Developing Digital Measures from Person-Generated Health Data

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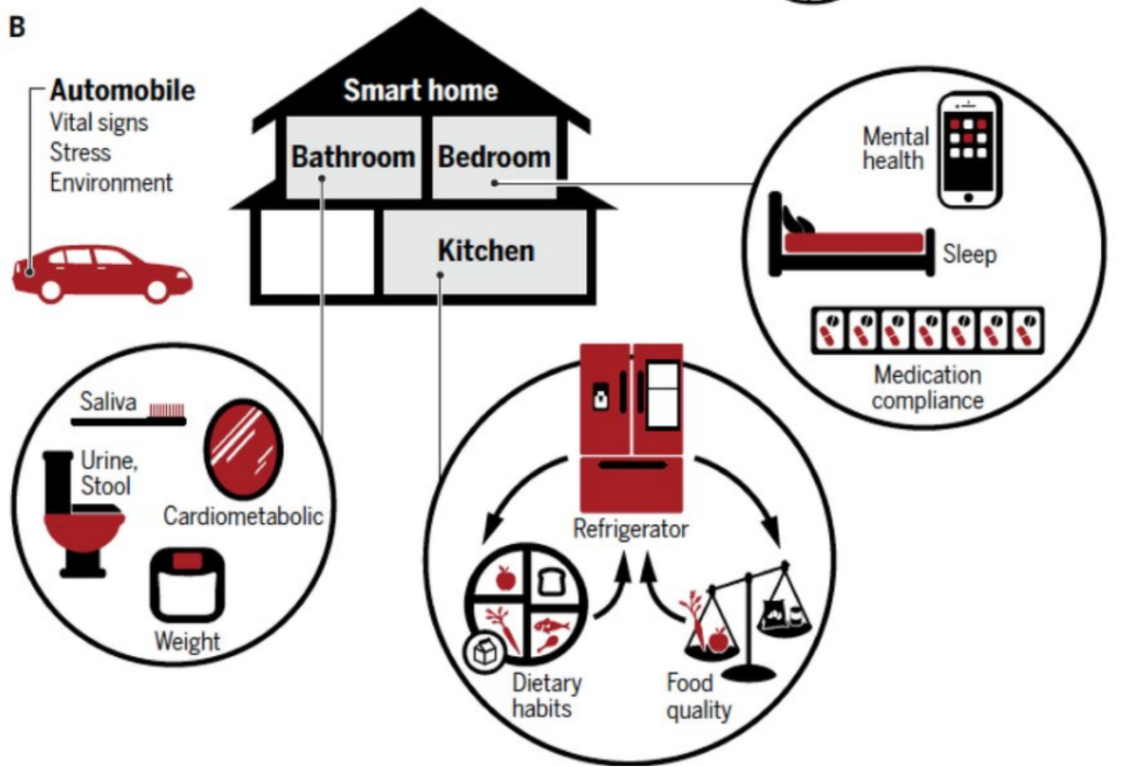
Person-Generated Health Data (PGHD) enables continuous monitoring of health outcomes at the individual level so we can better understand and measure a person's experience.



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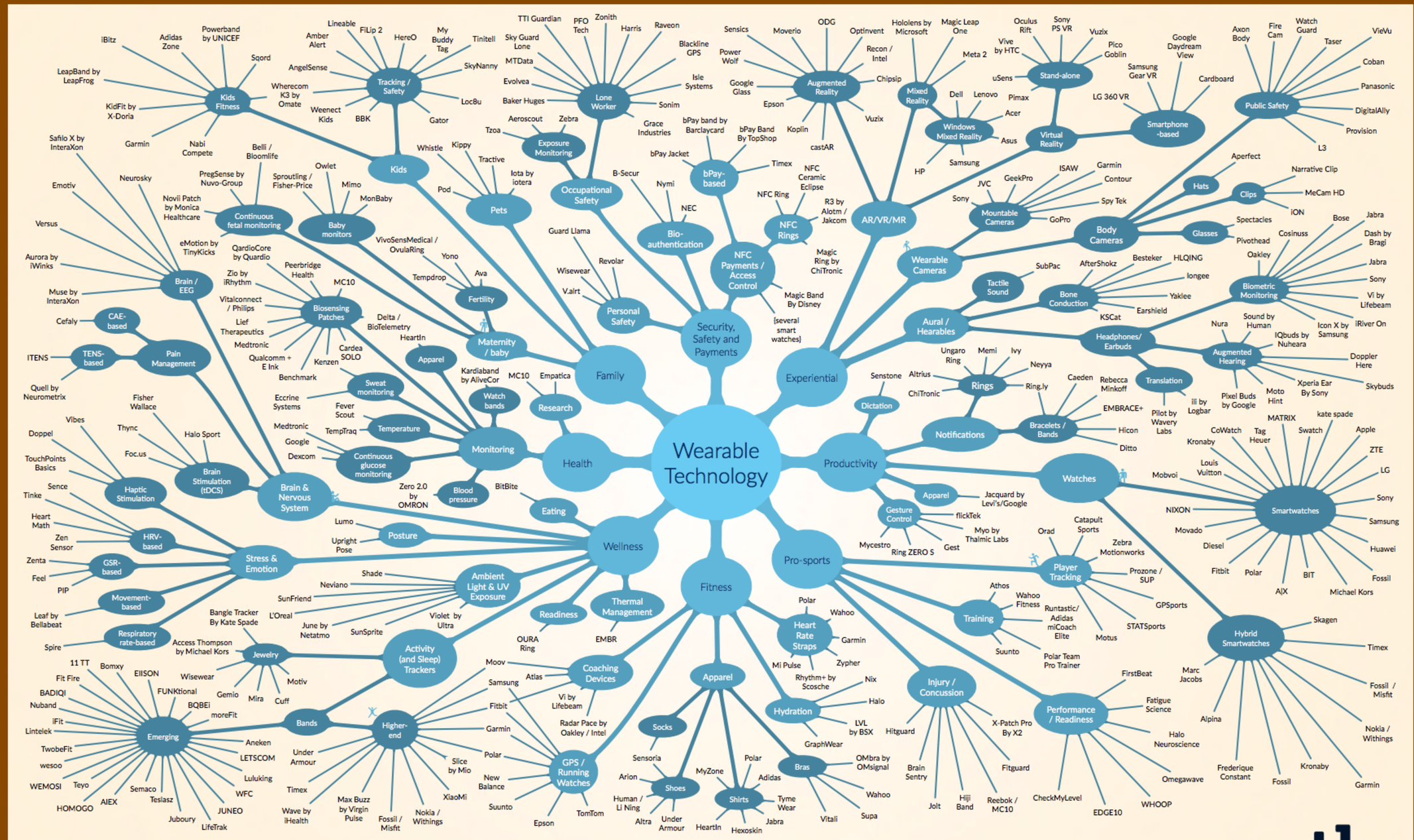
Wearable Technology
Health
Wellness
Fitness
Productivity
Experiential
Family
Security, Safety and Payments
Pro-sports
Kids
Kids Fitness
Tracking / Safety
Pets
Maternity / baby
Fertility
Baby monitors
Continuous fetal monitoring
Occupational Safety
Lone Worker
Exposure Monitoring
Personal Safety
Bio-authentication
bPay-based
NFC Payments / Access Control
NFC Rings
AR/VR/MR
Augmented Reality
Mixed Reality
Windows Mixed Reality
Virtual Reality
Stand-alone
Smartphone -based
Wearable Cameras
Mountable Cameras
Body Cameras
Hats
Clips
Glasses
Aural / Hearables
Tactile Sound
Bone Conduction
Headphones/ Earbuds
Augmented Hearing
Translation
Biometric Monitoring
Public Safety
Notifications
Rings
Bracelets / Bands
Dictation
Gesture Control
Apparel
Watches
Smartwatches
Hybrid Smartwatches
Player Tracking
Training
Injury / Concussion
Performance / Readiness
Pro-sports
Monitoring
Watch bands
Blood pressure
Temperature
Sweat monitoring
Continuous glucose monitoring
Research
Eating
Brain & Nervous System
Brain / EEG
Brain Stimulation (tDCS)
Pain Management
CAE-based
TENS-based
Biosensing Patches
Apparel
Stress & Emotion
Haptic Stimulation
HRV-based
GSR-based
Movement-based
Respiratory rate-based
Posture
Ambient Light & UV Exposure
Readiness
Thermal Management
Activity (and Sleep) Trackers
Bands
Emerging
Higher-end
Jewelry
Coaching Devices
GPS / Running Watches
Heart Rate Straps
Hydration
Apparel
Socks
Shoes
Shirts
Bras
Wearable Technology
2018 Wearable Technology Landscape
A sampling of interesting products, companies, and sub-segments
© Path Collaborative 2018
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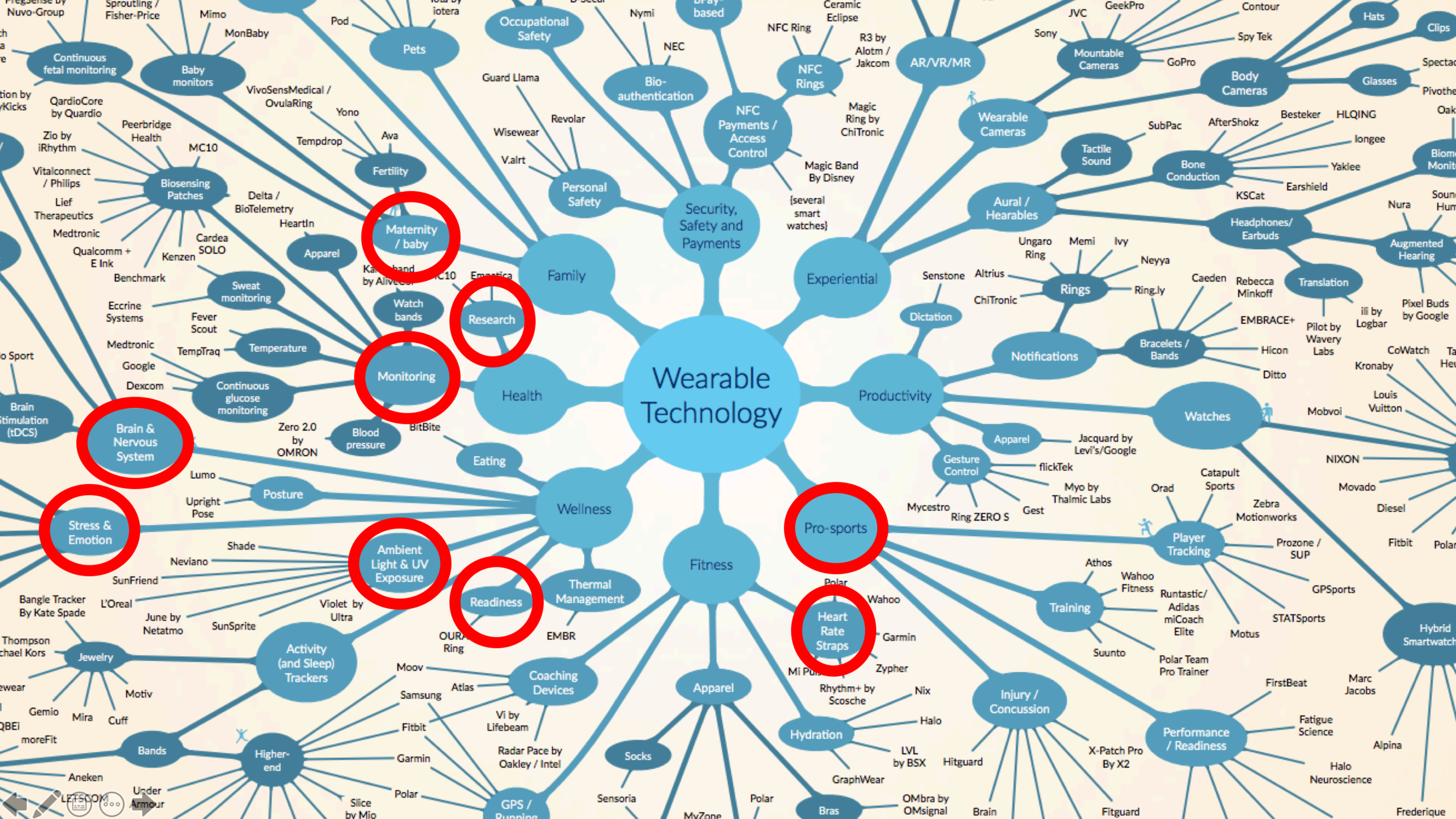
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Hicon
EMBRACE+
Rebecca Minkoff
Caeden
Ring.ly
Neyya
Ivy
Memi
Ungaro Ring
Altrius
Senstone
ChiTronic
Pilot by Wavery Labs
ili by Logbar
Nura
Yaklee
Earshield
KSCat
Longee
Besteker
HLQING
AfterShokz
SubPac
Contour
Spy Tek
GoPro
GeekPro
JVC
Sony
Magic Band By Disney
{several smart watches}
Magic Ring by ChiTronic
R3 by Alotm / Jakcom
NFC Ring
Ceramic Eclipse
NEC
Nymi
Revolar
Wisewear
V.alrt
Guard Llama
Ava
Yono
Tempdrop
VivoSensMedical / OvulaRing
MonBaby
Mimo
Pod
Iotera
Sprouting / Fisher-Price
Nuvo-Group
Peerbridge Health
MC10
QardioCore by Quardio
Zio by iRhythm
Vitalconnect / Philips
Lief Therapeutics
Medtronic
Qualcomm + E Ink
Benchmark
Kenzen
Cardea SOLO
Delta / BioTelemetry
HeartIn
Eccrine Systems
Fever Scout
TempTraq
Medtronic
Google
Dexcom
Zero 2.0 by OMRON
BitBite
Lumo
Upright Pose
Shade
Neviano
SunFriend
L'Oreal
June by Netatmo
SunSprite
Violet by Ultra
OURA Ring
EMBR
Bangle Tracker By Kate Spade
Thompson
Motiv
Gemio
Mira
Cuff
moreFit
Aneken
Under Armour
LETSCOM
Slice by Mio
Polar
Fitbit
Garmin
Samsung
Moov
Atlas
Vi by Lifebeam
Radar Pace by Oakley / Intel
Sensoria
MyZone
Polar
OMbra by OMsignal
Hitguard
Brain
Fitguard
X-Patch Pro By X2
GraphWear
LVL by BSX
Halo
Nix
Rhythm+ by Scosche
Zypher
Garmin
Wahoo
Polar
Suunto
Polar Team Pro Trainer
Runtastic/ Adidas miCoach Elite
Motus
STATSports
GPSports
Prozone / SUP
Zebra Motionworks
Catapult Sports
Orad
Athos
Wahoo Fitness
Marc Jacobs
Alpina
Halo Neuroscience
Fatigue Science
FirstBeat
Frederique
Fitbit
Polar
Diesel
Movado
NIXON
Mobvoi
Louis Vuitton
Kronaby
CoWatch
Jacquard by Levi's/Google
Apparel
flickTek
Myo by Thalmic Labs
Gest
Ring ZERO S
Mycestro

Apple Watch 4 Is Now An FDA Class 2 Medical Device: Detects Falls, Irregular Heart Rhythm

Jean Baptiste Su Contributor ⓘ
Enterprise & Cloud
Vice-President and Principal Analyst at Atherton Research

This invisible data enables a new approach to measuring and understand health, disease, and outcomes.

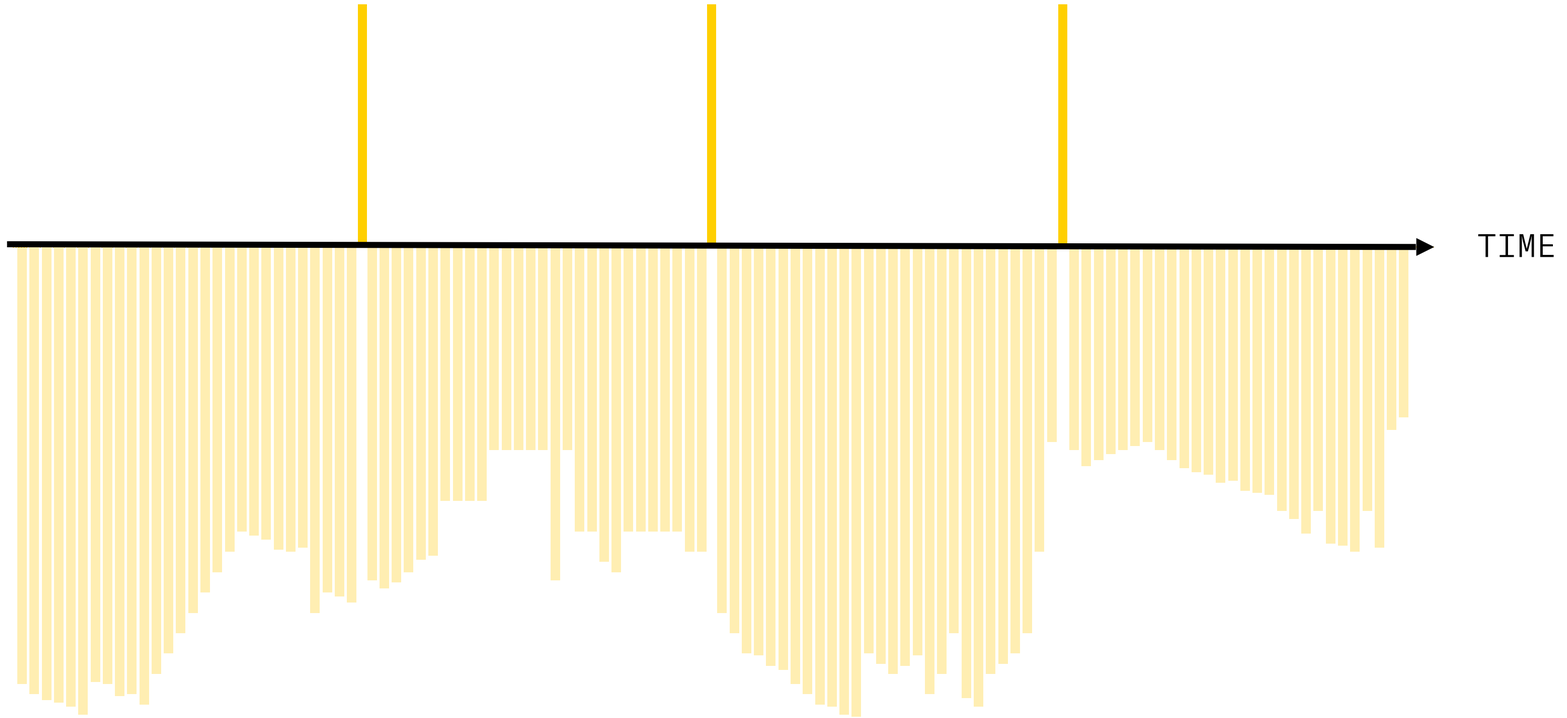
DATA POINTS

Visible — 0.03%

Episodic

Invisible — 99.97%

Continuous
Passive



Achievement allows members to earn rewards, connect health devices and apps, and participate in research–establishing a large scale, connected population.

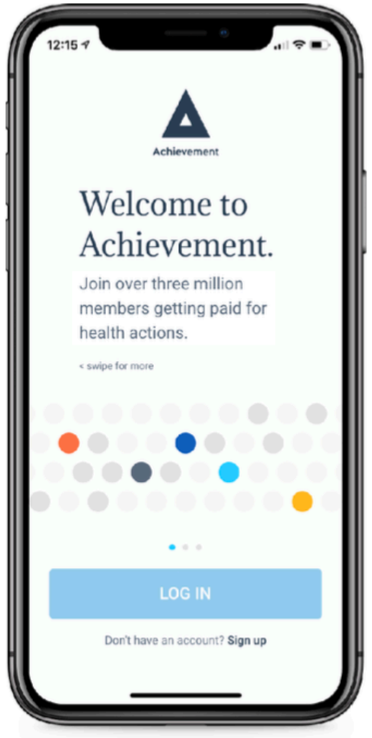
Completely virtual

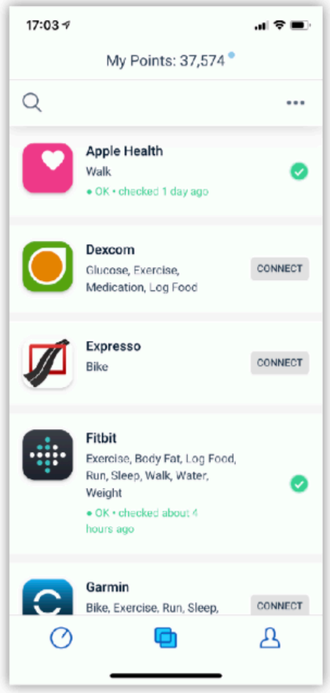
Open to any U.S. adult, multi-platform (web, iOS, Android)

Data is collected via individual permissioning

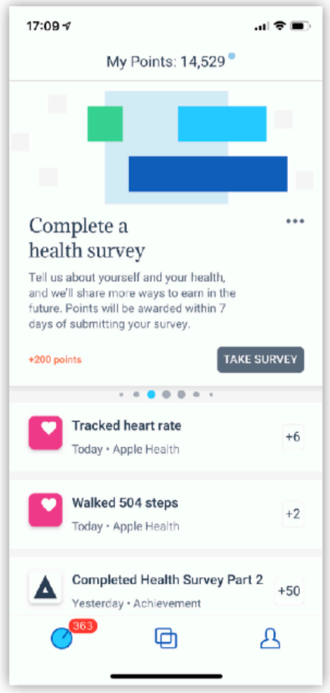
Only accessible to Evidation and our partners via a per use consent

Privacy-safe and secure

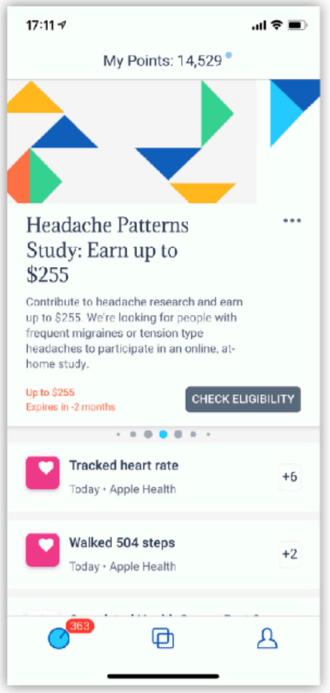




Objective data collection from consumer and clinical-grade devices and apps



Ongoing phenotypic labeling via both digital and self-reported methods



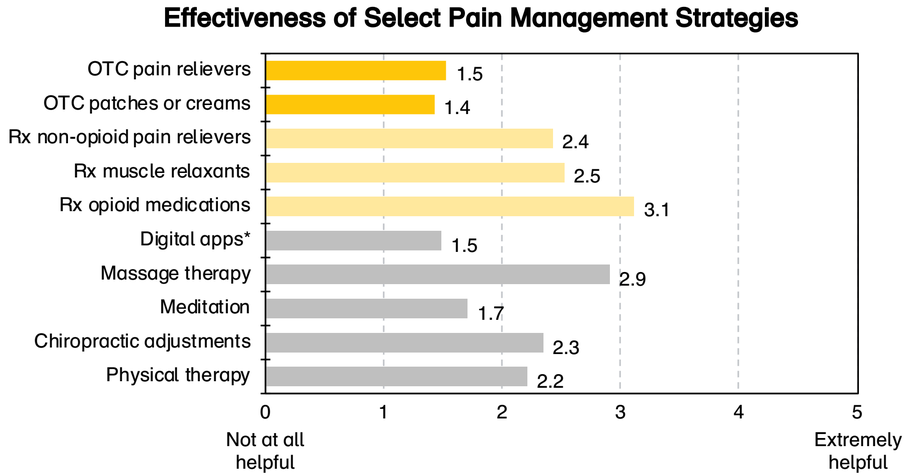
Targeted offers to participate in research based on known inclusion/exclusion criteria

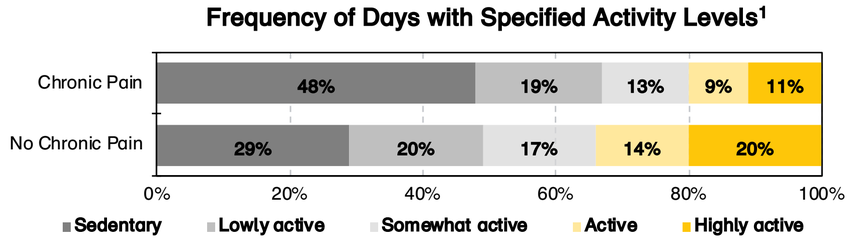
PGHD can can be collected remotely, enabling fast and high-volume recruitment and universal research.

Sample Baseline Characteristics	Chronic Pain (N = 5,832)	No Chronic Pain (N = 4,204)
Age, mean years (SD)	38.7 (10.7)	35.4 (9.8)
Female, n (%)	4,743 (81.3%)	2,650 (63.0%)
BMI, mean (SD)	32.0 (8.8)	30.1 (7.3)
QoL[a] [scale: 0-10], mean (SD)	6.3 (2.7)	8.5 (2.0)
PHQ-9[b] score, mean (SD)	11.9 (6.2)	6.3 (5.5)
GAD-7[c] score, mean (SD)	9.0 (6.0)	5.2 (5.0)

[a] QoL is based on the American Chronic Pain Association Quality of Life Scale
[b] PHQ-9 = Patient Health Questionnaire 9-item Scale (depression)
[c] GAD-7 = Generalized Anxiety Disorder 7-item Scale

SOURCE: **PAIN MANAGEMENT STRATEGIES AND ACTIVITY TRACKER UTILIZATION IN A LARGE-SCALE CHRONIC PAIN STUDY..** TRAN ET AL., ISPOR, MAY 2019





SEE ALSO: **ACCELERATING RESEARCH WITH TECHNOLOGY: RAPID RECRUITMENT FOR A LARGE-SCALE WEB-BASED SLEEP STUDY..** DEERING ET AL., JMIR RESEARCH PROTOCOL, JAN 2019

Results: Overall, 1156 participants enrolled in the study within a 5-day recruitment window.[…] Overall, 1132 participants completed the baseline questionnaires (1132/1156, 97.9%) and 1047 participants completed the initial Sleepiness Checker activity (1047/1156, 90.6%). Furthermore, 1000 participants provided activity-specific wearable data (1000/1156, 86.5%) and 982 provided sleep-specific wearable data (982/1156, 84.9%).

PGHD allows measuring novel outcomes for chronic conditions at the population level.

	T2DM trackers	Matched control trackers
Number of activity trackers	4,459	10,321
% days with tracked steps*	78.7%	80.7%
Mean nightly sleep duration (hours)*	6.48	6.69
Sleep regularity index (SRI)*	0.72	0.77
Resting heart rate (BPM)*	71.2	66.0

*p < 0.05

SOURCE: **USING CLAIMS AND WEARABLE DEVICES DATA TO QUANTIFY INFLUENZA OUTCOMES AMONG TYPE 2 DIABETES PATIENTS - A POPULATION STUDY.** SAMSON ET AL., AMERICAN DIABETES ASSOCIATION, JULY 2018

	MS trackers	Matched control trackers
Number of activity trackers	498	1,400
% days with tracked steps**	73%	77%
Mean daily step count**	6,379	7,188
Mean nightly sleep duration (hours)	6.3	6.5
Max time to fall asleep (minutes)**	18.58	13.91

*p < 0.05 **p < 0.001, FDR-ADJUSTED

SOURCE: **REAL-WORLD USE OF WEARABLE DEVICES IN A LARGE MULTIPLE SCLEROSIS COHORT.** FOSCHINI ET AL., AMERICAN ACADEMY OF NEUROLOGY, APRIL 2018

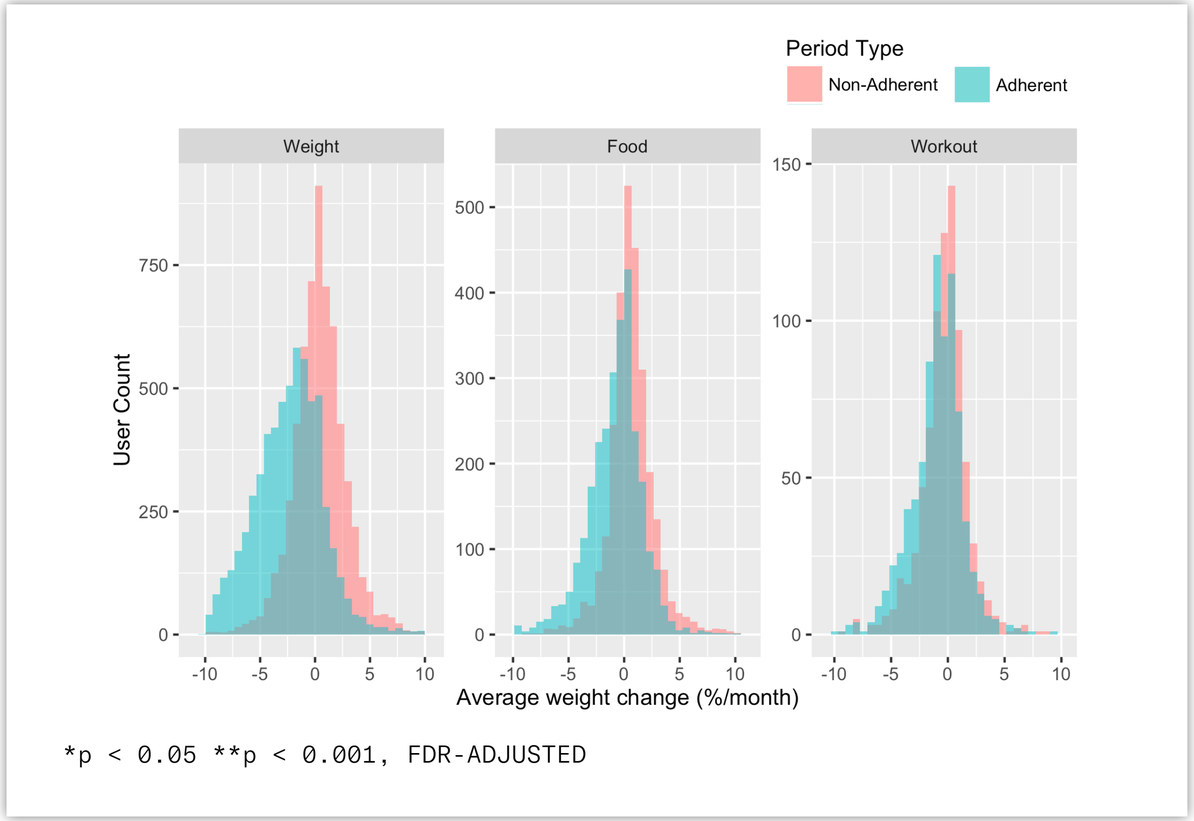
Missingness can be informative: Adherence to wearing a consumer device correlates with other forms of adherence.

Results: We identified 117,765 cases with diabetes, 317,340 with dyslipidemia, and 673,428 with hypertension […] Average fixed and variable PDC for all individuals ranged from 0.673 to 0.917 for diabetes, 0.756 to 0.921 for dyslipidemia, and 0.756 to 0.929 for hypertension.

A subgroup of 8553 cases also had health behavior data (eg, activity-tracker data). […] individuals who tracked steps, sleep, weight, or diet were significantly more likely to be adherent to medication than those who did not track any activities […] (odds ratio, OR 1.33, 95% CI 1.29-1.36), with age and sex as fixed effects.

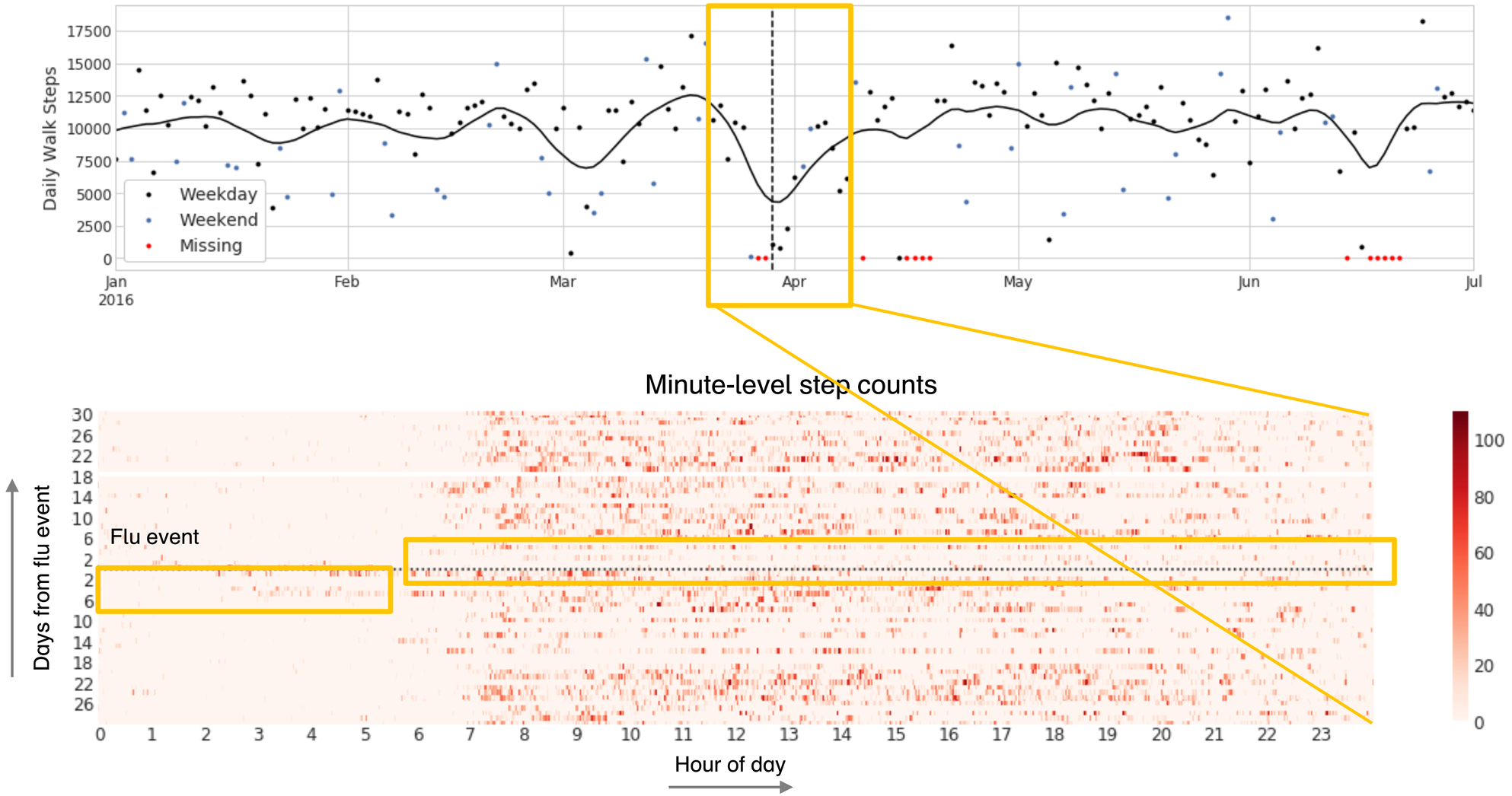
Furthermore, there was a positive association between frequency of activity tracking and medication adherence. In the logistic regression model, increasing the adjusted tracking ratio by 0.5 increased the fixed adherent status OR by a factor of 1.11 (95% CI 1.06-1.16).[…]

SOURCE: **THE ASSOCIATION BETWEEN MEDICATION ADHERENCE FOR CHRONIC CONDITIONS AND DIGITAL HEALTH ACTIVITY TRACKING: RETROSPECTIVE ANALYSIS.** QUISEL ET AL., JOURNAL OF MEDICAL INTERNET RESEARCH, MARCH 2019

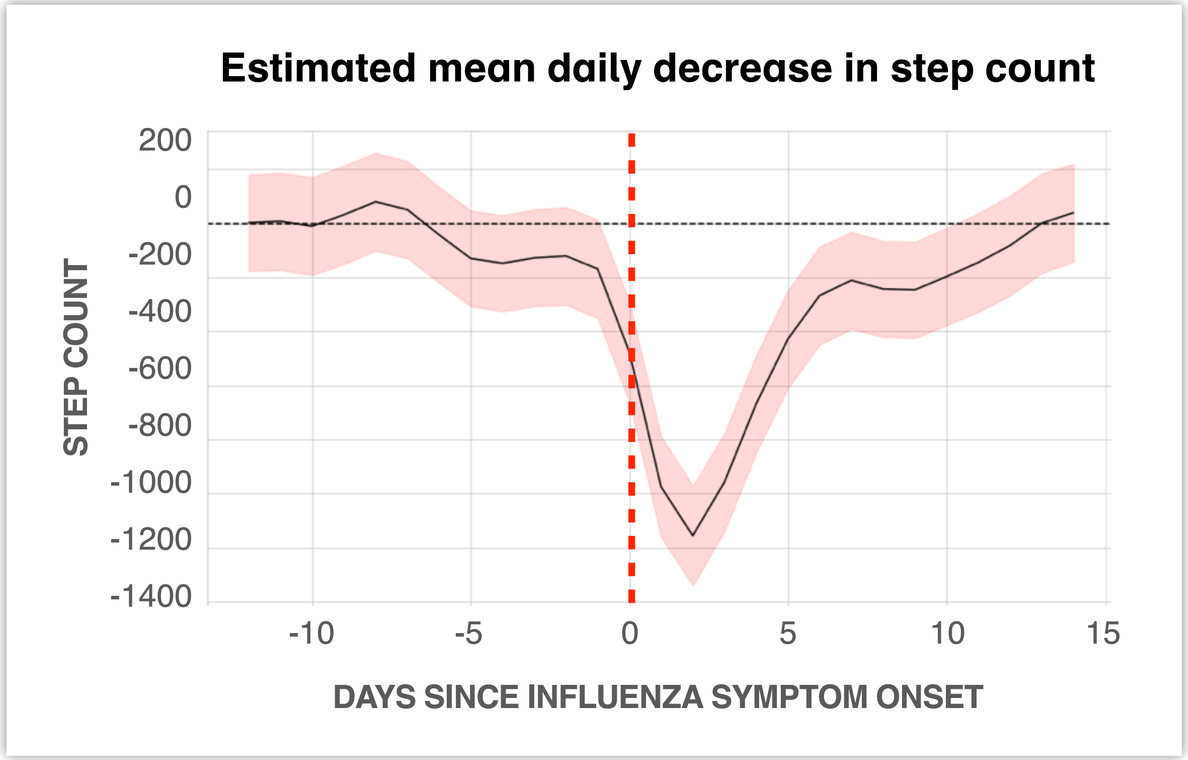


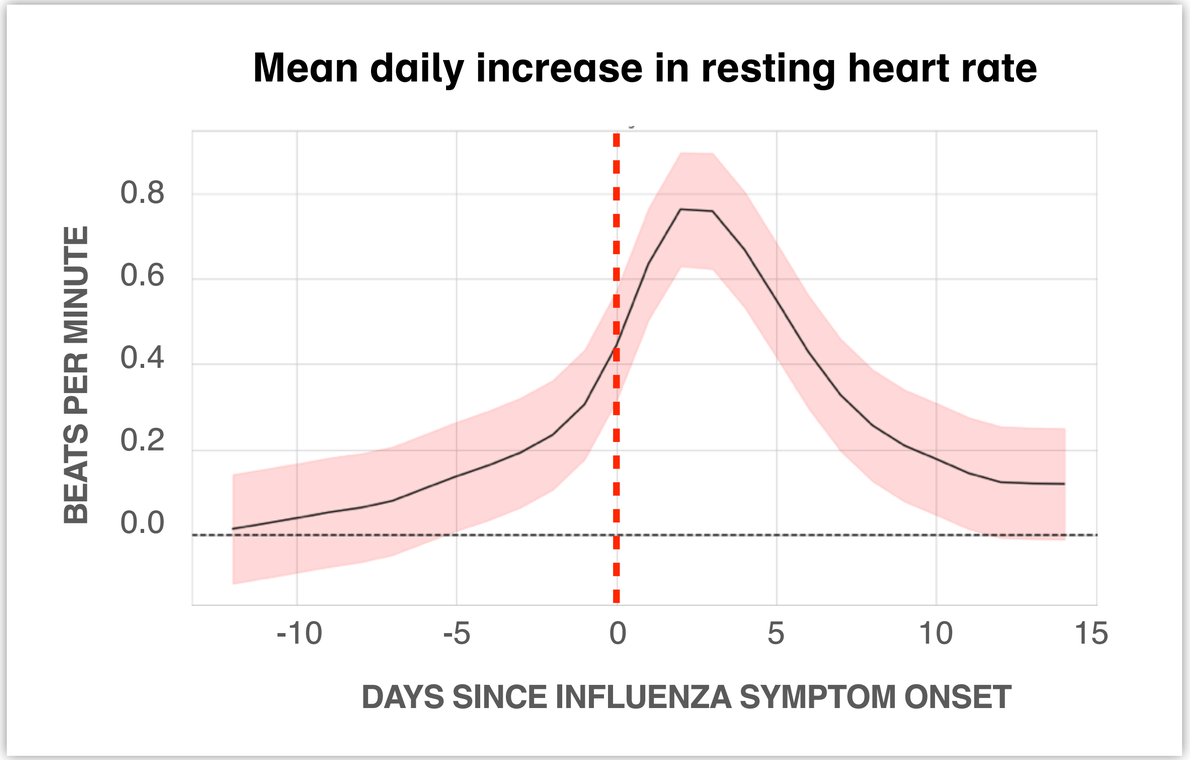
SOURCE: **ADHERENT USE OF DIGITAL HEALTH TRACKERS IS ASSOCIATED WITH WEIGHT LOSS.** POURZANJANI ET AL., PLOS ONE 2016

PGHD can captures outcomes relevant to the patient, at high frequency, at the individual level.



PGHD allows measuring burden of acute conditions invisible to the healthcare system, and its unfolding through time.

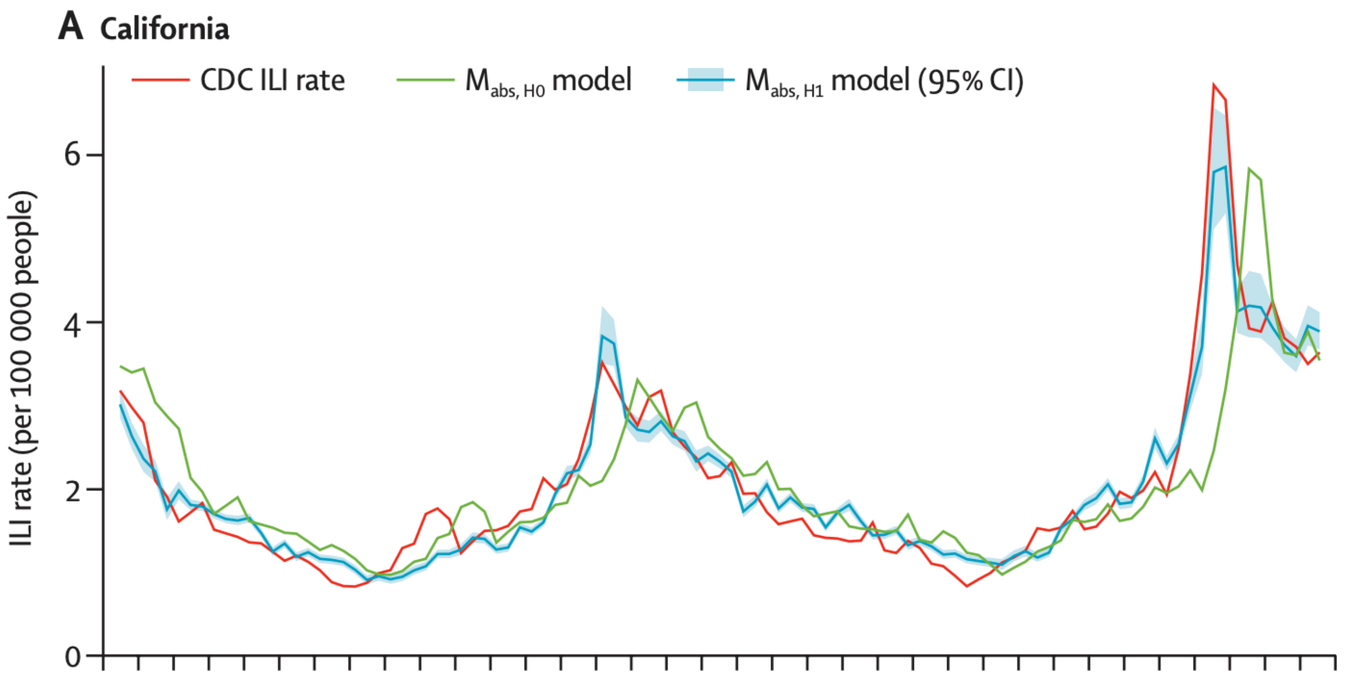




ADAPTED FROM: **INFLUENZA SURVEILLANCE USING WEARABLE MOBILE HEALTH DEVICES.** BRADSHAW ET AL., ONLINE JOURNAL OF PUBLIC HEALTH INFORMATICS, MAY 2019

NOTE: BASED ON 124K SURVEY RESPONDERS WHO REPORTED INFLUENZA SYMPTOMS IN 2018

Applications: flu now-casting



SOURCE: **HARNESSING WEARABLE DEVICE DATA TO IMPROVE STATE-LEVEL REAL-TIME SURVEILLANCE OF INFLUENZA-LIKE ILLNESS IN THE USA: A POPULATION-BASED STUDY.** RADIN ET AL., THE LANCET DIGITAL HEALTH, JAN 2020

"[…], we found that the prediction errors of the model presented by Radin and colleagues, one that combines Fitbit data with historical ILI activity, are larger than those obtained using historical influenza information from the past 52 weeks as inputs"

SOURCE: **FITBIT-INFORMED INFLUENZA FORECASTS.** VIBOUD ET AL., THE LANCET DIGITAL HEALTH, JAN 2020

CleanLink

Fitbit Data Could Help Predict Flu Outbreaks

In addition to tracking the sleep quality, heart rate and number of steps a person takes, researchers say the popular Fitbit wearable devices ...

3 days ago

NMSU Reporter

Fitbit Can Predict Flu Outbreak

The Fitbit in your wrist not solely counts your steps and minutes of sleep, and it could additionally assist inform if you happen to're coming down ...

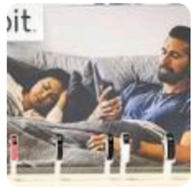
16 hours ago

Reuters

Health warning: How Fitbits can help predict flu outbreaks

The Fitbit on your wrist not only counts your steps and minutes of sleep, it can also help tell if you're coming down with the flu - and warn health ...

1 week ago



CNN International

Your Fitbit could help health officials predict flu outbreaks in real-time

(CNN) That Fitbit you've been wearing could be doing a lot more than tracking your trips to the store. It may help health officials stop the flu from ...

1 week ago

Fox Business

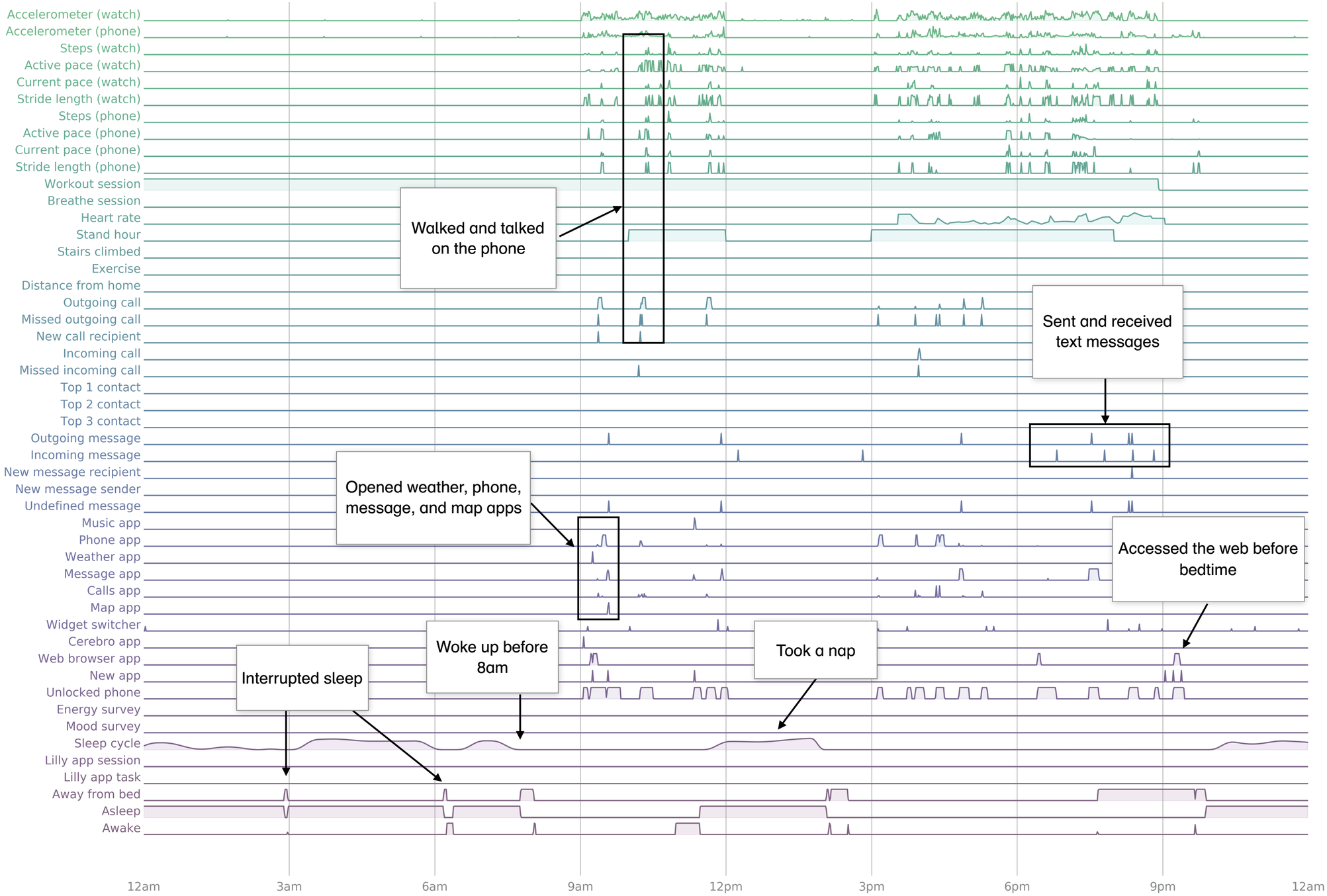
Can Fitbit spot the flu?

Fitbit devices, designed to help individuals live a healthier lifestyle, can even help prevent the spread of the flu in real-time by predicting when ...

1 week ago

A **behaviorgram** offers a rich representation of an individual's behavior.

It also serves as tool for data exploration, hypothesis generation, and most importantly, a way inspect the **quality of the data**.



SOURCE: **DEVELOPING MEASURES OF COGNITIVE IMPAIRMENT IN THE REAL WORLD FROM CONSUMER-GRADE MULTIMODAL SENSOR STREAMS.** MARINSEK ET AL., KDD, AUGUST 2019

evidation.com/research

2019

Large-scale influenza vaccination promotion on a mobile app platform: A randomized controlled trial. *Lee WN, Stück D, Konti K, Rivers C, Brown CR, Zbikowski SM, Foschini L*. **VACCINE 2019**

Quantifying the Impact of Influenza Among Persons with Type 2 Diabetes Mellitus: A New Approach to Determine Medical and Physical Activity Impact. *Samson SI, Konty K, Lee WN, Quisel T, Foschini L, Kerr D, Liska J, Mills H, Hollingsworth R, Greenberg M, Beal AC*. **JOURNAL OF DIABETES SCIENCE AND TECHNOLOGY 2019**

African American Participants Experience Greater Pain Severity and Pain Interference Compared to Non-Hispanic Whites in a Large-Scale Virtual Study on Chronic Pain. *Cerrada C J, Tai C, Kumar S, Scherer K, Eulogio R, Ramirez E, Foschini L, Juusola J*. **SMDM 2019**

Effect of Different Financial Incentive Structures on Promoting Physical Activity Among Adults. *Bachireddy C, Joung A, John LK, Gino F, Tuckfield B, Foschini L, Milkman KL.* **JAMA NETWORK OPEN 2019**

Developing Measures of Cognitive Impairment in the Real World from Consumer-Grade Multimodal Sensor Streams. *Chan R, Jankovic F, Marinsek N, Foschini L, Kourtis L, Signorini A, Pugh M, Shen J, Yaari R, Maljkovic V, Sunga M, Hee Song H, Joon Jung H, Tseng B, Trister A*. **KDD 2019**

At Home Cognitive Testing (CANTAB Battery) in Healthy Controls and Cognitively Impaired Patients: A Feasibility Study. *Maljkovic V, Pugh MAM, Yaari R, Shen J, Juusola, JL*. **AAIC 2019**

A systematic review of feasibility studies promoting the use of mobile technologies in clinical research. *Bakker JP, Goldsack JC, Clarke M, Coravos A, Geoghegan C, Godfrey A, Heasley MG, Karlin DR, Manta C, Peterson B, Ramirez E, Sheth N, Bruno A, Bullis E, Wareham K, Zimmerman N, Forrest A, Wood WA*. **NPJ DIGITAL MEDICINE 2019**

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Adversarial Examples for Electrocardiograms. *Han X, Hu Y, Foschini L, Jankelson L, Ranganath R* **ICLR 2019 workshop**

Reproducibility in Machine Learning for Health. *McDermott M, Wang S, Marinsek N, Ranganath R, Ghassemi M, Foschini L.* **ICLR 2019 workshop**

The association between medication adherence for chronic conditions and digital health activity tracking. *Quisel T, Foschini L, Zbikowski SM, Juusola J*. **JMIR PUBLICATIONS 2019**

Comparison of Heart Rate Measurement Between the Fitbit Charge 2 and OMsignal Smart Garments: A Free-Living Study. *Wildman M, Eulogio R, Singh R, Ramirez R, Foschini L, Nadarajan A, Booth B, Mundnich K, Ferrara E, Lerman K, Narayanan S.* **SOCIETY OF BEHAVIORAL MEDICINE 2019**

Longitudinal Changes in Activity and Sleep Behaviors from Activity Trackers Are Associated with Change in Depression Severity. *Ramirez E, Tran JL, Bradshaw B, Kumar S, Tai C, Foschini L, Juusola JL*. **SBM 2019**

Digital biomarkers for Alzheimer's disease: the mobile/wearable devices opportunity. *Kourtis LC, Regele OB, Wright JM, Jones, GB.* **NPJ DIGITAL MEDICINE 2019**

Influenza Surveillance Using Wearable Mobile Health Devices. *Bradshaw B, Konty K, Ramirez E, Lee WN, Signorini A, Foschini L*. **INTERNATIONAL SOCIETY FOR DISEASE SURVEILLANCE CONFERENCE 2019**

Accelerating Research with Technology: Rapid Recruitment for a Large-Scale Web-Based Sleep Study *Deering S, Grade MM, Uppal JK, Foschini L, Juusola JL, Amdur AM, Stepnowsky CJ.* **JMIR R PROTOCOLS 2019**

Want to collaborate on research?

Let's chat! research@evidation.com

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