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)
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
  - Mymee.com
    - (data-driven coaching)

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

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

Actigraphy:
- Activity and energy levels

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

Indoor air quality

Weight

Sleep logging

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

Quantified Self
ICAN-QU Visualization Dashboard

Figure 1. The visualization dashboard for actigraphy data and biometrics analysis.
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
How Popular are Smartwatches/Wearables?

Global Wearables Shipment Forecast, By Device

*Millions*

- Rest Of Wearables Market
- Fitness Bands And Other Activity Trackers
- Smartwatches

Source: IDC, BI Intelligence estimates
Wearables Example: Fitbit Charge 2

Fitbit Charge 2

Smartphone companion app (displays all variables tracked)

synchronize
Example: Samsung Gear SmartWatch Uses
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

Evolved into Google Wear OS in June 2018!!

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

<table>
<thead>
<tr>
<th>Wear OS version</th>
<th>System versions</th>
<th>Release date</th>
<th>New features</th>
<th>Notes</th>
</tr>
</thead>
</table>
| 1.0             | Android 8 Oreo  | March 2016   | • Rebranding to Wear OS[^2]  
• Expand Google Pay Support in more countries | Version number reset to “1.0”  
Wear OS App version: 2.10[^3] |
| 1.4             | Android 8 Oreo  | July 2018    | • Faster Google Pay startup  
• More glanceable design for events and appointments  
| 2.0             | Android 8 Oreo  | September 2018 | • Swipe actions for faster access to Google Assistant and Google Fi[^6]  
• Google Assistant feed with proactive personalized information  
• New design for quick toggles and notifications stream  
• New music controls with physical button support  
• Bolder font in the app launcher | Wear OS App version: 2.18 |
| 2.2             | Android 9 HMR1 | November 2018 | New features for System version HMR1:  
• Brings Android 9.0 Pie features to smartwatches  
• Enables Battery Saver mode to only display the time once the battery falls below 10%  
• Improves restoring the state of previously used apps  
• Watches now enter a deep sleep mode after 30 minutes of inactivity  
• Holding down the power button now provides options for shutting down or restarting the watch | Wear OS App version: 2.20 |
| 2.6             | Android 9 HMR1 | May 2019     | • Tiles functionality when swiping left, providing access to next calendar events, weather forecast, heart rate, news headlines and timer functionality[^7] | Wear OS App version: 2.24 |
| 2.7             | Android 9 HMR1 | June 2019    | • Bugfixes | Wear OS App version: 2.25 |
| 2.9             | Android 9 HMR1 | July 2019    | • Notifications | Wear OS App version: 2.26 |
| 2.17            | Android 9 HMR1 | April 2020   | • New ‘Wash hands’ timer regarding coronavirus  
• New UI and Tiles for Google Fit | Wear OS App Version: 2.35 |
| 2.19            | Android 9 HMR2 | September 2020 | Changes in System HMR2[^8]:  
• CPU core improvements: app launch and boot time up to 20% faster  
• Stylish improvements: more intuitive controls for managing different watch modes and workouts  
• Improved performance with the Qualcomm Snapdragon Wear 4100 and 4100+ platforms  
• Improved LTE support  
• Simplified pairing process  
• Better battery life  
• Support for an increased number of Tiles  
• New Weather Tile design  
• Upcoming changes to Music | Wear OS App version: 2.40 |

**Upcoming**  
| Android 11 | 2021 | Brings Android 11 features to smartwatches | Wear OS App version: |
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
Empatica E4 WristBand

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

- Arrhythemia: 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

- Heart rate 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 PPG

- Amount of oxygen in the blood determines how much infrared 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
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)


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.
Differentiating Productive Workers
Differentiating Higher and Lower Job Performers in the Workplace Using Mobile Sensing
Mirjafari et al, IMWUT Journal 2019

- Workplace performance uses subjective evaluations which are manual, burdensome and potentially biased
  - E.g. peer ratings, supervisor ratings and self assessments
- Paper’s goal: User smartphone sensor and wearable data to create an objective method to separate higher and lower workplace performers
  - Discover distinguishing behavioral patterns, in different types of companies
- Can provide objective criteria for promotions, firing?
- 1 year study of N=554 IT workers in mid-sized company, consultancy, Android and iOS
- Participated in study for between 2-8.5 months
Devices/Data Gathered

- **Smartphone data gathering app:**
  - Physical activity, location, phone usage (e.g., lock/unlock) and ambient light levels.

- **Garmin Vivosmart wearable**
  - Heart rate, heart rate variability and stress, sleep quality and duration, light sleep, deep sleep, REM sleep and entire sleep time duration

- **Gimbal Beacons**
  - Workers presence in office
Features Extracted

- Subjects answered job performance (ITP, IRB, OCB, CWB) and health questionnaires (e.g., heart rate, sleep) at beginning, end of study at 3 times a week
- **Features extracted**: mobility, activity, phone usage, physiological signals and movement within the workplace features
## Job Performance Questionnaires

<table>
<thead>
<tr>
<th>Survey</th>
<th>Items</th>
<th>Answer Choices</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITP</td>
<td>Please indicate how often you carried out these three behaviors today</td>
<td>Response scale:</td>
</tr>
<tr>
<td></td>
<td>1. Carried out the core parts of your job well</td>
<td>1 (Very little)</td>
</tr>
<tr>
<td></td>
<td>2. Completed your core tasks well using the standard procedures</td>
<td>2 (Somewhat)</td>
</tr>
<tr>
<td></td>
<td>3. Ensured your tasks were completed properly</td>
<td>3 (Moderately)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 (Considerably)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 (A great deal)</td>
</tr>
<tr>
<td>IRB</td>
<td>Please indicate your level of agreement with whether you...</td>
<td>Response scale:</td>
</tr>
<tr>
<td></td>
<td>1. Adequately completed your assigned duties</td>
<td>1 (Strongly disagree)</td>
</tr>
<tr>
<td></td>
<td>2. Fulfilled responsibilities specified in your job description</td>
<td>2 (Moderately disagree)</td>
</tr>
<tr>
<td></td>
<td>3. Performed tasks that are expected of you</td>
<td>3 (Slightly disagree)</td>
</tr>
<tr>
<td></td>
<td>4. Met formal performance requirements of your job</td>
<td>4 (Neutral)</td>
</tr>
<tr>
<td></td>
<td>5. Engaged in activities that will directly affect your performance</td>
<td>5 (Slightly agree)</td>
</tr>
<tr>
<td></td>
<td>evaluation</td>
<td>6 (Moderately agree)</td>
</tr>
<tr>
<td></td>
<td>6. Neglected aspects of the job you are obligated to perform</td>
<td>7 (Strongly agree)</td>
</tr>
<tr>
<td></td>
<td>7. Failed to perform essential duties</td>
<td></td>
</tr>
<tr>
<td>OCB</td>
<td>Today, I...</td>
<td>Response scale:</td>
</tr>
<tr>
<td></td>
<td>1. Went out of my way to be a good employee</td>
<td>Yes/No</td>
</tr>
<tr>
<td></td>
<td>2. Was respectful of other people’s needs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Displayed loyalty to my organization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Praised or encouraged someone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Volunteered to do something that was not required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. Showed genuine concern for others</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. Tried to uphold the values of my organization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8. Tried to be considerate to others</td>
<td></td>
</tr>
<tr>
<td>CWB</td>
<td>Today, I...</td>
<td>Response scale:</td>
</tr>
<tr>
<td></td>
<td>1. Spent time on tasks unrelated to work</td>
<td>Yes/No</td>
</tr>
<tr>
<td></td>
<td>2. Gossiped about people at my organization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Did not work to the best of my ability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Said or did something that was unpleasant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Did not fully comply with a supervisor’s instructions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. Behaved in an unfriendly manner</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. Spoke poorly about my organization to others</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8. Talked badly about people behind their backs</td>
<td></td>
</tr>
</tbody>
</table>
References

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- The Ultimate Guide to The Quantified Self
  http://www.slideshare.net/ramykhuffash/the-ultimate-guide-to-the-quantified-self