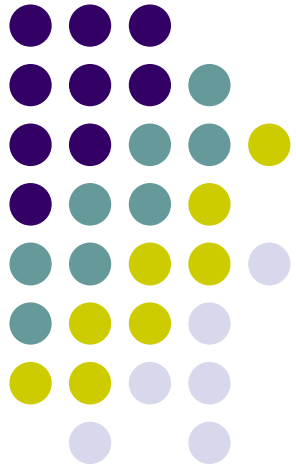
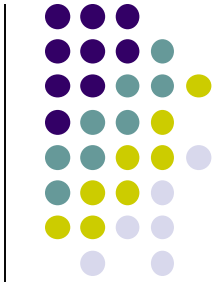
CS 528 Mobile and Ubiquitous Computing

Lecture 9a: Wearables, Quantified Self & Physiological Sensing

Emmanuel Agu





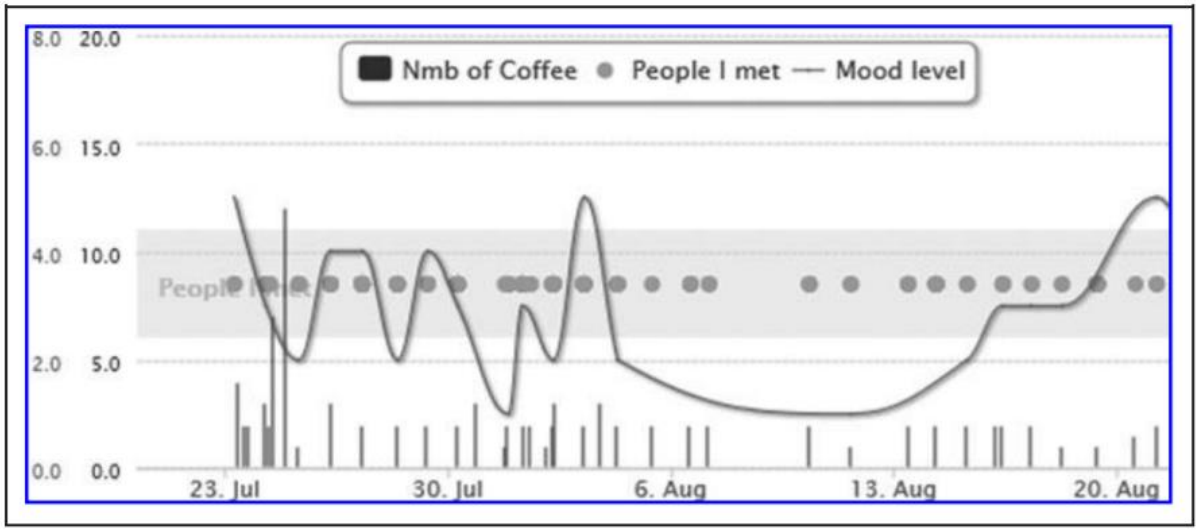
Tracking Health, Wellness & Quantified Self

Quantified Self (QS)

- QS: Community of People who want to measure, log, share metrics about various aspects of their lives. E.g.
- **Defn:** Obtaining self-knowledge through self-tracking
- Also known as personal informatics or lifelogging
  - Sleep, daily step count, food consumed, air quality, mood, etc.
- Measurements typically done using wearables/technology
  - Activity trackers, steps, sleep tracker, calories burned, etc
  - Now more available, cheaper

QS: Why Track?

- Why track? To figure out causes of certain behaviors, improve health/wellness
  - E.g. Why do I feel tired on Friday afternoons?
- Data to back up your choices/decisions
  - Did that cup of coffee make you more productive?
- Discover new patterns that are fixable
  - Whenever I go to my mother's house, I add at least 5 pounds on Monday morning
  - Am I happier when I meet more people or when I drink more coffee?



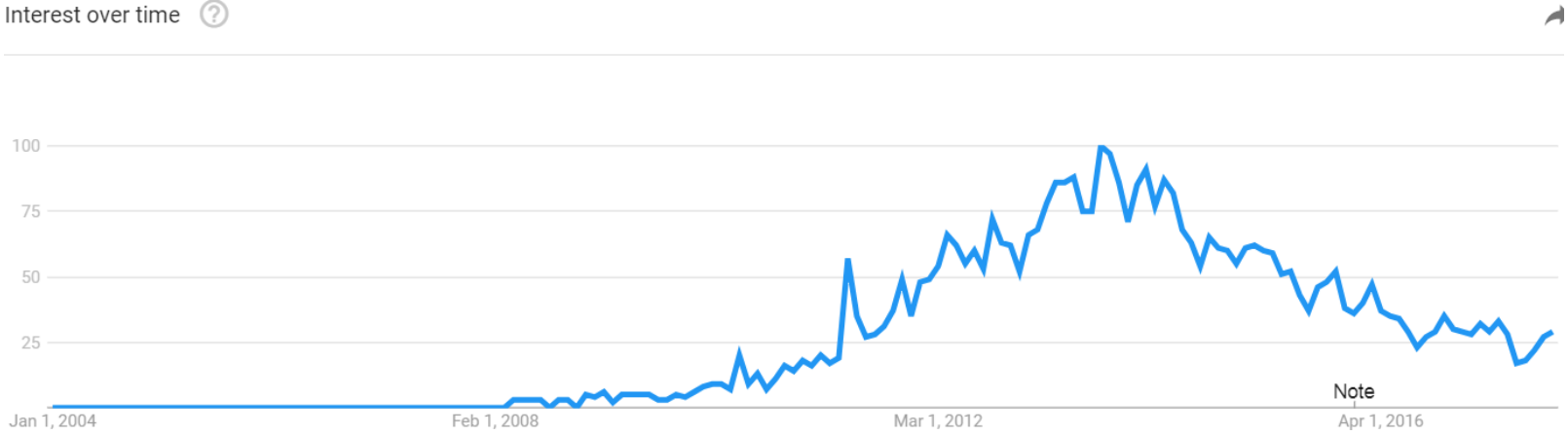
Courtesy
Melanie Swan

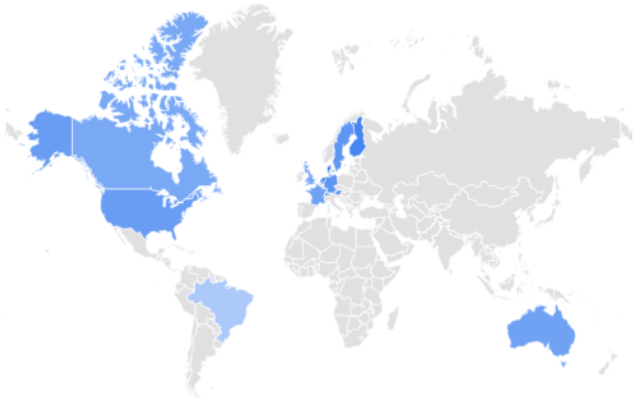
QS: How Popular?

- 69% of US adults already track at least 1 health metric (Pew Research)
- Local meetings, conferences, website
  - quantifiedself.com/

QS: Google Search Trends

- Google Trends displays how often a term is searched
- “Quantified Self” Searches peaked ~ 2014
- Now more popular in Europe (Netherlands = 1, USA = 8)





6	Germany	47
7	Austria	43
8	United States	41
9	Australia	37
10	France	37

QS Wellness Tracking Devices

Smart fork: eating/calories

Sleep manager

Bluetooth scale

Body worn activity trackers
(steps, activities, calories)

Quantified Self Big Picture

1. Track

Physiological

Eating

Exercise

Sleep

Weight

Blood pressure

Heart rate

Stress

+ Other Context

Location

Travel

Calendar

Email

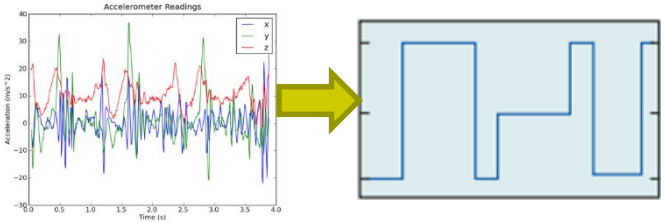
Lab results

2. Analyze

Analytics websites

Bodytrack.org

Machine Learning



Regression, classification, etc

3. Inform

Mobile App

Hire Coach/Dr

Mymee.com
(data-driven
coaching)

Bodytrack Project

http://www.cmucreatelab.org/projects/BodyTrack

BodyTrack chest strap:
EKG, respiration, accelerometry;
stress, cough/sneeze, snoring

Phone:
Pictures, GPS location, activity;
food, events, self-reporting

Actigraphy:
Activity and energy levels

Indoor air
quality

BodyTrack Indoor
Environmental station:
Temp, humidity, barometric, sound
levels, light levels;
Sleep hygiene, air quality (with
external sensor), charger and data
gateway for chest strap

Quantified
Self

Weight

Sleep logging

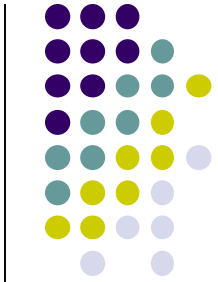
Regional air quality:
Particulates, other pollutants,
pollen, mold

FluxStream QS Visualization

Fluxstream Unified QS Dashboard

Source: http://johnfass.wordpress.com/2012/09/06/bodytrackfluxtream/

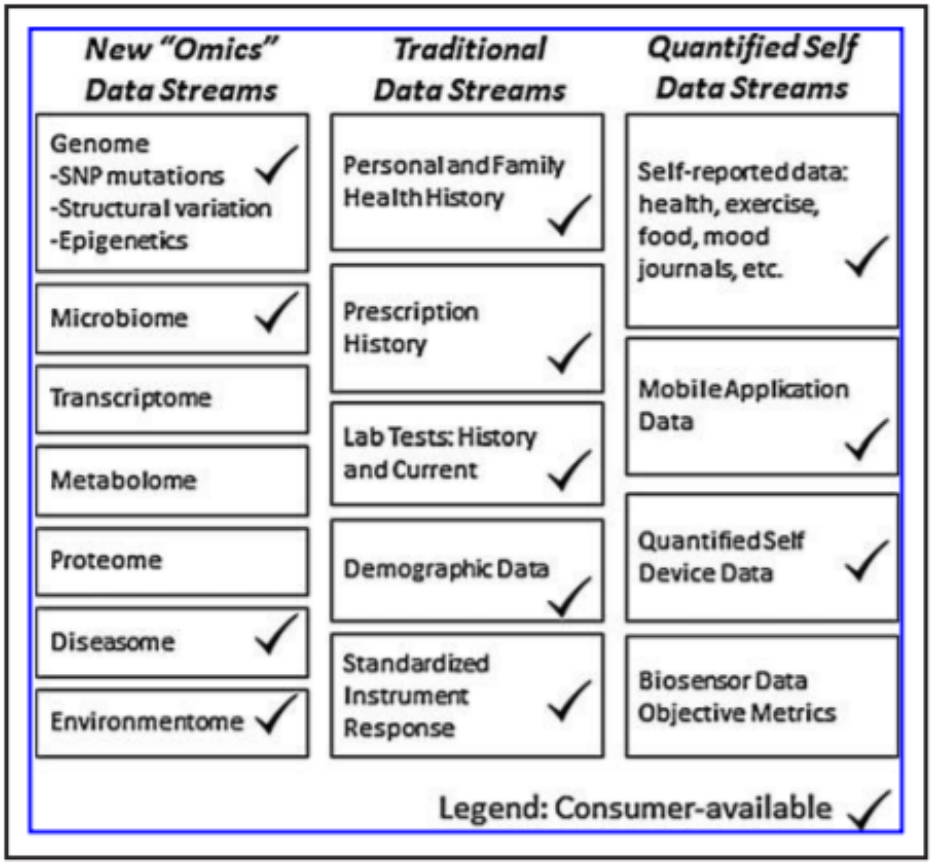
QS: Other Personal Data Sources

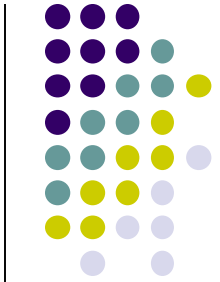


- Social media: Facebook, Twitter, Foursquare
- Search engines: Google, Bing
- E-commerce sites: Amazon, Airline sites
- Entertainment/game sites: Netflix
- Email: Outlook, gmail, etc

The Future: Precision Medicine

- In future combine data from quantified self + medical data + genomics data = Precision medicine





Smartwatches + Wearables

Main Types of Wearables

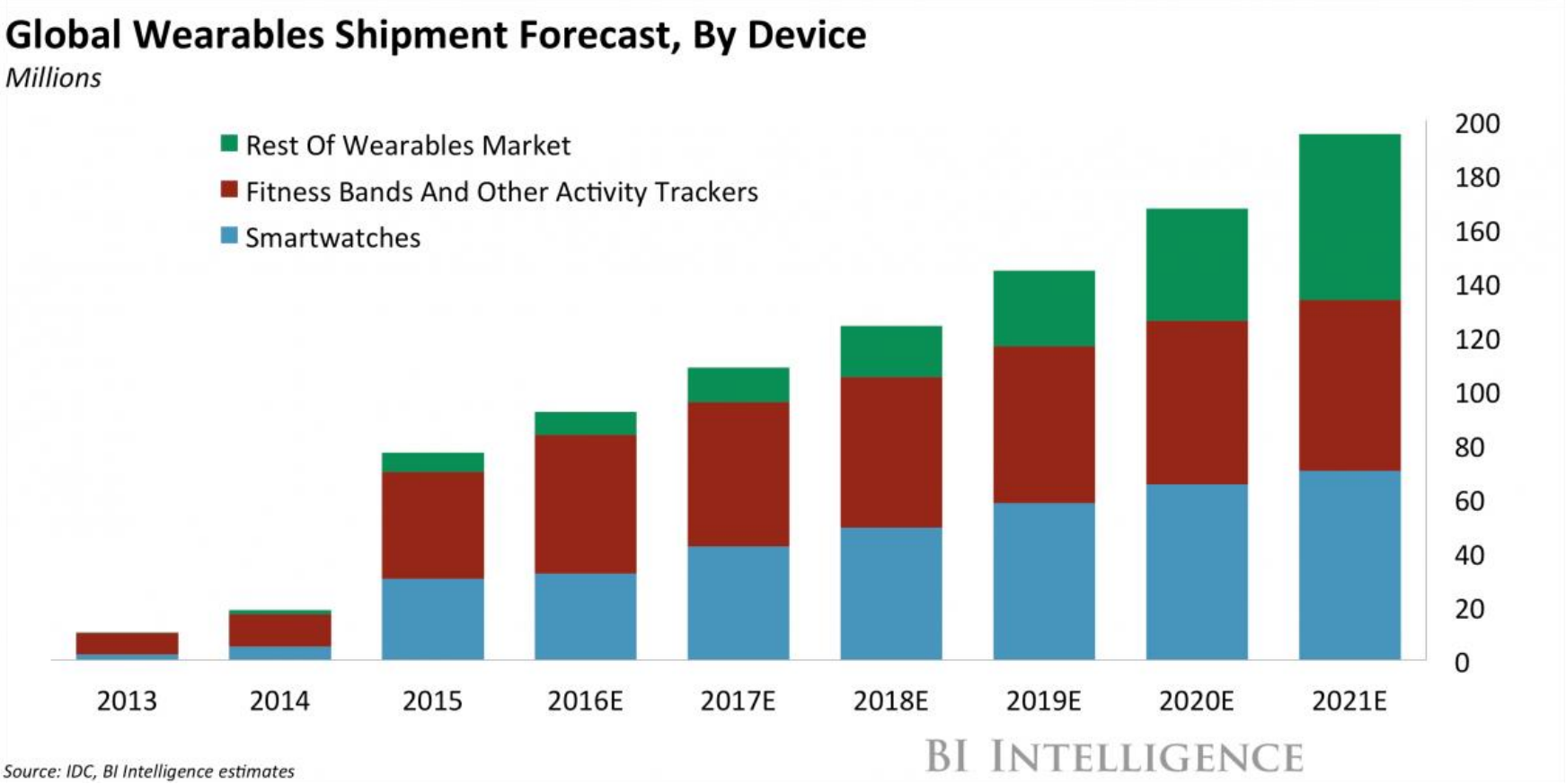
- **Activity/Fitness Trackers:**
  - physiological sensing (activity, step count, sleep duration and quality, heart rate, heart rate variability, blood pressure, etc)
  - E.g. Fitbit Charge 2
- **Smartwatches**
  - Some activity/fitness tracking
  - Also programmable: notifications, receive calls, interact/control smartphone
  - E.g. Apple watch, Samsung Gear

Fitbit Charge 2

Apple Watch

Samsung Gear 2 SmartWatch

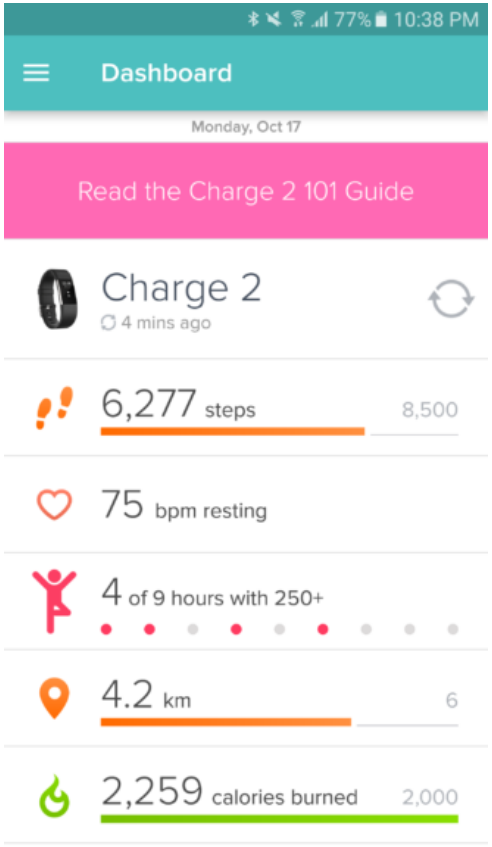
How Popular are Smartwatches/Wearables?



Wearables Example: Fitbit Charge 2

Fitbit Charge 2

synchronize

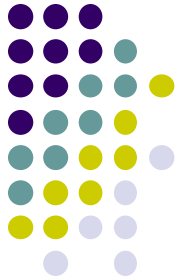


Smartphone companion app
(displays all variables tracked)

Example: Samsung Gear SmartWatch Uses

Image credits: Samsung

SmartPhone Vs Smartwatch



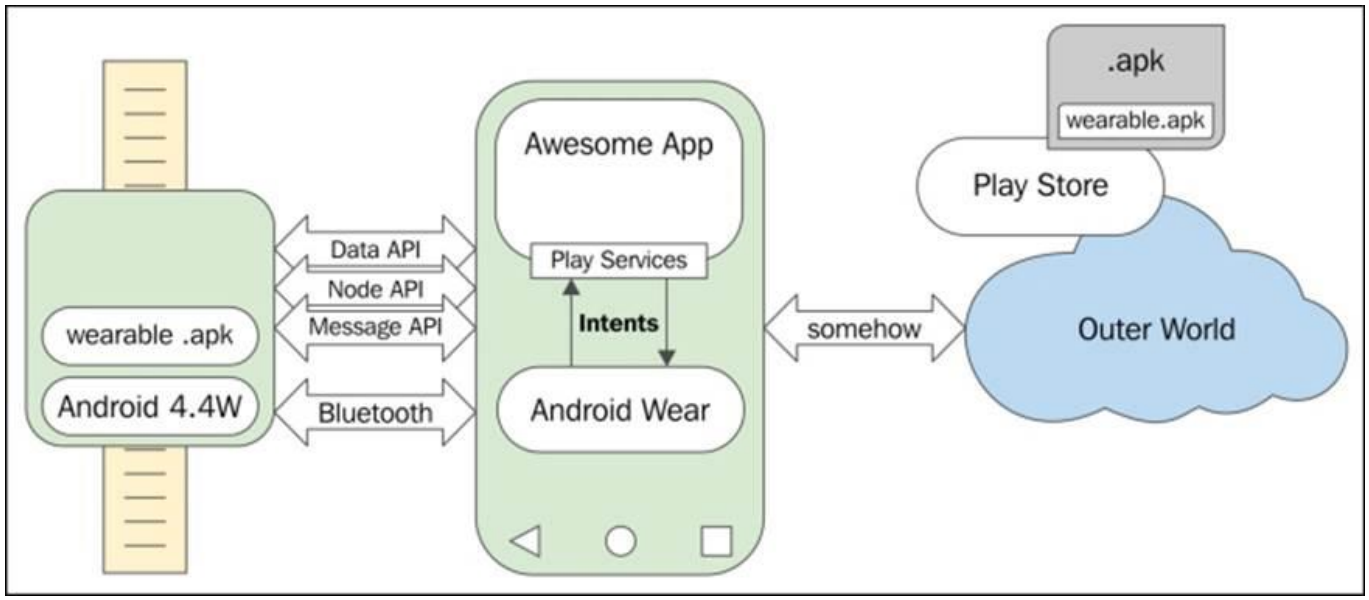
- Smartphone:
  - More processing power, memory, sensors
  - More programming APIs

- Smartphone Cons:
  - Sometimes not carried (Left on table, in pocket, bag, briefcase, gym locker)
    - Smartphone within arms reach, on person ~50% of the time (Anind Dey *et al*, Ubicomp 2011)
  - Why? Sometimes inconvenient, impossible (e.g when swimming)
  - Consequence: Missed activity (steps, activity, etc), incomplete activity picture

- Smartwatch:
  - Lower processing power, memory, sensors, but
  - Always carried/worn
  - Can sense physiological variables continuously, or require contact (e.g. skin temperature)

Programming Android Wearables

- Programmable using Android Wear (latest version is 2.0)
- Supported by Android Studio
- Needs to be connected to a smartphone (via Bluetooth)
- Architecture:
  - **Node API:** tracks all connected/disconnected nodes (E.g. wearables, smartwatches)
  - **Message API:** Used to send messages between wearable and smartphone
  - **Data API:** Used to synch data between app and smartwatch



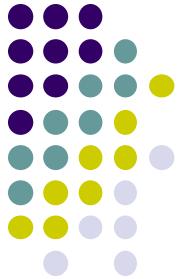
A bit outdated, but nice overview for Android Wear for kitkat Android 4.4W

Android Wear Evolution

https://en.wikipedia.org/wiki/Android_Wear

Android Wear Version	Android Smartphone Version	Release Date	Major New Features
4.4W1	4.4	June 2014	Initial release at Google I/O 2014
4.4W2	4.4	Oct 2014	GPS support, music playback
1.0	5.0.1	Dec 2014	Watch face API (face design) Sunlight & theater modes, battery stats
1.1	5.1.1	May 2015	WiFi, Drawable Emojis, Pattern Lock, swipe left, wrist gestures
1.3	5.1.1	Aug 2015	Interactive Watch Face, Google Translate
1.4	6.0.1	Feb 2016	Speaker support, send voice messages
1.5	6.0.1	June 2016	Restart watch, Android security patch
2.0	7.1.1	Feb 2017	UI (material design, circular faces), watch keyboard, handwriting recognition, cell supp.

Evolved into Google Wear OS in June 2018!!

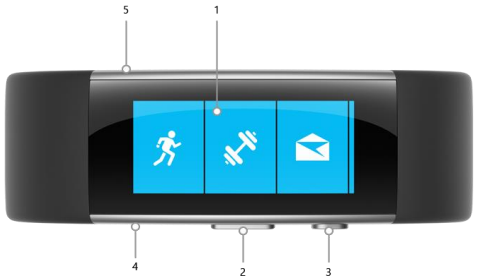


Physiological Sensing

Wearables for Physiological Sensing

- Some wearables measure more physiological signals
  - Cardiac rhythms (heartbeat), breathing, sweating, brain waves, gestures, muscular contractions, eye movements, etc
- Basis Health tracker: heart rate, skin temperature, sleep
- Microsoft Band 2: Heart rate, UltraViolet radiation, Skin conductance

Basis Health tracker



Microsoft Band 2

Empatica E4 WristBand

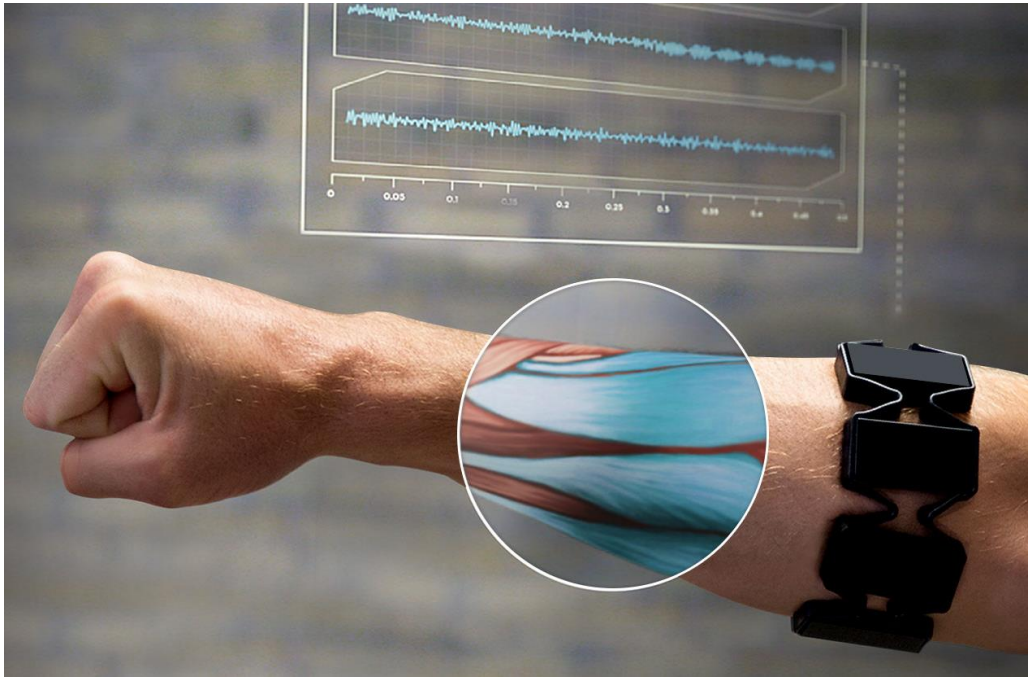
- Wristband measures physiological signals real time (PPG, EDA, accelerometer, infra-red temperature reader)

E4 wristband

Companion app

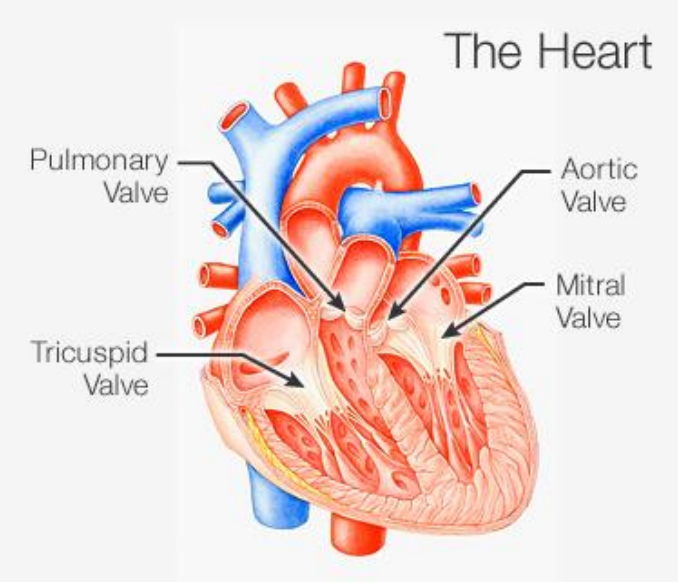
Myo Armband

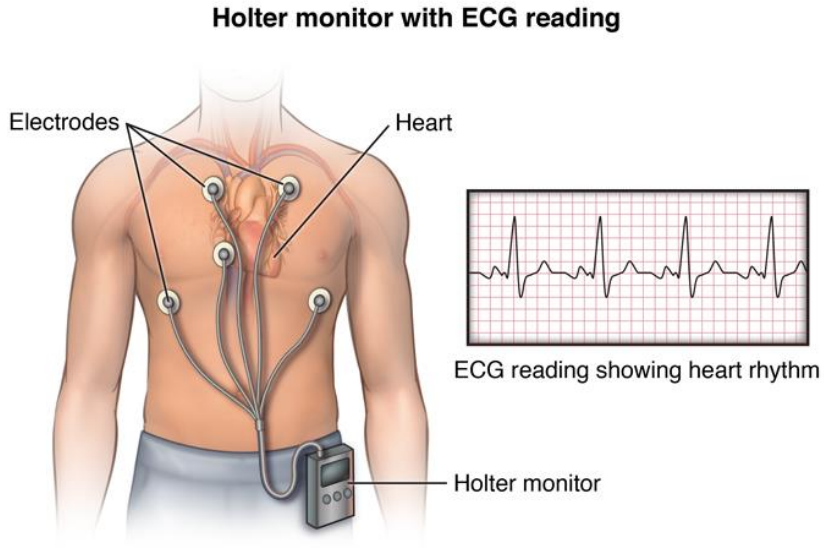
- Measures muscle contraction (electromyography or EMG), to detect gestures
- EMG measures electrical activity, used to assess health of muscles



Electrocardiogram (ECG)

- ECG (or EKG): recording of electrical activity of the heart
- Each heartbeat causes electrical signal to spread from top to bottom of heart
- Electric Signal
  - is rhythmic, causes heart to contract and pump blood
  - Can be measured electric activity between 2 electrodes placed on chest

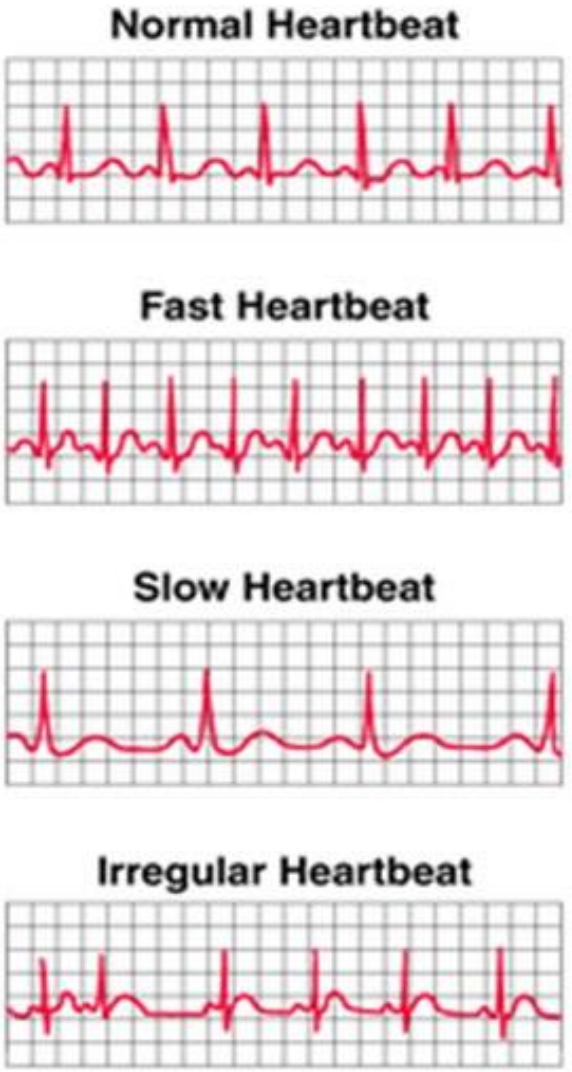




Electrocardiogram (ECG)

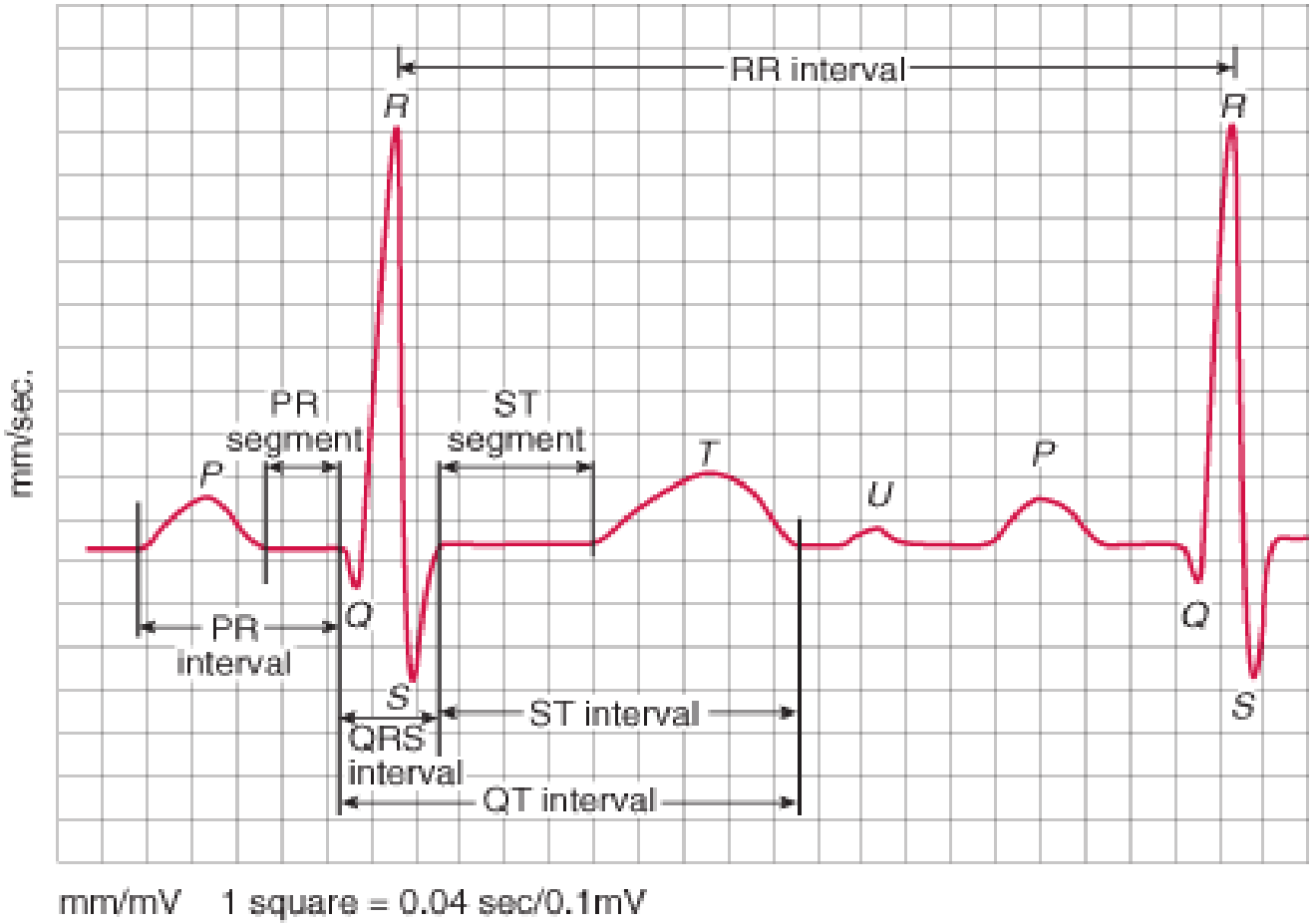
- ECG shows:
  - How fast the heart is beating
  - Rhythm of heartbeat (steady vs irregular)
  - Strength and timing of electrical signals

- **Arryhthmia:** fast or irregular heartbeat, can cause stroke or heart failure



Electrocardiogram (ECG)

- ECG waveform comprises sequence of peaks and trough (P,Q,R,S,T), which repeats
  - Occasionally a U wave after T

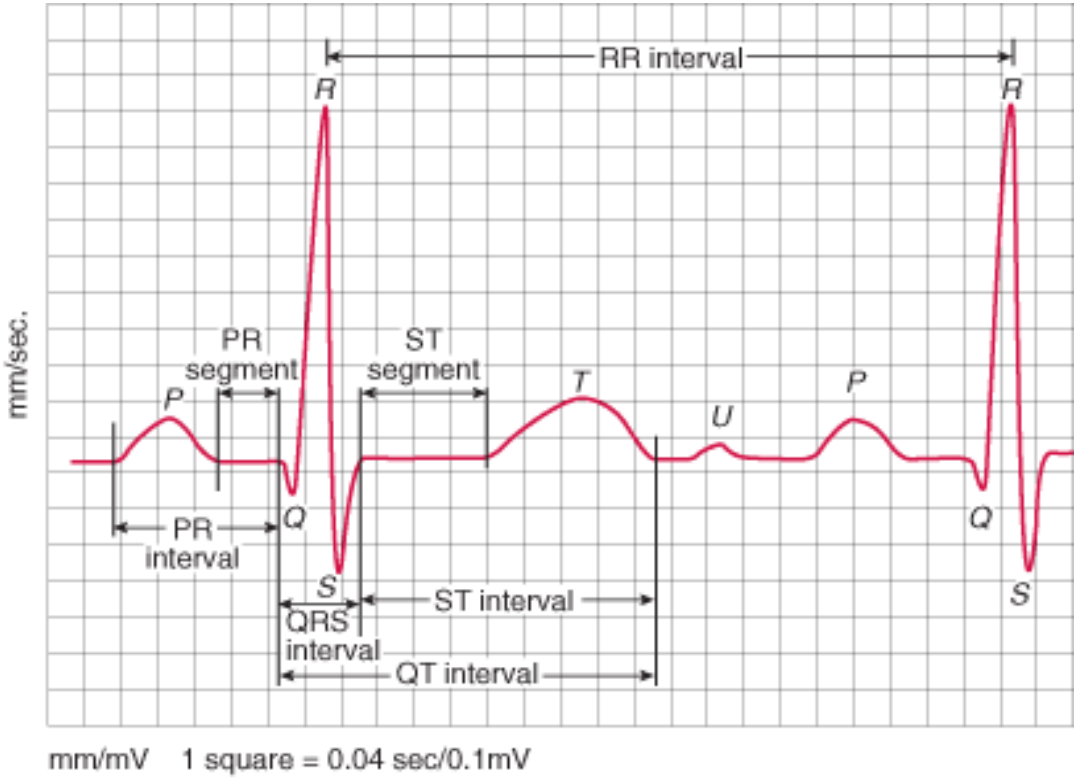


ECG Features for Classification

- From a waveform with at least 5 peaks, can extract as features for classification, the following timing intervals
  - RR interval
  - PR interval
  - QRS interval
  - QT interval, etc

- Heartrate is number of RR intervals/min = 60 / RR

- Note: RR is in seconds



Trends: Mobile ECG

- E.g. AliveCor kardia ECG
  - Hold 2 fingers on metal plates (ECG recorder) for at least 30 seconds

Photoplethysmography (PPG)

- **PPG:** Non-invasive technique for measuring blood volumes in blood vessels close to skin
- Now popular non-invasive method of extracting physiological measurements e.g. heart rate or oxygen saturation
- Traditional device for PPG is pulse oximeter
  - Measures concentration of oxygen in the blood
  - Low oxygen levels (< 80%) can compromise organs, lead to heart attack , etc

Pulse Oximeter

Pulse Oximeter PPG

- Amount of oxygen in the blood determines how much infared light absorbed, scattered, passes through (from LED to photodiode)

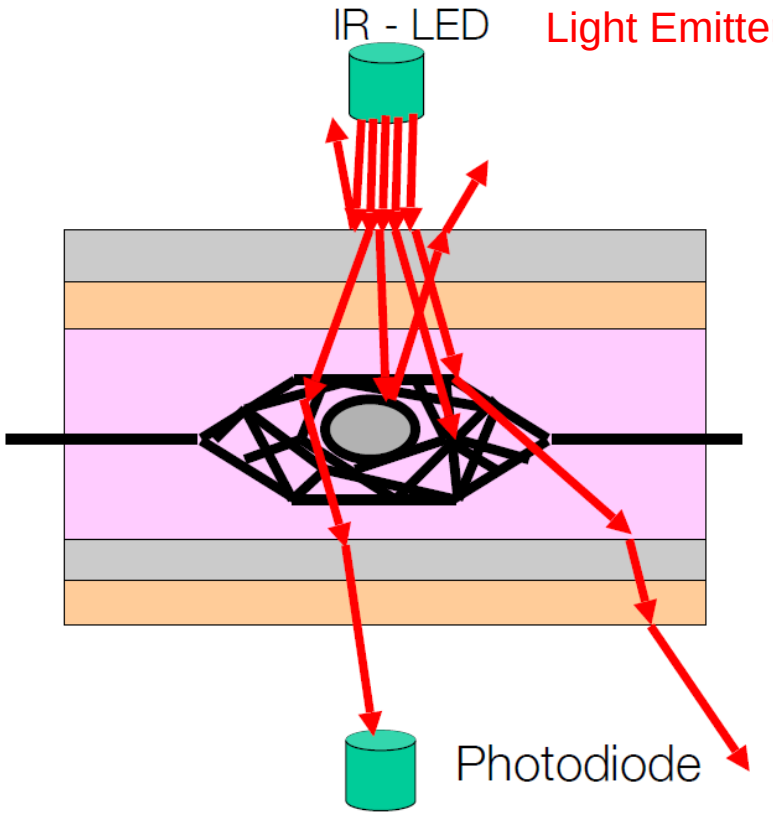
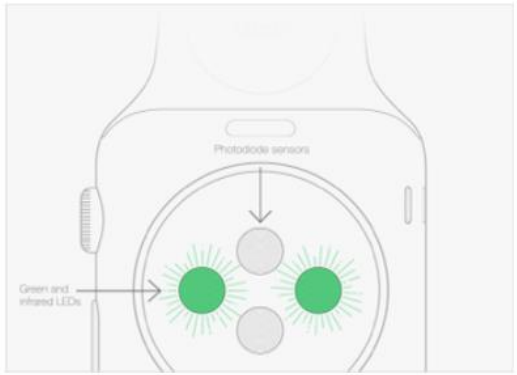
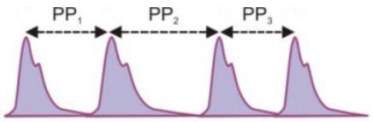


Image credit: Deepak Ganesan

Smartphone/Smartwatch PPG: Estimating HR

- **Principle:**
  - Blood absorbs green light
  - LED shines green light unto skin (back of wrist)
  - Blood pumping changes blood flow and hence absorption rhythmically
  - Photodiode measures rhythmic changes in green light absorption => HR





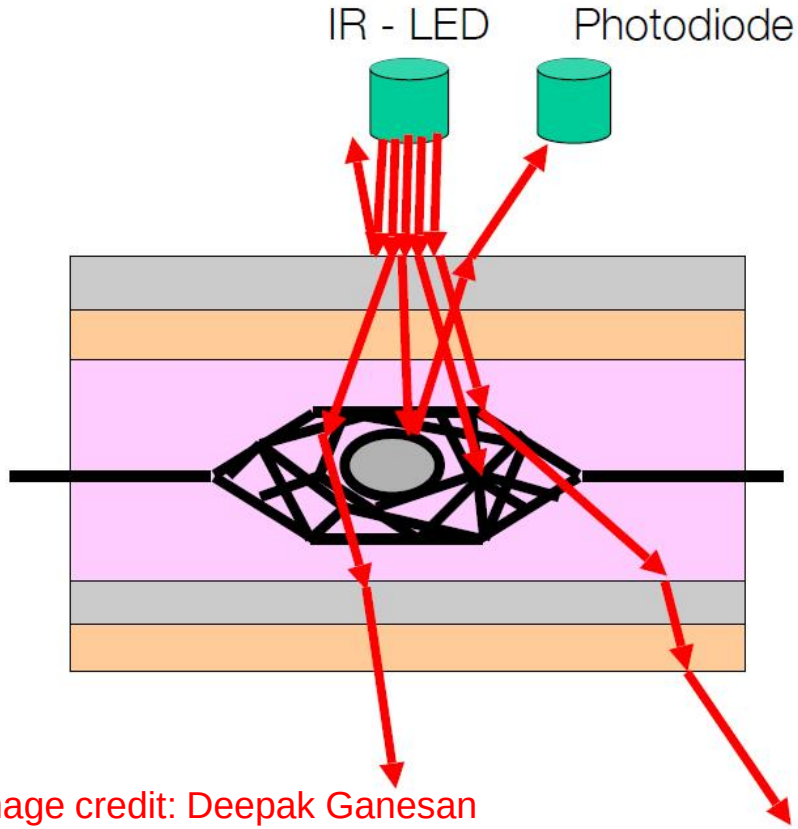


Image credit: Deepak Ganesan

Smartphone PPG: Heart Rate Detection

- Like smartwatch, use camera flash (emitter), camera as detector
- Place finger over smartphone's camera, shine light unto finger tip
- Heart pumps blood in and out of blood vessels on finger tip
  - Changes how much light is absorbed (especially green channel in RGB)
  - Causes rhythmic changes of reflected light
- **Ref:** Scully CG, Lee J et al."Physiological parameter monitoring from optical recordings with a mobile phone", IEEE Trans Biomed Eng, 2012 Feb;59(2):303-6

Smartphone PPG: Heart Rate Detection

- **Idea:**
  - Color expressed as (R G B)
  - Track intensity of Green channel of Camera response
  - Use peak finding algorithm (similar to step counter)
  - Time between peak is 1 cycle
  - Heart rate = cycles per minute = 60 / time for 1 cycles
- Can also extract breathing rate, heart rate variability

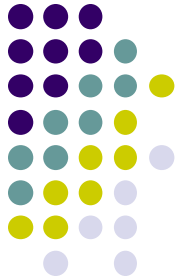
PPG: Final Words

- PPG (or similar ideas) have been attempted:
  - on other body parts (ear lobes, face)
  - from video frames (detect, magnify small changes in facial color 100x)
  - Using other ubiquitous devices (e.g. Medical Mirror, Poh *et al*)

H.Y Wu, M. Rubinstein, E. Shih, J. Guttag, F. Durand, W.T. Freeman, Eulerian Video Magnification for Revealing Subtle Changes in the World. SIGGRAPH 2012

MZ **Poh**, D McDuff, R Picard A medical **mirror** for non-contact health monitoring, ACM SIGGRAPH 2011 Emergin

Electrodermal Activity (EDA)



- When people experience emotional arousal (e.g. danger), stress, cognitive load or physical exertion => increased sweating
- Increased sweating changes electrical conductance of skin
- Sometimes called Galvanic Skin Response (GSR)
- This response cannot be controlled by person
  - Hence, widely used in emotion/lie detection

EDA Features

- Features useful for classifying measured human EDA response
  - **Latency:** time between stimulus and response
  - **Rise time:** time for skin conductance to peak
  - **Amplitude:** Height of conductance signal
  - **Half recovery time:** Time for conductance signal to lose half of its peak value

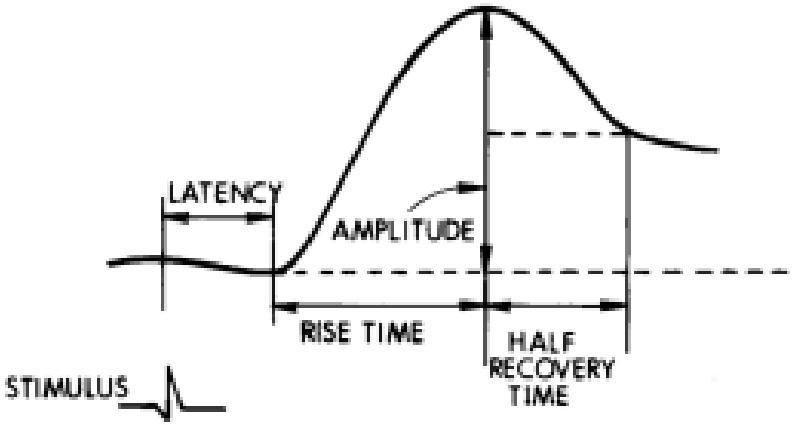


Figure 5. Graphical representation of principal EDA components.

References

- Deepak Ganesan, Behavioral Health Sensing, Course Notes Fall 2015
- Melania Swan, The Quantified Self: Fundamental Disruption in Big Data Science and Biological Discovery,
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- NY Times, The Data-Driven Life
- The Ultimate Guide to The Quantified Self

  http://www.slideshare.net/ramykhuffash/the-ultimate-quide-to-the-quantified-self