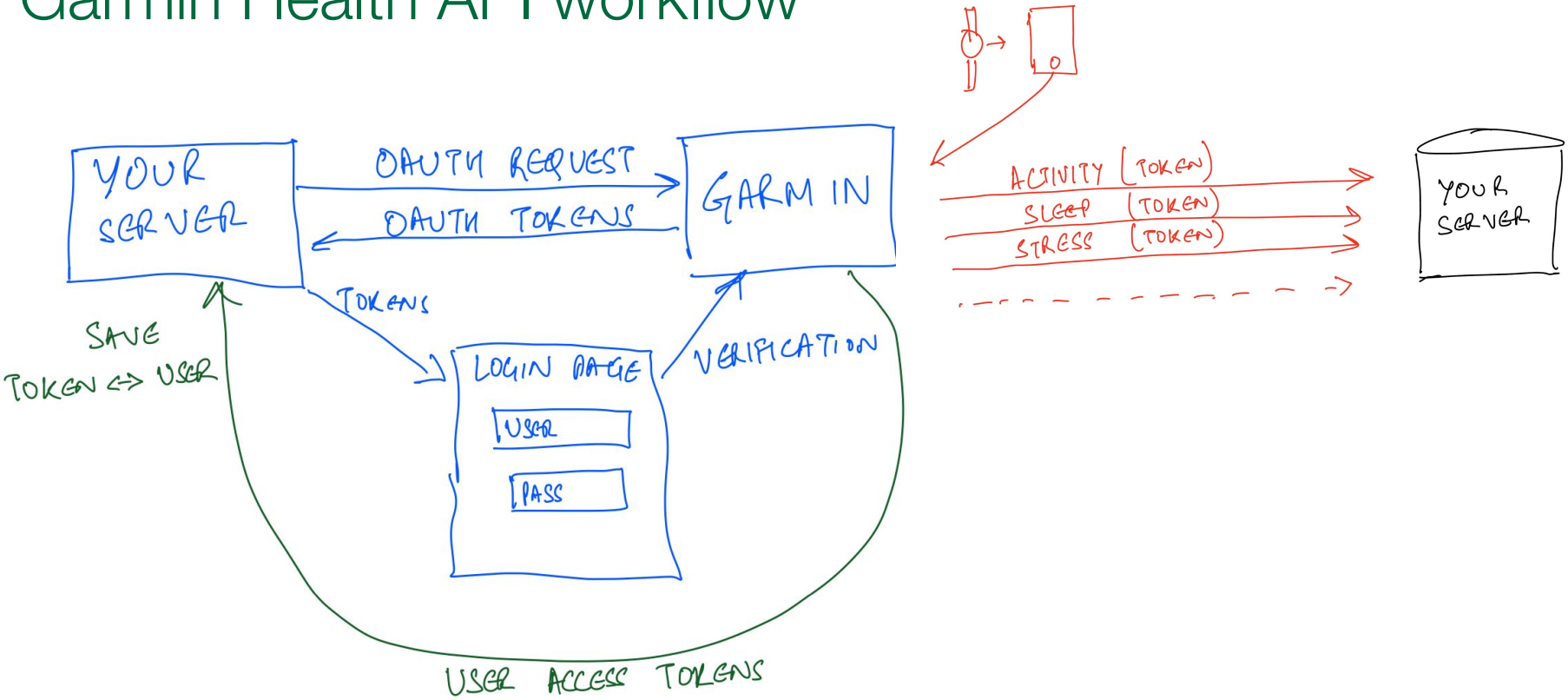
- Garmin Health API:
  - Access to all-day metrics, such as sleep stages, heart-rate, steps, etc.
  - Doesn't require any phone programming
  - Uses Garmin's standard/proprietary algorithms for various biomarkers: stress prediction, step count, sleep stage detection, calories burnt, etc.



Practical considerations for Health API

- Participants need to install the Garmin app on their phones
- The data will first go to Garmin's servers
- Garmin will run its algorithms and periodically push data to your server
- Garmin also allows a "pull" where your server can periodically request data from Garmin
- Requires some web development: you need to create endpoints for Garmin to push data to your server. But it's a one-time thing!
- You need to develop your own dashboard to visualize the data and track data collection and compliance.

Garmin Health API workflow



Sample Data

Stress


```
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    "userAccessToken" : "5b0ab665-5bec-4a2b-84ac-4608dfb51713",
    "summaryId" : "x32c5a4b-5f290770-15180",
    "startTimeInSeconds" : 1596524400,
    "startTimeOffsetInSeconds" : -25200,
    "durationInSeconds" : 86400,
    "calendarDate" : "2020-08-04",
    "timeOffsetStressLevelValues" : {
        "0" : 8,
        "180" : 6,
        "360" : 6,
        "540" : 8,
        "720" : 3,
        "900" : 3,
        "1080" : 7,
        "1260" : 17,
        "1440" : -2,
        "1620" : -1,
        "1800" : -1,
        "1980" : -2,
        "2160" : -2,
        "2340" : -2,
        "2520" : -2,
        "2700" : -2,
        "2880" : -2,
        "3060" : -2,
        "3240" : -2,
        "3420" : -1,
        "3600" : -1,
        "3780" : -2,
        "3960" : -2,
        "4140" : 0,
        "4320" : 0,
        "4500" : 0,
        "4680" : 1,
        "4860" : 1,
        "5040" : 4,
        "5220" : -2,
        "5400" : -2,
        "5580" : -1,
        "5760" : -1,
        "5940" : -1,
        "6120" : 20,
        "6300" : 3
```


Daily


```
{
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    "userAccessToken" : "862abefd-b4d9-4fc7-997f-b46657671726",
    "summaryId" : "x3483cc3-5ee86df0-15180-6",
    "calendarDate" : "2020-06-16",
    "activityType" : "WALKING",
    "activeKilocalories" : 12,
    "bmrKilocalories" : 1966,
    "steps" : 224,
    "distanceInMeters" : 174,
    "durationInSeconds" : 86400,
    "activeTimeInSeconds" : 534,
    "startTimeInSeconds" : 1592290800,
    "startTimeOffsetInSeconds" : -25200,
    "moderateIntensityDurationInSeconds" : 0,
    "vigorousIntensityDurationInSeconds" : 0,
    "floorsClimbed" : 1,
    "minHeartRateInBeatsPerMinute" : 62,
    "maxHeartRateInBeatsPerMinute" : 99,
    "averageHeartRateInBeatsPerMinute" : 72,
    "restingHeartRateInBeatsPerMinute" : 65,
    "timeOffsetHeartRateSamples" : {
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        "82410" : 74,
        "82425" : 74,
        "82440" : 74,
        "82455" : 78,
        "82470" : 78,
        "82485" : 78,
        "82500" : 78,
        "82515" : 76,
        "82530" : 76,
        "82545" : 76,
        "82560" : 76,
        "82575" : 78,
        "82590" : 78,
        "82605" : 78,
        "82620" : 78,
        "82635" : 80,
        "82650" : 80,
        "82665" : 80,
        "82680" : 80,
        "82695" : 77,
        "82710" : 77,
        "82725" : 77,
        "82740" : 77,
        "82755" : 79,
        "82770" : 79,
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        "82905" : 95,
        "82920" : 95,
        "82935" : 91,
        "82950" : 91,
        "82965" : 91,
```


Epochs


```
{
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    "userAccessToken" : "5b0ab665-5bec-4a2b-84ac-4608dfb51713",
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    "steps" : 0,
    "distanceInMeters" : 0,
    "durationInSeconds" : 900,
    "activeTimeInSeconds" : 284,
    "startTimeInSeconds" : 1596586500,
    "startTimeOffsetInSeconds" : -25200,
    "met" : 1,
    "intensity" : "SEDENTARY",
    "meanMotionIntensity" : 0,
    "maxMotionIntensity" : 4,
    "uid" : "t01",
    "start_timestamp" : 1596586500,
    "activity_type" : "SEDENTARY"
}
{
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    "userAccessToken" : "5b0ab665-5bec-4a2b-84ac-4608dfb51713",
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    "activeKilocalories" : 27,
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    "maxMotionIntensity" : 3,
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    "start_timestamp" : 1596587400,
    "activity_type" : "WALKING"
}
{
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    "userAccessToken" : "5b0ab665-5bec-4a2b-84ac-4608dfb51713",
    "summaryId" : "x32c5a4b-5f29fd88-0",
    "activityType" : "GENERIC",
    "activeKilocalories" : 8,
    "steps" : 0,
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    "durationInSeconds" : 900,
    "activeTimeInSeconds" : 0,
    "startTimeInSeconds" : 1596587400,
    "startTimeOffsetInSeconds" : -25200,
    "met" : 1,
    "intensity" : "SEDENTARY",
    "meanMotionIntensity" : 0,
    "maxMotionIntensity" : 5,
    "uid" : "t01",
    "start_timestamp" : 1596587400,
    "activity_type" : "GENERIC"
}
```


Sleep


```
{
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    "userAccessToken" : "862abefd-b4d9-4fc7-997f-b46657671726",
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    "startTimeOffsetInSeconds" : -25200,
    "unmeasurableSleepInSeconds" : 0,
    "deepSleepDurationInSeconds" : 11820,
    "lightSleepDurationInSeconds" : 15540,
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            },
            {
                "startTimeInSeconds" : 1592382420,
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            {
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            },
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            },
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            {
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            }
        ],
        "light" : [
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            },
            {
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            {
                "startTimeInSeconds" : 1592385600,
                "endTimeInSeconds" : 1592385900
            },
```

Data Granularity

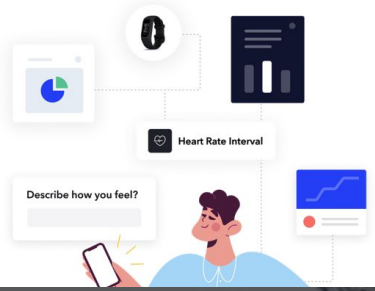
Activities, Steps, Intensity	Every 15 minutes (epochs)
Heart-rate	Every 15 seconds
Stress	Every 3 minutes
Body Battery	Every 3 minutes
Respiration	Every 60 seconds
Sleep	On Event
Pulse Ox	Every 60 seconds
Daily Summary	Daily

Low-burden start!

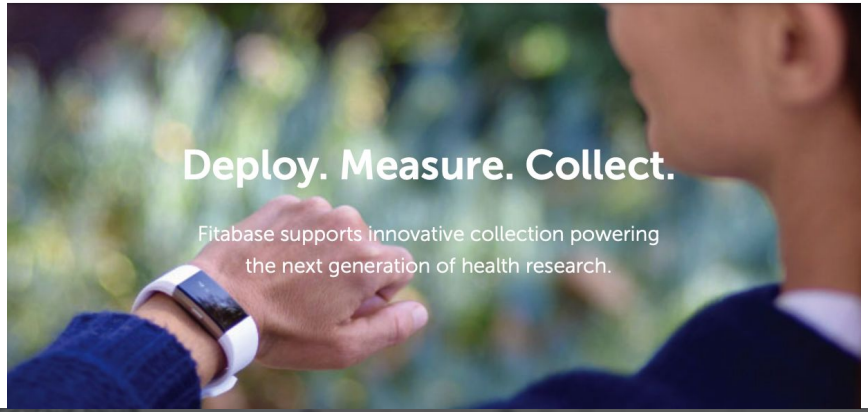
Labfront Why Labfront Solutions How it Works Pricing Devices Resources Log in Get Started

All-in-one research solution for real-world data capture

Improved data collection, easier adherence management, and faster analysis - all aggregated in one easy-to-use research platform.



fitabase HOW IT WORKS RESOURCES Request a Demo Log In



Health Data Research & Healthcare Platform for Garmin Wearables

Easily synchronize Garmin wearables with access to high resolution physiological raw data, independent and secure hosting, survey and questionnaire responses, real-time data streams, health data reports and exports.

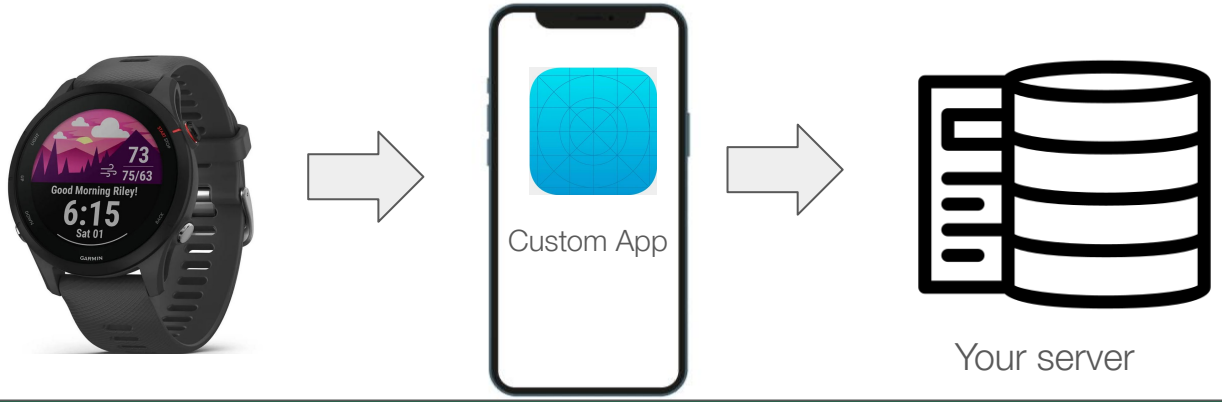
Analyze HE high resolution raw data.

Learn More

Secure Platform GDPR Compliant ISO Certified Cloud

Garmin Health Companion SDK

- Garmin Companion SDK
  - Access to raw sensor streams: accelerometer, IBI (inter-beat interval), respiration rate, etc.
  - Does require phone programming
  - Some metrics are through Garmin's algorithms, but you can use the raw data to develop your own algorithms.



Practical considerations for Companion SDK

- Create/install a custom app using Garmin SDK
- The app will pair with Garmin device and initialize the logging rules and configurations
- Data will be logged on Garmin devices and synced periodically with the app
- The app is responsible for storing the data and uploading to a server
- “Garmin Connect” app is not necessary, but can be used in parallel to collect the daily metrics, especially the sleep summaries.
- You need your own server to store all the data.
- Depending on the type of data and frequency, sizes could range from 200-500 MB per day per person
- You need your own dashboard to track data collection and compliance

Why use the SDK over API?

- You need
  - Buildin ess")
  - Using er biomarkers
  - Obser or free-living scena
- You need r Gyroscope
  - Develo
  - Develo

Data Granularity of the Companion SDK

Respiration, Pulse Ox	Every 10 seconds - 60 minutes
Heart-rate	Every 1 second - 60 minutes
Stress	Every 10 seconds - 60 minutes
Steps	Every 60 seconds
IBI	On Event
Actigraphy	Every 1 or 30 seconds - 60 minutes
Accelerometer	25 Hz
Gyroscope	32 Hz

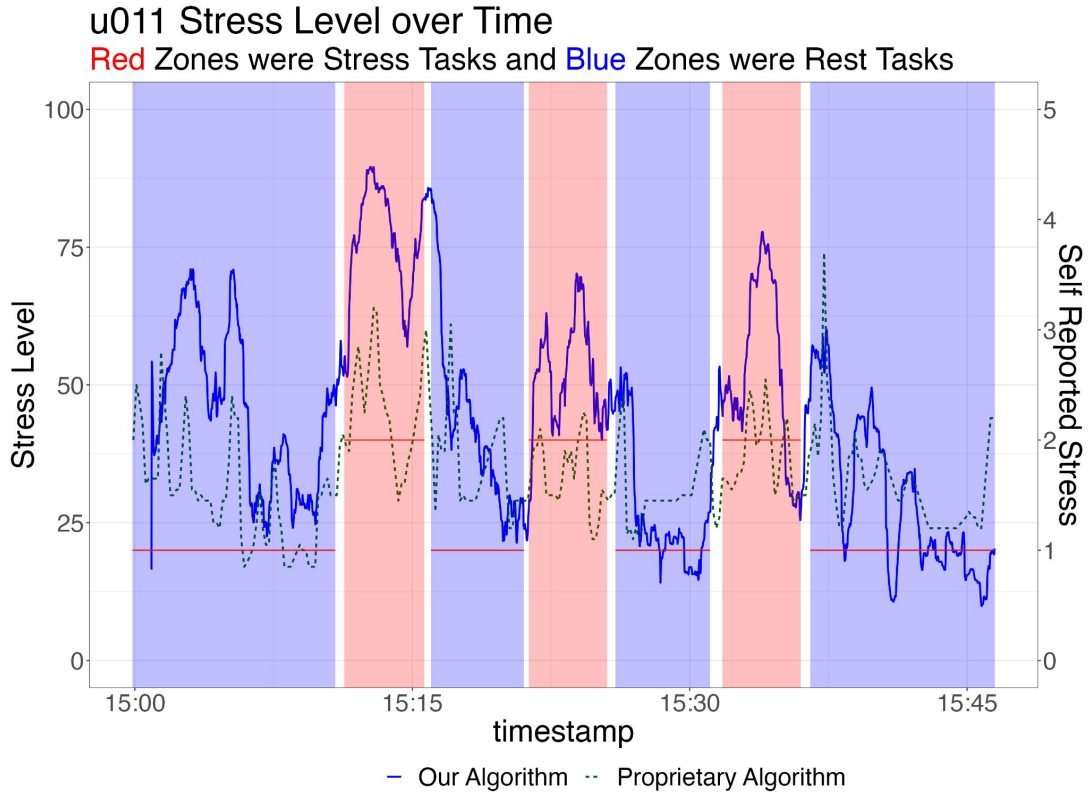
Think carefully about what sampling frequency

- Accelerometer and Gyroscope generate a lot of data!
  - Syncing 1 hour of accelerometer data from watch to phone takes 4.5 minutes
  - Syncing 1 hour of gyroscope data takes 6 minutes
- Can have real-impact on the data sizes, performance, and battery life of both the phone and the watch
- Example:
  - Garmin Forerunner 55: without ACC and Gyro, could last 9-11 days
  - With ACC: lasts 4-5 days

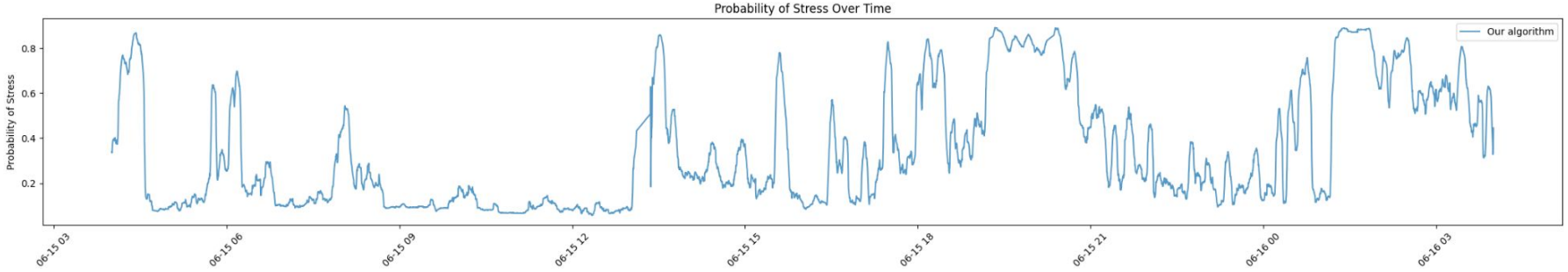
Reliability of IBI and calculated HRV metrics

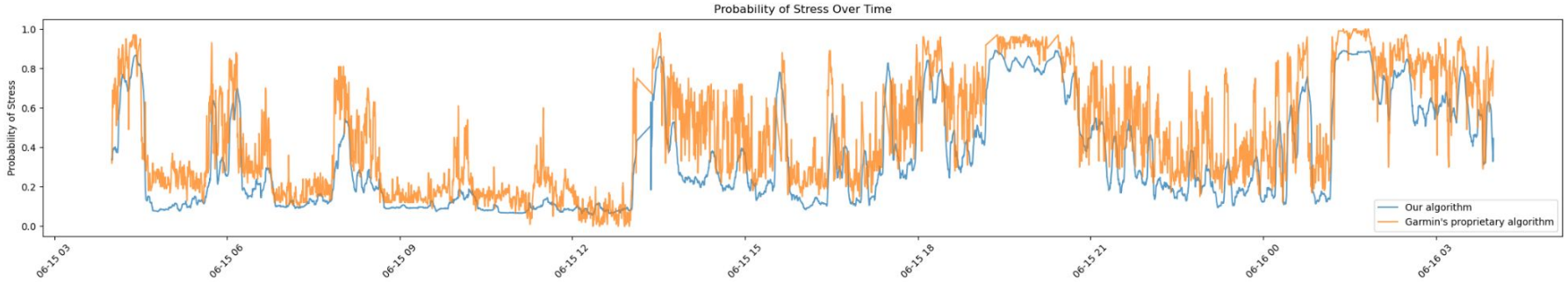
- In a lab study where participants underwent stress-induction tasks:
  - We used data from Garmin, Polar H10, and Empatica E4 to collect raw IBI/RR interval data
  - We used a pre-built stress predictor (from previous studies) to detect probability of “stress”
  - With careful data processing:
    - Garmin devices performed almost at-par with polar devices in all tasks
    - Garmin devices performed significantly better than Empatica E4 devices

What about Garmin's built-in "stress" measurement

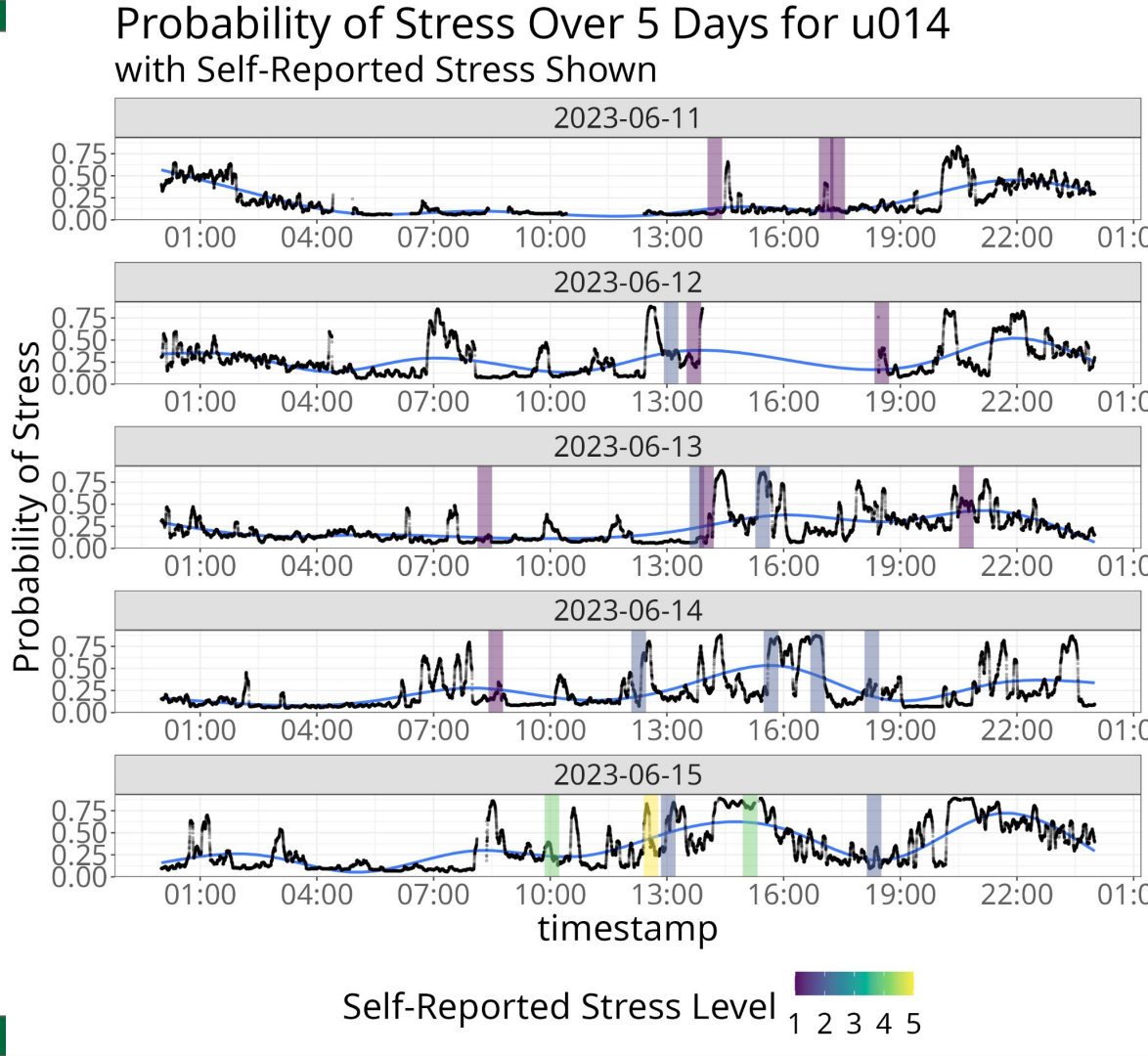


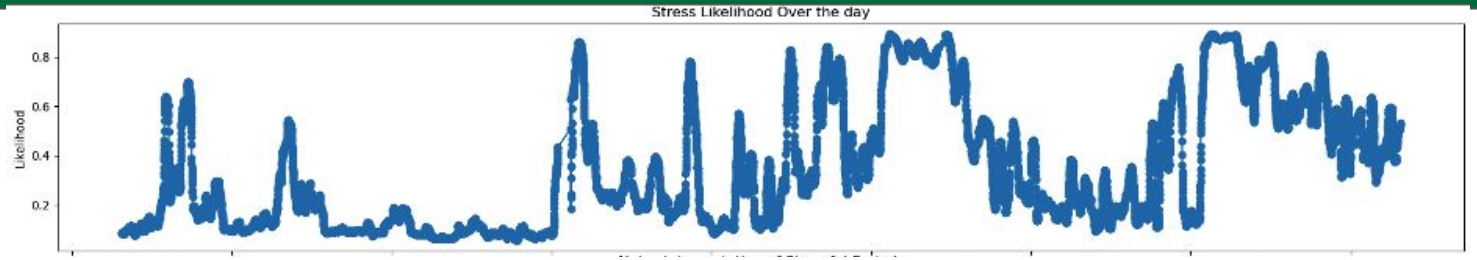
What about on a full-day?

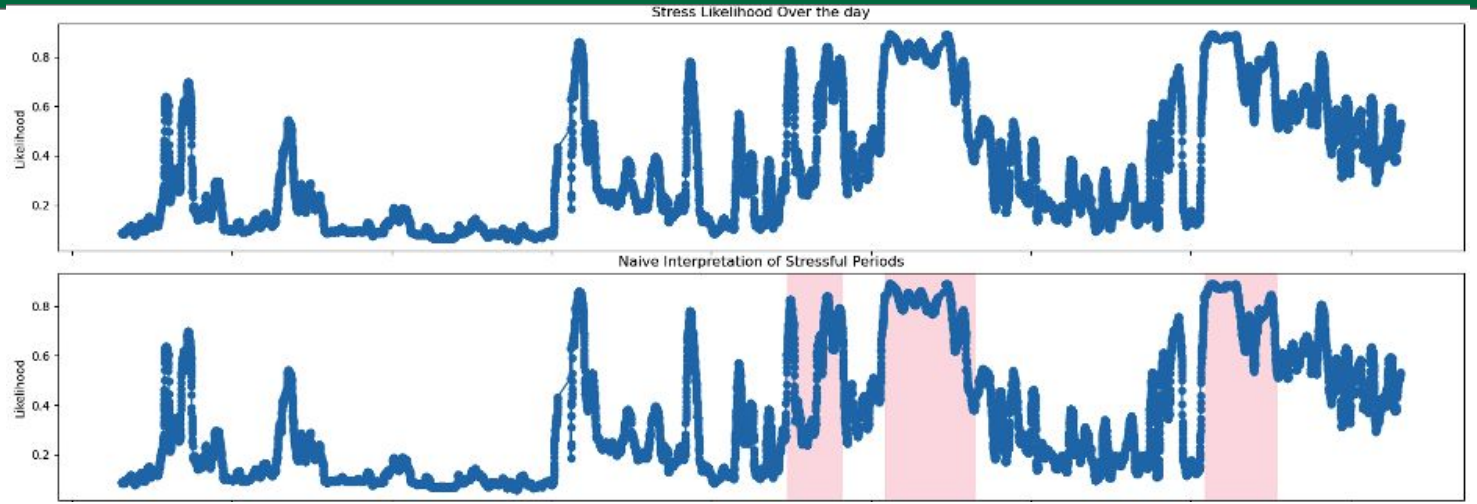


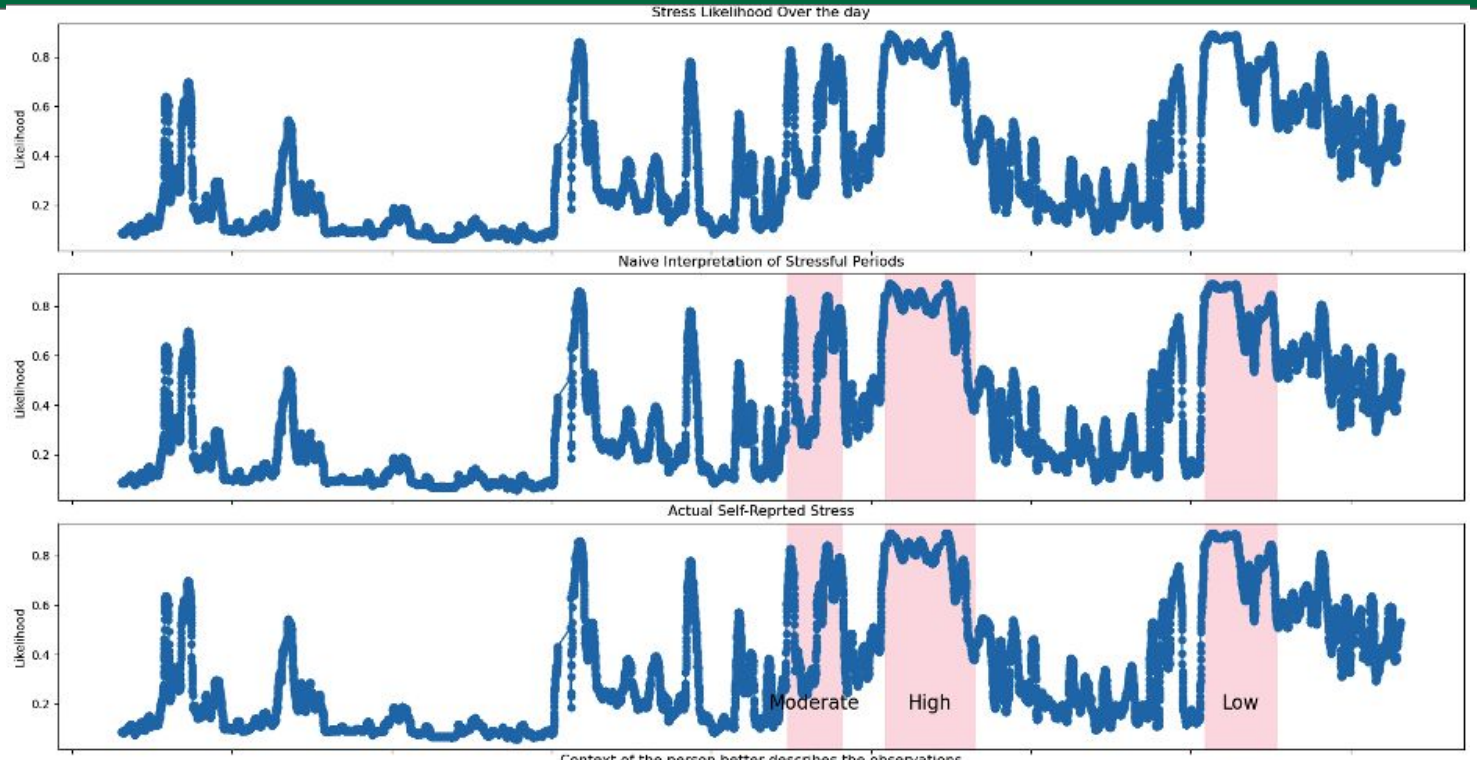


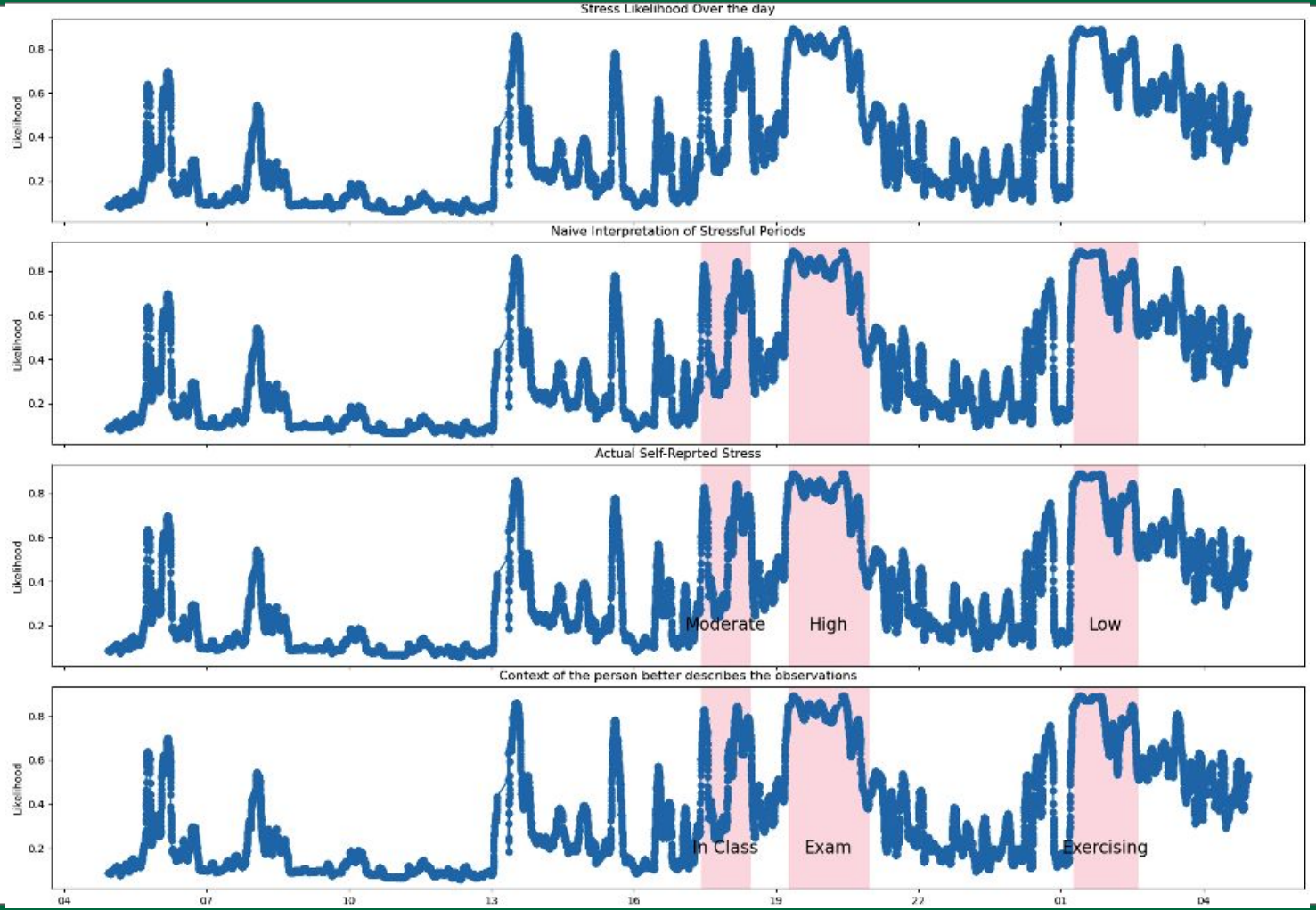
Our algorithm also shows relationships with perceived stress




Stress Likelihood Over the day
Likelihood
0.8
0.6
0.4
0.2


Stress Likelihood Over the day
Likelihood
0.8
0.6
0.4
0.2
Naive Interpretation of Stressful Periods
Likelihood
0.8
0.6
0.4
0.2

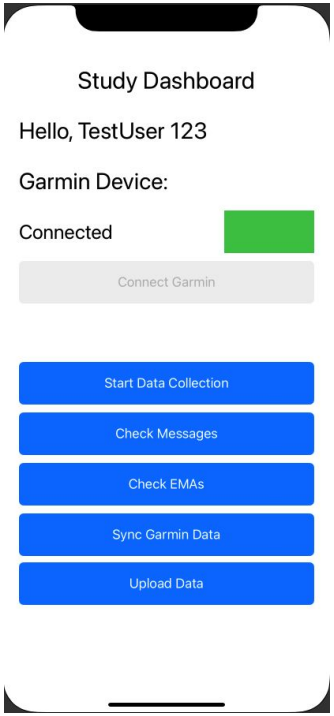

Stress Likelihood Over the day
Likelihood
0.8
0.6
0.4
0.2
Naive Interpretation of Stressful Periods
Likelihood
0.8
0.6
0.4
0.2
Actual Self-Reprted Stress
Likelihood
0.8
0.6
0.4
0.2
Moderate
High
Low

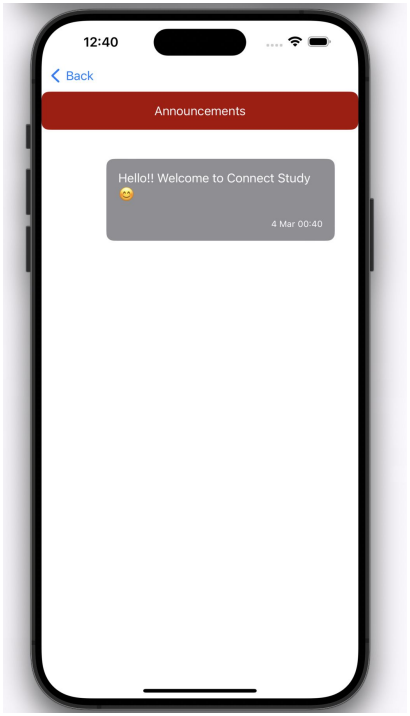

Stress Likelihood Over the day
Likelihood
0.8
0.6
0.4
0.2
Naive Interpretation of Stressful Periods
Likelihood
0.8
0.6
0.4
0.2
Actual Self-Reprted Stress
Likelihood
0.8
0.6
0.4
0.2
Moderate
High
Low
Context of the person better describes the observations
Likelihood
0.8
0.6
0.4
0.2
In Class
Exam
Exercising
04
07
10
13
16
19
22
01
04

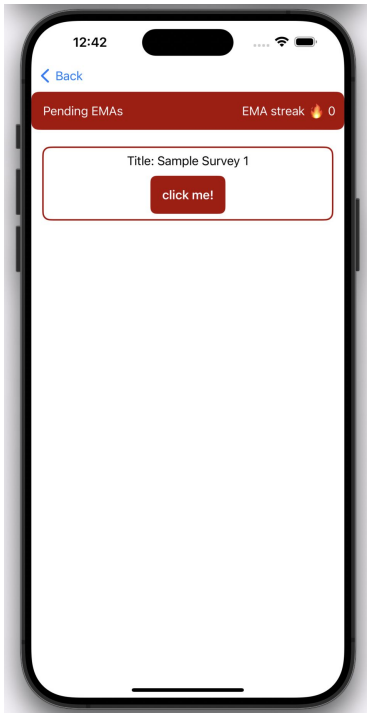
How to use Companion SDK?

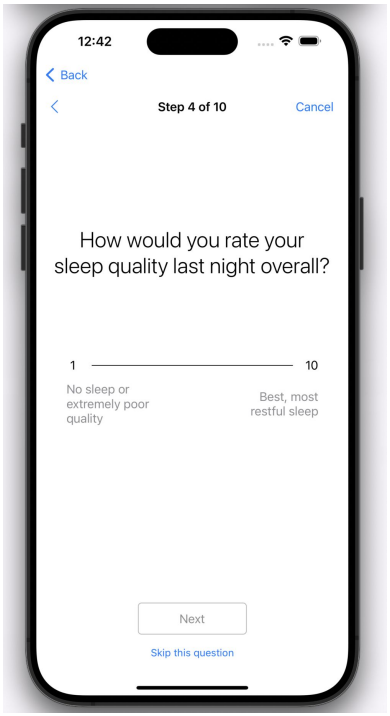
- Requires a license!
- At CTBH we are creating a generalized version of the app, that will enable Garmin data collection and EMAs.
- This will only be available internally to CTBH affiliates starting late summer.
- However, not a direct plug-n-play solution
  - You still need your own server for data collection
  - We will provide a basic server container with simple processing/dashboard code
  - Requires working closely/consulting with the ETDA and TDE cores

Screenshots of the App









Sample dashboard

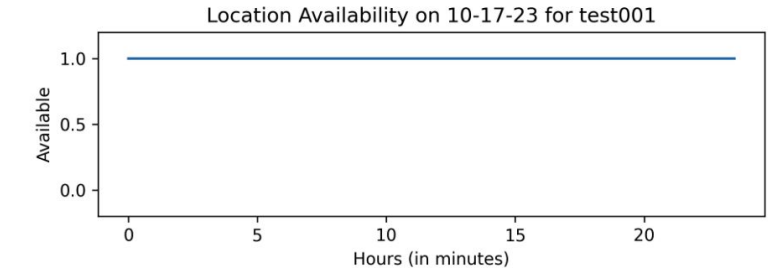
Dashboard Summary 10-17-23

Next || Previous

User	MobileCoach ID	Phone Duration	Garmin wear Duration	Garmin on Duration	Details
u028	650b1311a1de18000e67b22a	23.916944444444443	18.966666666666665	18.95277777777778	Details
u029	650b6742a1de18000e67b55a	23.365555555555556	19.708333333333332	19.708333333333332	Details
u030	650cbcb9a1de18000e67b9ff	0.0	0.0	0.0	Details
u031	650cc48ea1de18000e67ba23	23.833055555555557	8.766666666666667	10.291666666666666	Details
u032	650db151a1de18000e67bb17	23.875	17.766666666666666	18.008333333333333	Details
u033	650dfacba1de18000e67bc10	23.83361111111111	20.625	20.863888888888887	Details
u034	650e065ca1de18000e67bc59	21.93	15.058333333333334	15.477777777777778	Details
u035	6511a609a1de18000e67c2a8	23.00055555555555	6.266666666666667	13.430555555555555	Details
u036	651344dea1de18000e67c5f4	23.833055555555557	14.25	14.58611111111111	Details
u037	6514632da1de18000e67c7f6	0.0	0.0	0.0	Details
u038	6515dbcba1de18000ea4ceda	21.577222222222225	10.691666666666666	18.727777777777778	Details
u039	6516e393a1de18000ea4d23b	23.74972222222222	18.058333333333334	18.269444444444446	Details
test001	647b6a2da1de18000cdb77c5	23.75027777777778	19.741666666666667	21.522222222222222	Details

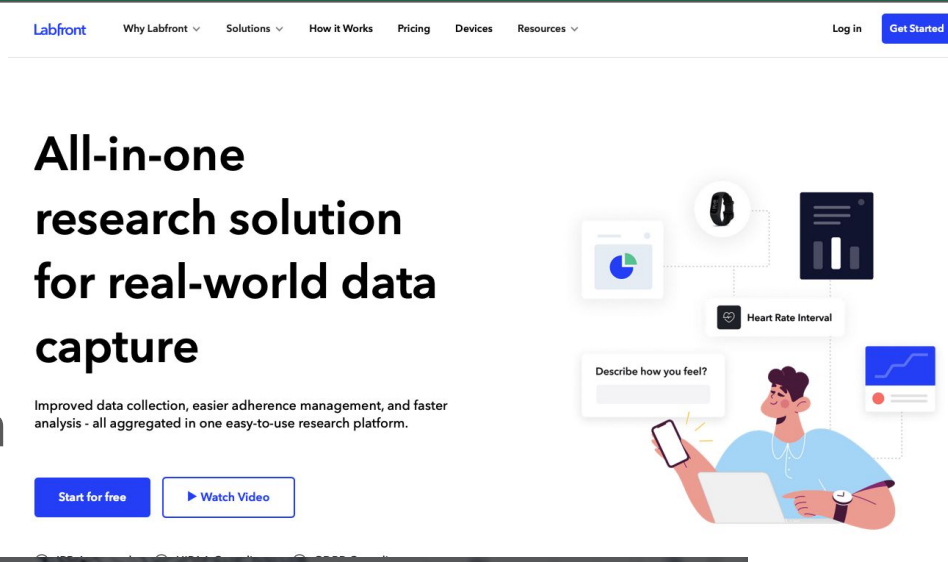
User: test001

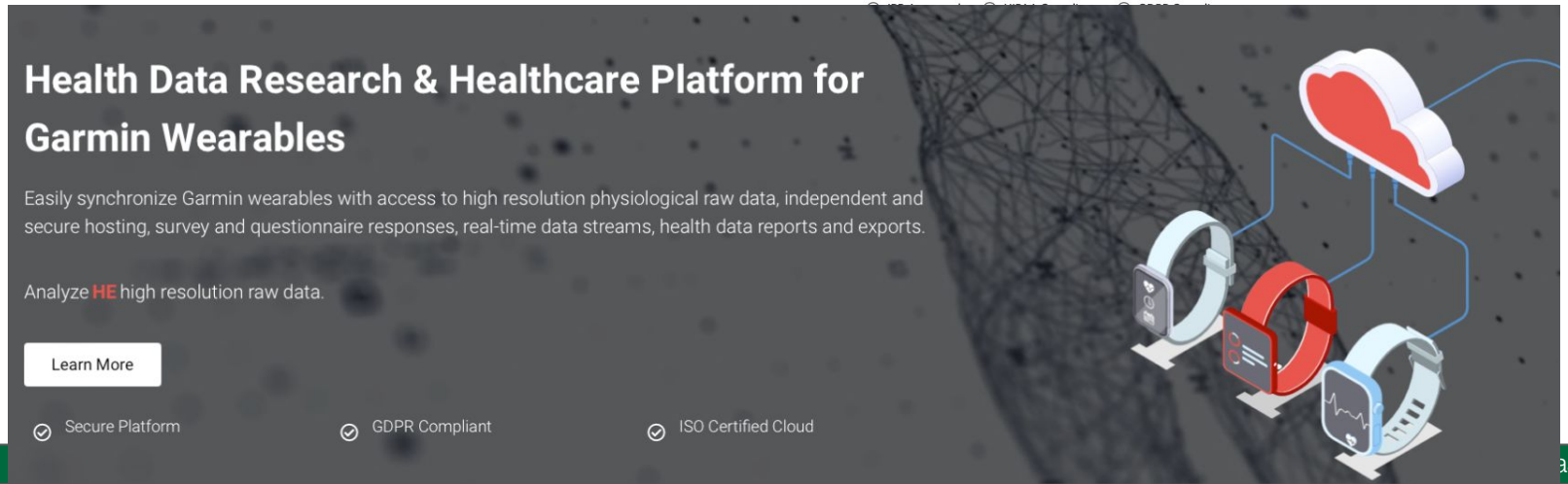
Date: 10-17-23



Low-burden start

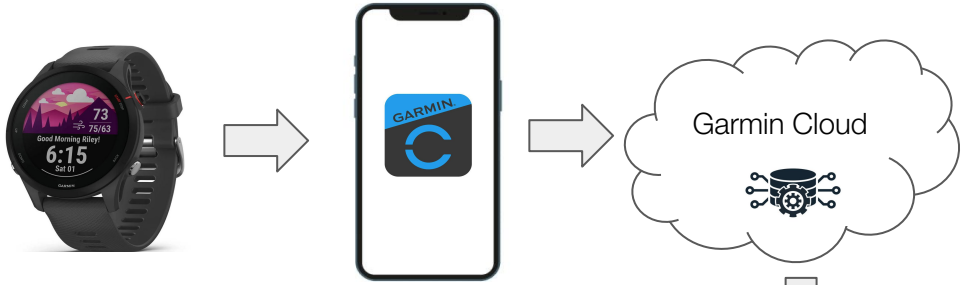
- LabFront
- Fitrockr
- Partnered directly with Garmin
- HIPAA, GDPR compliant.



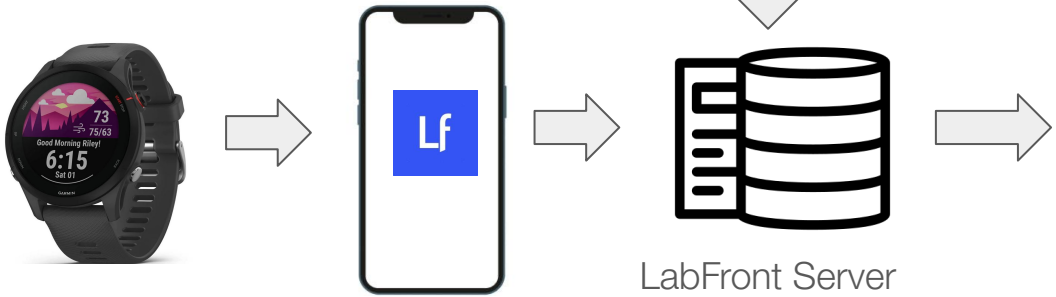


Using LabFront

- Garmin Health API



- Garmin Companion SDK



LabFront Dashboard
- View adherence
- Manage Participants
- Download data

Let’s hear from Garmin!

- Jesse Blackstock from Garmin Health

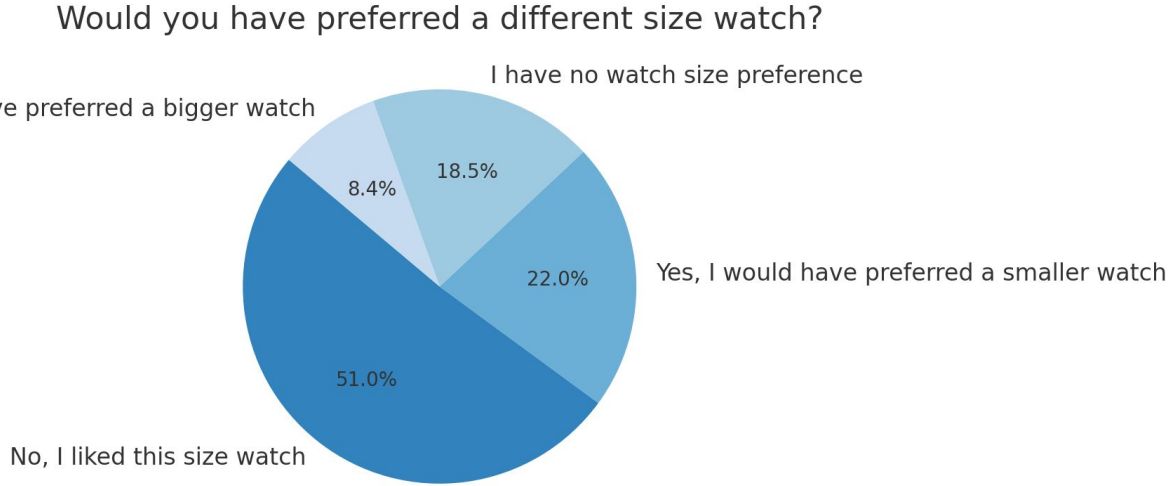
https://www.youtube.com/watch?v=bj5aU1QCgLQ

Experiences and Challenges with Garmin wearables for Digital Phenotyping

Device Size

Standardize the hardware across participants

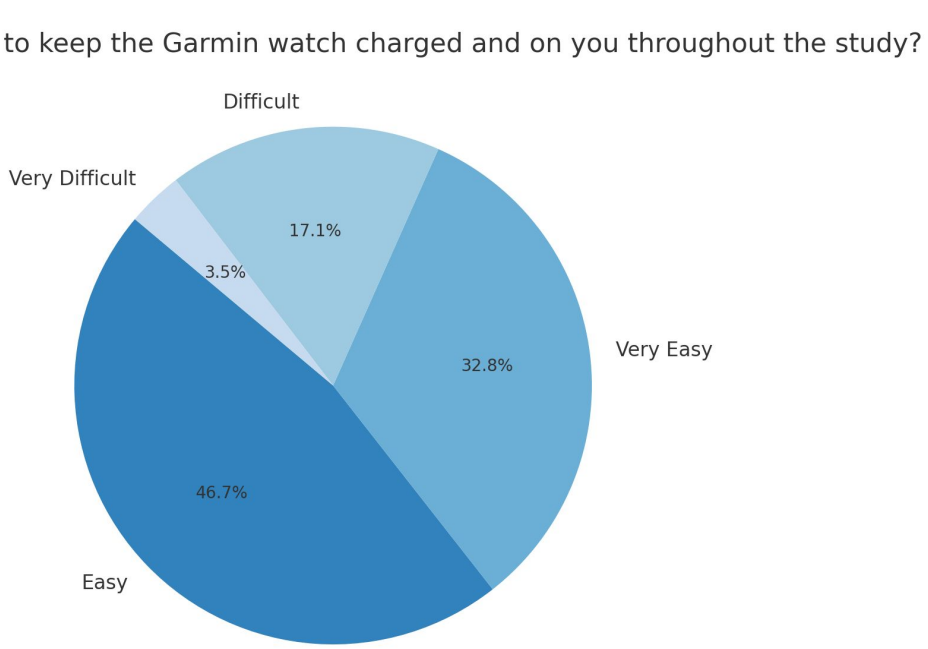
Went with the Garmin Vivoactive 4s (on right)



Device Charging

Some participants report that it's difficult to keep the device charged

The rate of difficulty is about 5% higher than just keeping one's phone charged

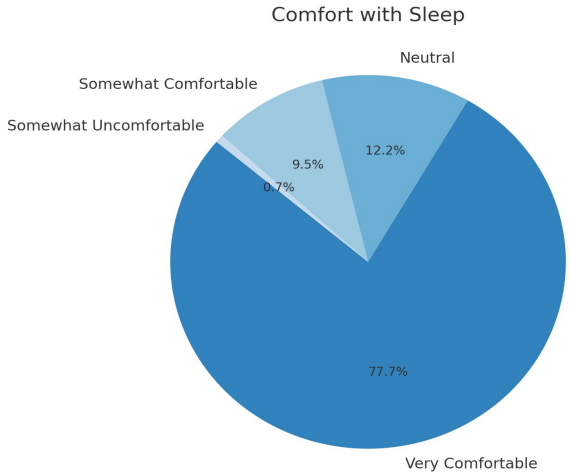


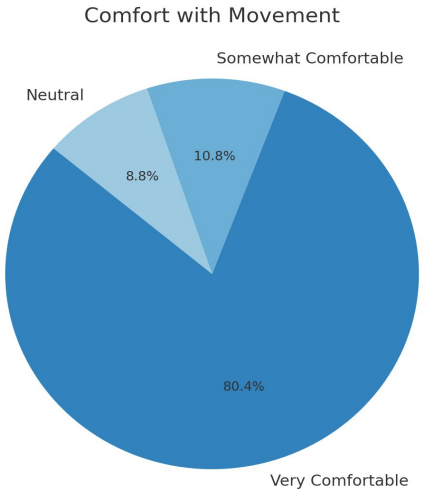
Participant Feedback

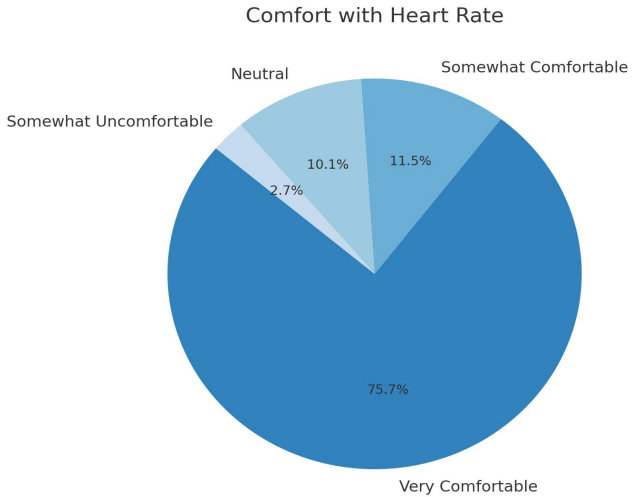
Mixed view on Garmin notifications

- Most participants found it annoying and too loud
- We disabled all notifications
- Some people wanted to be notified when their phone received the notification
- Some participant training (or basic “how to”) would enhance participant experience

Privacy Concerns: Not an Issue







Technical Concerns: Garmin SDK - Expiring

Most Garmin SDK keys come with an expiration

Participants needed to restart their phones

Labfront

Participants needed to keep Labfront open to upload the data

Maybe a configuration issue on our end? - but research coordinator couldn’t figure this out

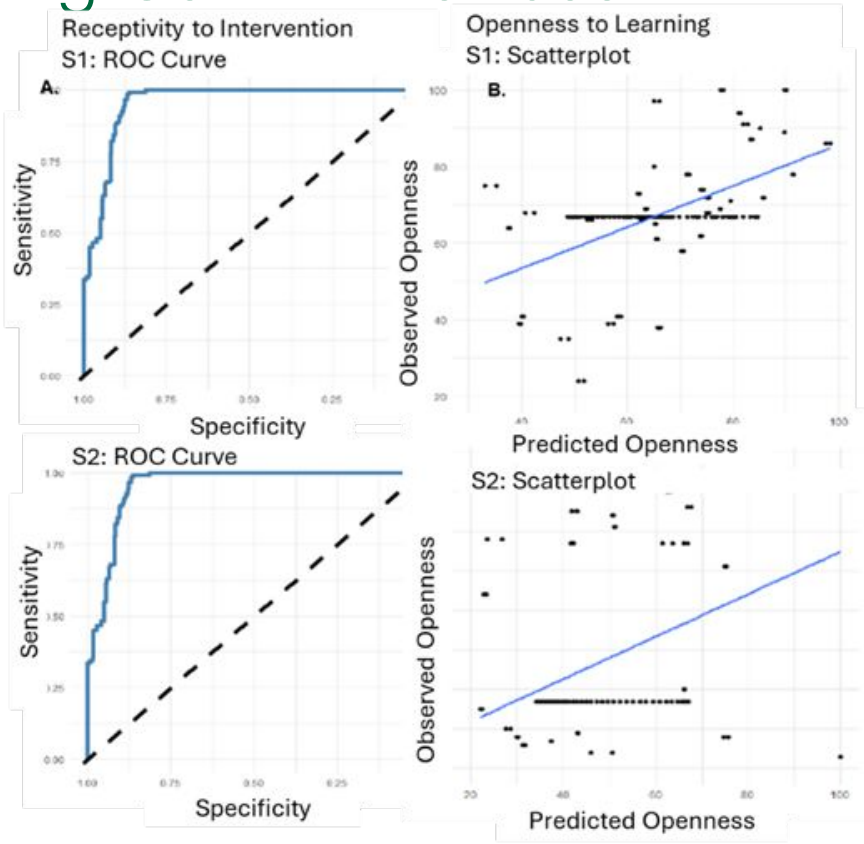
Examples of Research Based on Garmin Devices

Interim Analyses: Research Using Garmin Devices

Pilot study - predicting momentary receptivity

R^2 = 0.407 to predict openness to learning

Receptivity to intervention: AUC = 0.878



Interim Analyses: Future Weekly Variation in Depressive Symptoms Based on Movement Data Alone

Sample of persons with MDD (N =177) - predicting variation in depressive symptoms based on 270 ecological momentary assessments per person

Performance Metric	Test Set	Validation Set(s)
	Mean ± S.D.	Mean ± S.D.
AUC	0.59 ± 0.06	0.64 ± 0.02
Sensitivity	0.56 ± 0.21	0.57 ± 0.10
Specificity	0.59 ± 0.23	0.68 ± 0.12
Accuracy	0.59 ± 0.18	0.66 ± 0.09
Kappa	0.09 ± 0.09	0.15 ± 0.05
F1 Score	0.26 ± 0.07	0.31 ± 0.04