MOOC 2: Sensing the Human

Overview

- In MOOC-1 we looked at the human brain and human memory and how it works, and often doesn't, and how we use search and information seeking to support our memory function.
- In MOOC-2 we'll look at technologies for sensing the human body and where it is and what its doing, and applications which use such sensing
- This covers sensing location, sensing the body's activities, sensing our physiology with a particular focus on sleep applications, and finishing with sensing activity in the brain

Why Know About User Context ?

- There are many reasons for wanting to sense the human body and where it is and what its doing … health is an obvious one
- There's also information-finding, when we search for information it is usually about documents and pages, and user query & matching but knowing what we're doing and/or where we are when we're seeking information will help improve the systems we use
- But we don't know **why** the user is searching, or what they are doing while searching, or what their emotional or other state is, why they need to find information or what the effect of the information finding will be, so search is stateless, it doesn't have context;
- What kinds of contexts about a user can we capture and how could we fold these into information access ?

Kinds of Context

- There is no universally agreed classification of "user context", just an arbitrary one, different kinds of user context that can be captured.
- I divide it into 4 areas as follows
  - Location – where you are on planet earth
  - Human Activity – what you are doing, now
  - Your body – what signals are your body giving about its state
  - Brain Computer Interfaces

Week 1: Sensing Location

- Week 1: Sensing Actual Location
- GPS how it works, in smartphones, computers, watches, cars, etc.
- A review of some Location Based Services (LBS) that use actual location
- Strava and MapMyRun for the individual
- Google and Apple tracking … iPhone locations … to illustrate ethical and data privacy issues.

Location Tracking - GPS

- GPS is a system of c.20 satellites in geostationary orbit around the early, at 20,000km altitude.
- Each emits a different radio frequency signal
- On earth, a GPS receiver (phone, watch, satnav, etc.) picks up signals from a number of satellites with direct line of sight, the signal includes the time taken for the signal to reach the receiver
- Using simple triangulation, the receiver's location is determined
- This works all over the planet but not underground, indoors or in natural or man-made canyons (cities)

Location Tracking – Cellular masts

- GPS is based on satellites but its not the only location identifier
- Phones collect cellular network signals including signal strength, from masts which have fixed, known locations so phones also use cellular data to determine location
- These work indoor but depend on a dense array of phone coverage masts, so not great in rural areas, for example, or where there's just one mast for contact

Location tracking - WiFi

- Some companies have mapped the availability of WiFi networks in urban areas – a form of extreme Wardriving
- They pick up availability of public and private WiFis, not to log in, just to record that they are there
- A WiFi-enabled device will "see" a number of available WiFi networks, including signal strength (a proxy for distance) and use this to triangulate location

Determining Location

- Using any of GPS, cellular networks and WiFi networks, or more likely a combination of all three, a smartphone can determine location to within a couple of meters, outdoor or indoor
- This used to be computationally expensive but now smartphones have dedicated chips to do this, so it effectively costs almost nothing.

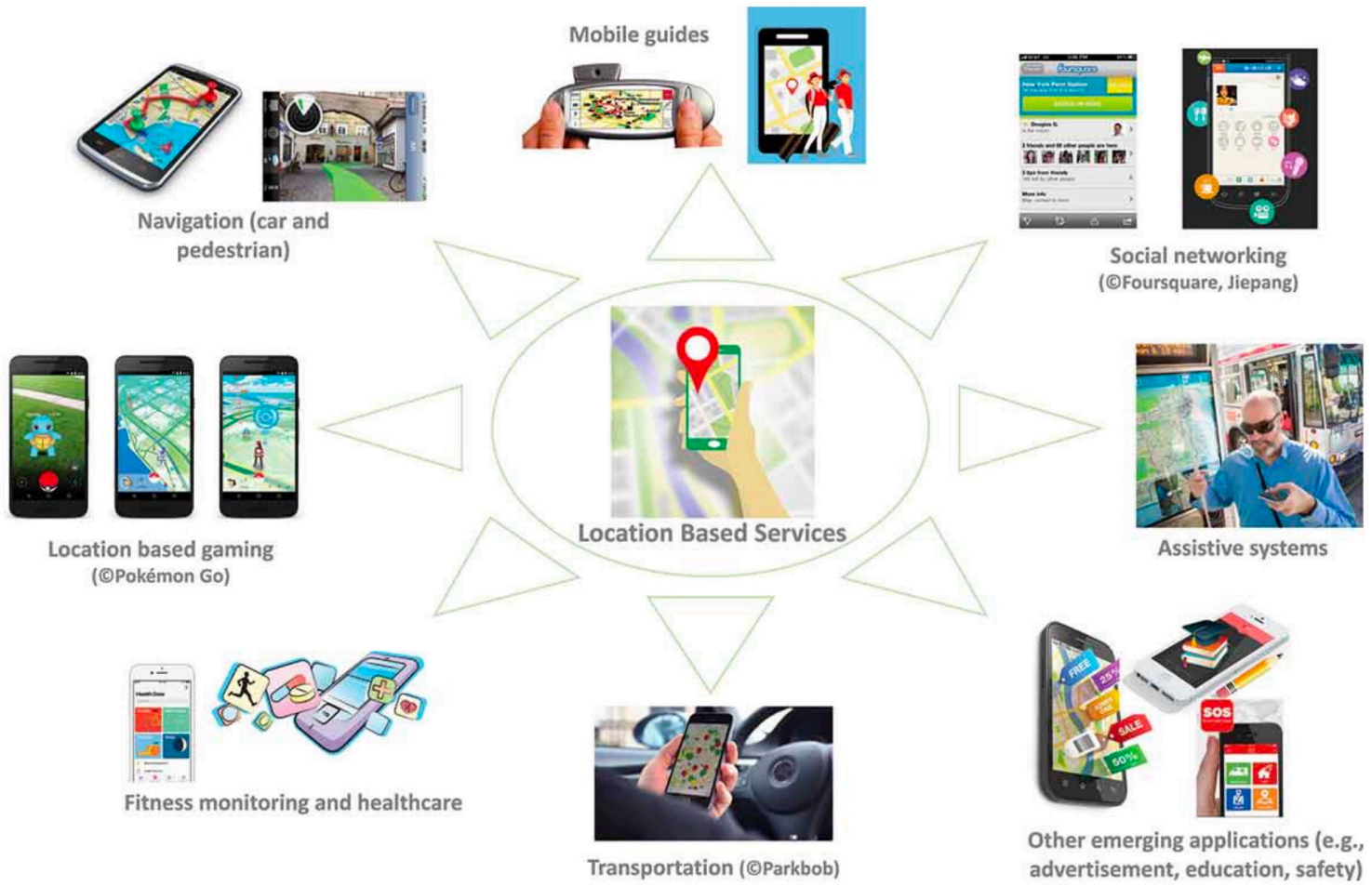
Using Location on Smartphones

- There are many services which use smartphone location which we take for granted
  - Google and Apple maps for directions from your location
  - Personalised services like searching for nearest pizza restaurant
  - Pinning the location of your tent at a music festival
  - Sharing your location on WhatsApp so friends can meet or on Free Now or Uber so driver can find you
  - … can you think of more ?

Using Location on Smartphones

- Location Based Services (LBS) using actual location are pretty much complete, they are reliable, they work, they bring us advantage, its hard to think of ways to improve them
- They first appeared in early 1990s with standalone GPS devices coupled to phones
- LBS initially were outdoor and then through 2000s moved indoors into shopping malls, museums, airports, many other indoor environments
- In May 2000 President Clinton passed a law to make high quality GPS available to everyone, not just military
- As evidence of how well they work, what would the world be like if they were taken away … no satnav, no Uber, no Free Now taxis, no location-awareness on phones … no thanks !
- Lets look at some LBS applications

Types of LBS



Haosheng Huang, Georg Gartner, Jukka M. Krisp, Martin Raubal & Nico Van de Weghe (2018) Location based services: ongoing evolution and research agenda, Journal of Location Based Services, 12:2, 63-93, DOI: 10.1080/17489725.2018.1508763

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Mobile Guides

- Mobile Guides are like tourist route guides, downloadable apps on smartphones
- Similar to travel guides but being location-based they can personalize messages .. You are only 100m from an interesting exhibit or tourist spot
- Because the know the location of the user they are great opportunities for tourist advertising … “eat at our restaurant”, or “visit our museum”

Haosheng Huang, Georg Gartner, Jukka M. Krisp, Martin Raubal & Nico Van de Weghe (2018) Location based services: ongoing evolution and research agenda, Journal of Location Based Services, 12:2, 63-93, DOI: 10.1080/17489725.2018.1508763

Location-Based Social Networking

- FourSquare used to have 50M users but not as popular now
- Users used to "check in" to locations and rate them and accumulate points the more they travelled
- Based on which of your friends checked into where, and their ratings, a user is recommended places to go nearby
- Not as popular now because Facebook does location check-ins and people are now more wary of tracking of users' locations, and Foursquare is openly tracking

Haosheng Huang, Georg Gartner, Jukka M. Krisp, Martin Raubal & Nico Van de Weghe (2018) Location based services: ongoing evolution and research agenda, Journal of Location Based Services, 12:2, 63-93, DOI: 10.1080/17489725.2018.1508763

Assistive Systems

- Assistive LBS is more than navigation for the elderly, it supports older adults with memory loss or dementia and their caregivers during getting lost events
- Sometimes used by defining physical areas where normal activities take place like the route to the shops or to friends (called geofencing) and when deviating from geofenced areas it triggers a “potentially getting lost” event

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Location based services: ongoing evolution and research agenda, Journal of Loc ervices,
12:2, 63-93, DOI: 10.1080/17489725.2018.1508763

DCU

Other Apps

- An open-ended catch-all category
  - LBS safety is lone workers carrying trackers
  - Advertising is in-taxi screens showing adverts for local restaurants based on taxi location, or Google search results on smartphone filtered for location
  - Education is Loop on mobiles, tailoring content depending on whether you're on-campus or not

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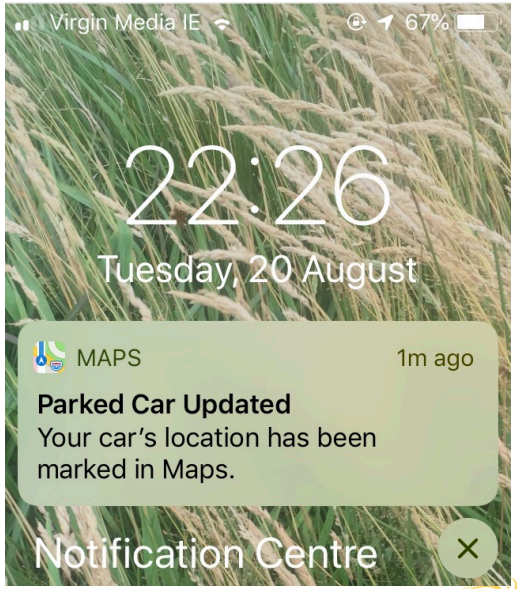
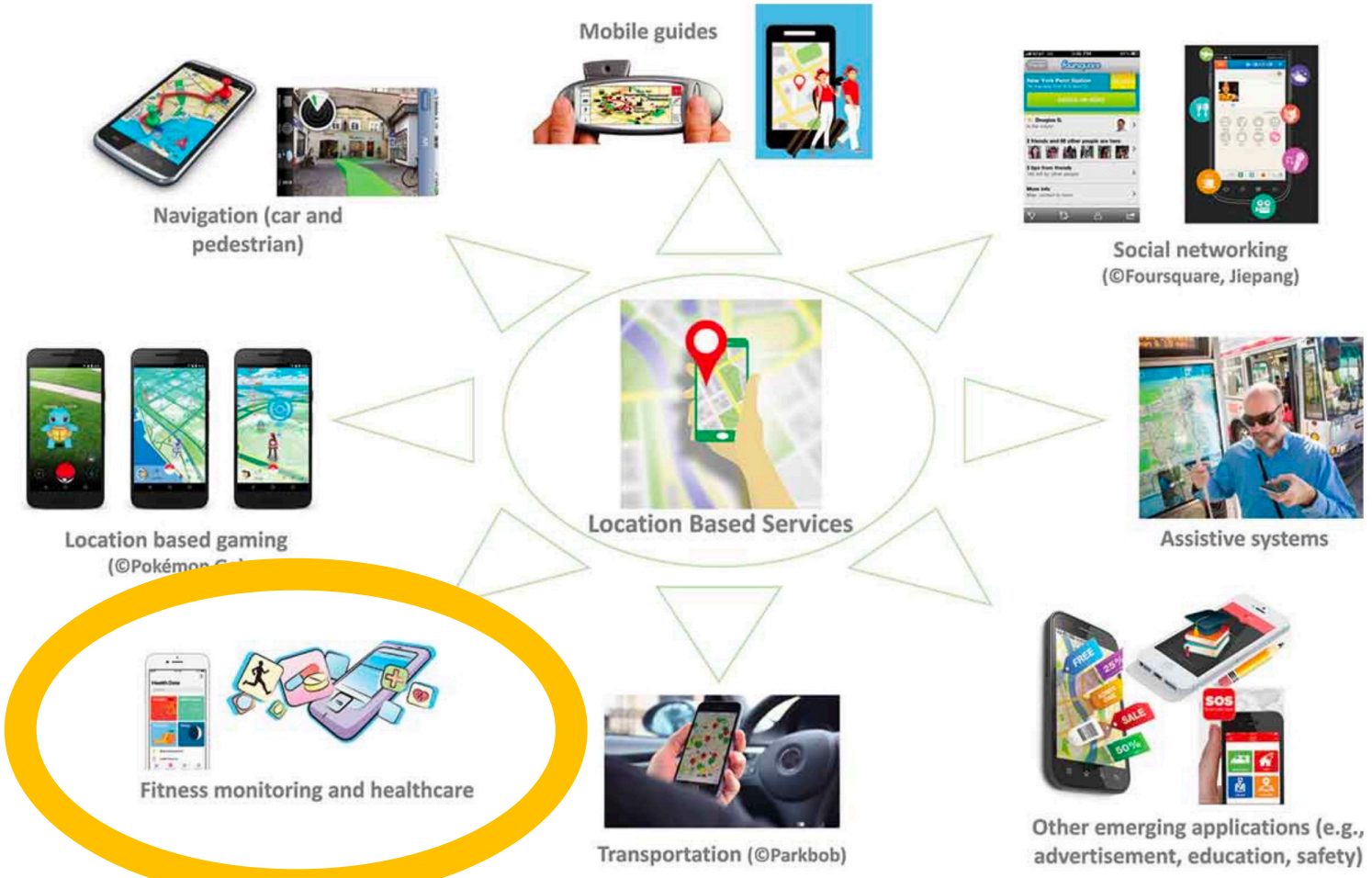
LBS in Transport

- This one is easy …
  - "Free Now" or Uber .. You track the taxi, the taxi tracks you
  - Parking … nearest available spots, or where you parked your car (Google Maps)
  - Bus or train arrival times, on-screen bus locations
  - Estimated arrival times on navigation apps based on where you are, and where everybody else is, namely causing traffic jams





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LBS Fitness Monitoring

- Strava a service for running/cycling that uses a smartphone or watch to record runs or bike rides
- It logs (GPS) location and from that it gives time, pace, elevation gain and profile, power output (bike), calories, map .. all very useful and interesting for each individual
- MapMyRun, several others exist

Alan Smeaton – Ride

6 0

5:31 PM on Sunday, July 28, 2019

Lighthouse climb x3

Add a description

21.30 km	1:22:55	524 m
Distance (?)	Moving Time	Elevation

124 W	615 kJ
Estimated Avg Power	Energy Output

With someone who didn't record? Add Friends

STRAVA LABS
View Flybys ›

	Avg	Max
Speed	15.4km/h	62.6km/h
Calories	686	
Elapsed Time	1:25:55	

Show Less

Strava iPhone App

Bike: Endurance Bike

TOP RESULTS

View all

- **PR** on Valentia Island Return from Lighthouse (7:52)
- **2nd fastest time** on Valentia Island Return from Lighthouse (7:53)
- **2nd fastest time** on Feaghmaan Climb - Valencia - Steep Part (6:38)

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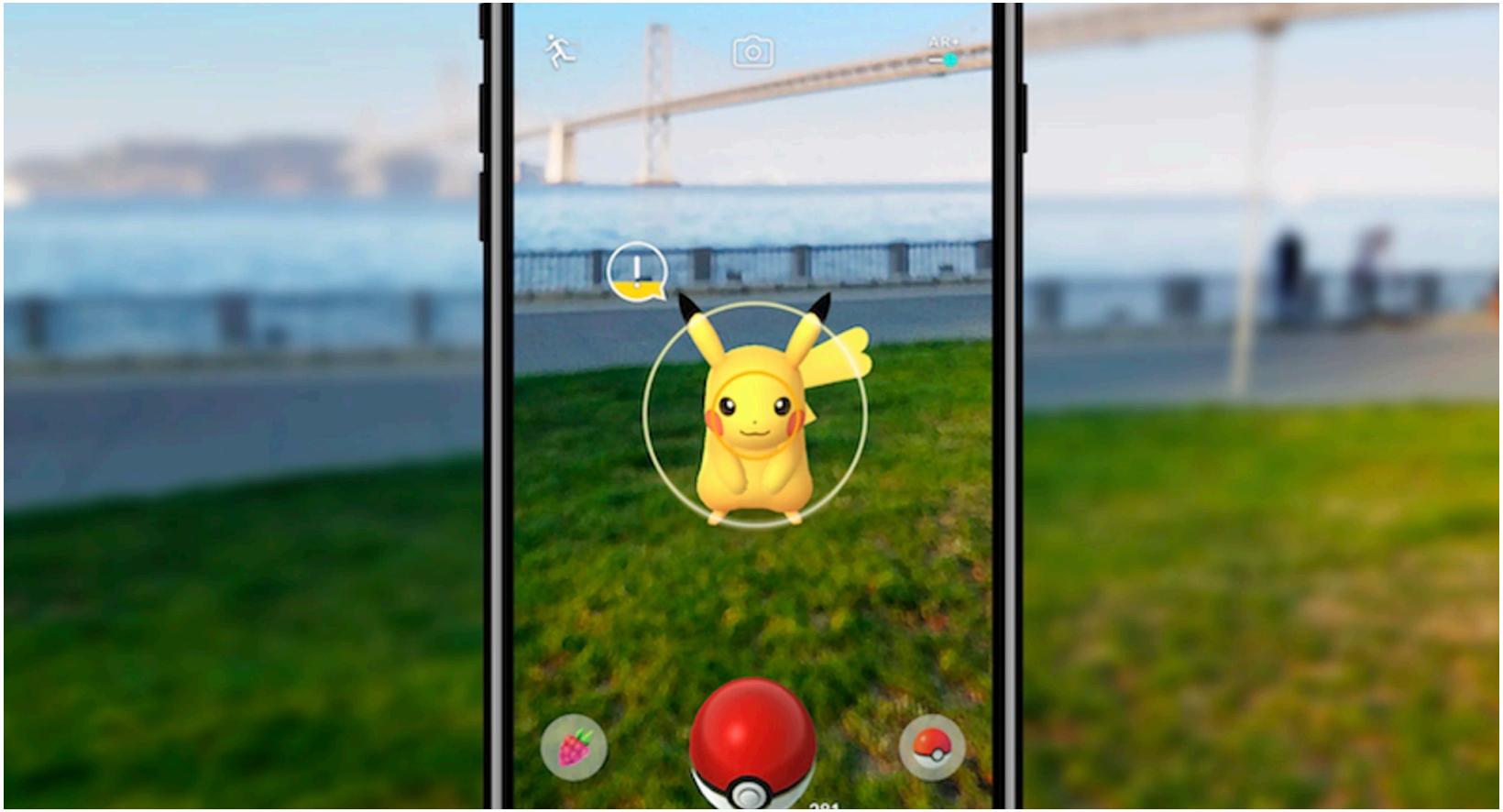
LBS games – Pokémon Go

- Released in 2016, Pokémon Go is an augmented reality mobile game for smartphones
- If you've played it, you'll know it; if you haven't then it will seem weird !
- Basically your cameraphone screen is augmented with cartoon characters that you have to "catch" and the characters exist at precise (GPS) locations so you have to go to those locations to find them
- If these are rare characters in the game, then many players will gather there, with smartphones and battery packs because their phone batteries run out ;-)

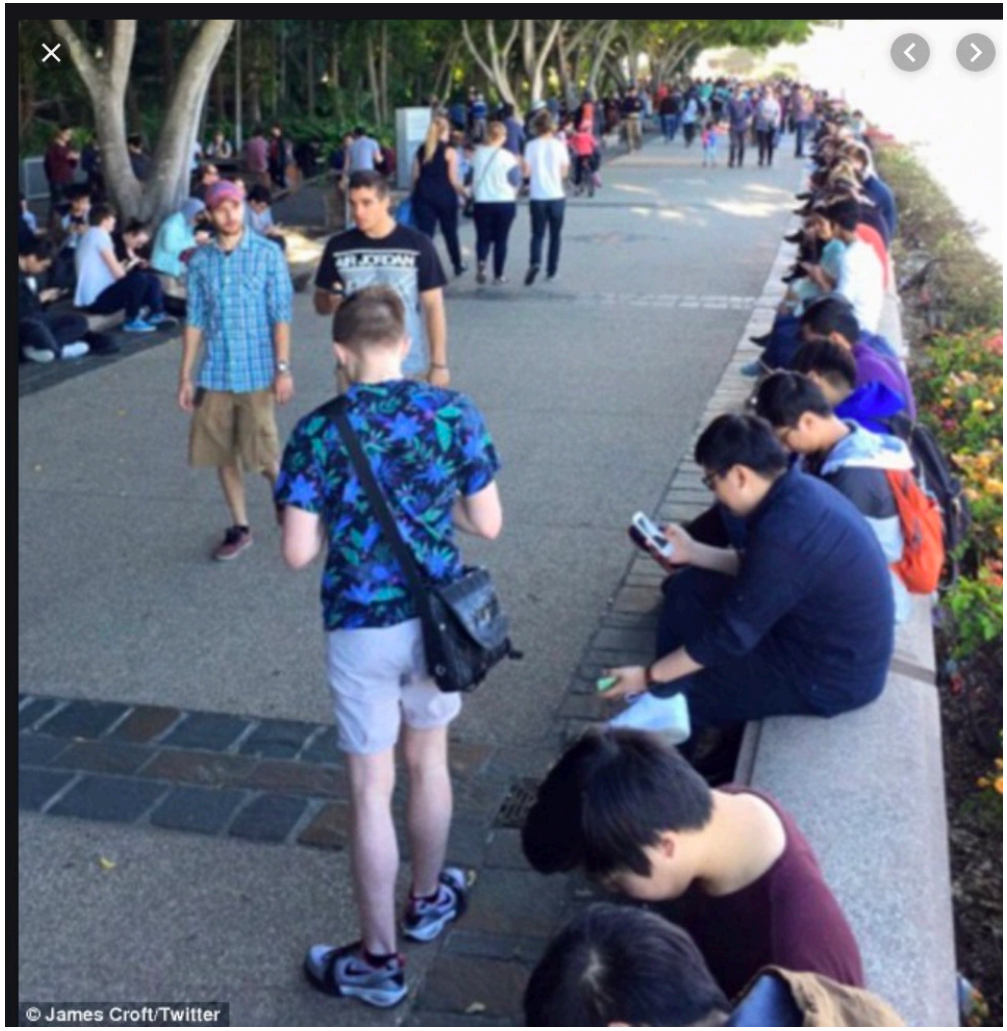
Pokémon Go



Pokémon Go

Pokémon Go players swarm a housing development in Rhodes, Sydney. | Vincent Chu (Facebook)

Pokémon Go



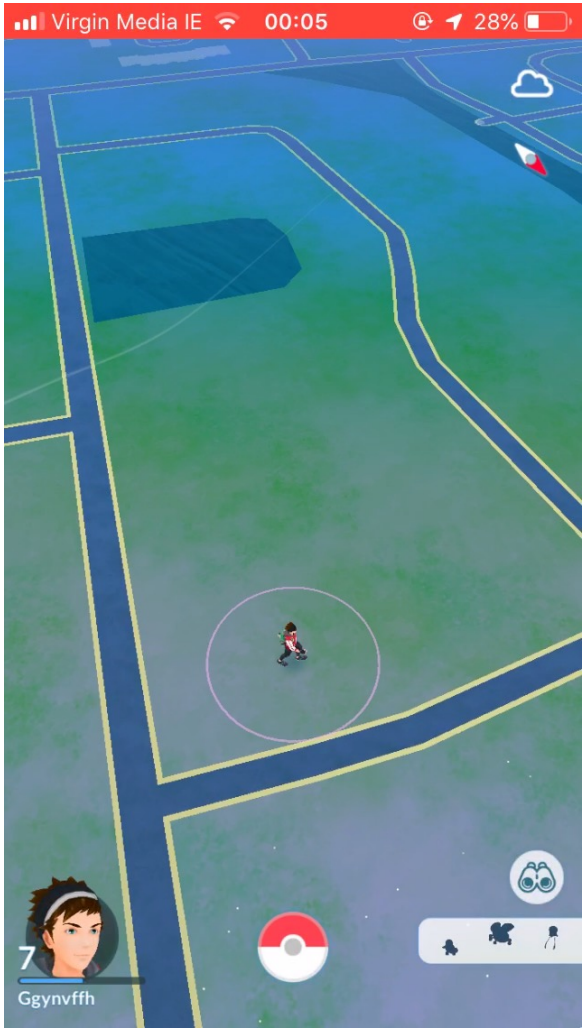
Pokémon Go

People play Pokémon GO at a park in Tin Shui Wai on July 26, 2016 in Hong Kong.

Lam Yik Fei/Getty Images AsiaPac/Getty Images

Pokémon Go

- Here's a videograb of me plating Pokémon Go, at home, the blue lines are roads, houses are not marked.
- There are no Pokémons around so I'd have to move somewhere to find them or wait until they pop up (see how it promotes exercise by making me move elsewhere ;-)



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LBS Navigation

- Navigation was the first LBS service, for satnav or for games
- Aimed at mobile navigation and guiding
- This is Google Maps on your smartphone
- Used for navigation (pedestrian and vehicular)
- Has in-built personalised advertising

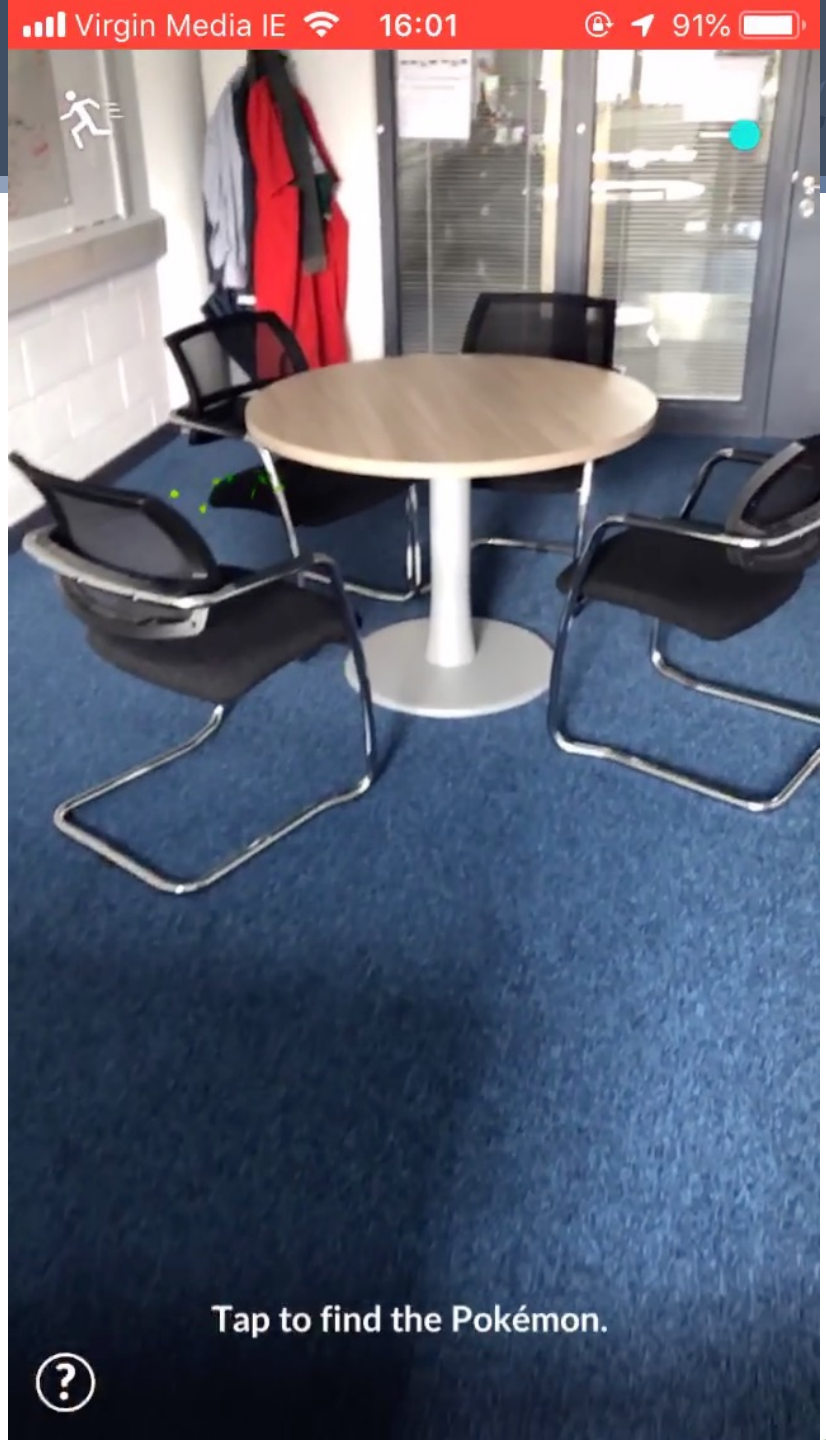
Augmented Reality

- One of the very attractive types of technology on smartphones which use location, camera and screen is augmented reality (AR)
- Virtual Reality (VR) is not the same, its immersive, you wear a headset which controls all that you see, and you believe you move into a different world
- In the picture here, I'm making pottery on a spinning wheel, or so I believe
- VR platforms include Microsoft HoloLens or Oculus Rift (which is Facebook's)

Augmented Reality

- AR is different, its a form of interaction which exploits location-as-context using location and compass
- Typically it uses the smartphone's camera and augments the screen with additional information, super-imposing something onto reality
- Pokémon Go is AR .. Lets see an example …

- Video shows Alan’s office and as I move around some green bushes appear, then an actual Pokémon (it’s a wild Numen, if you didn’t recognize it) which I then catch and score points
- Notice this is live video capture, from the camera onto the screen, with reality being augmented with bushes appearing on my desk and then a Pokémon

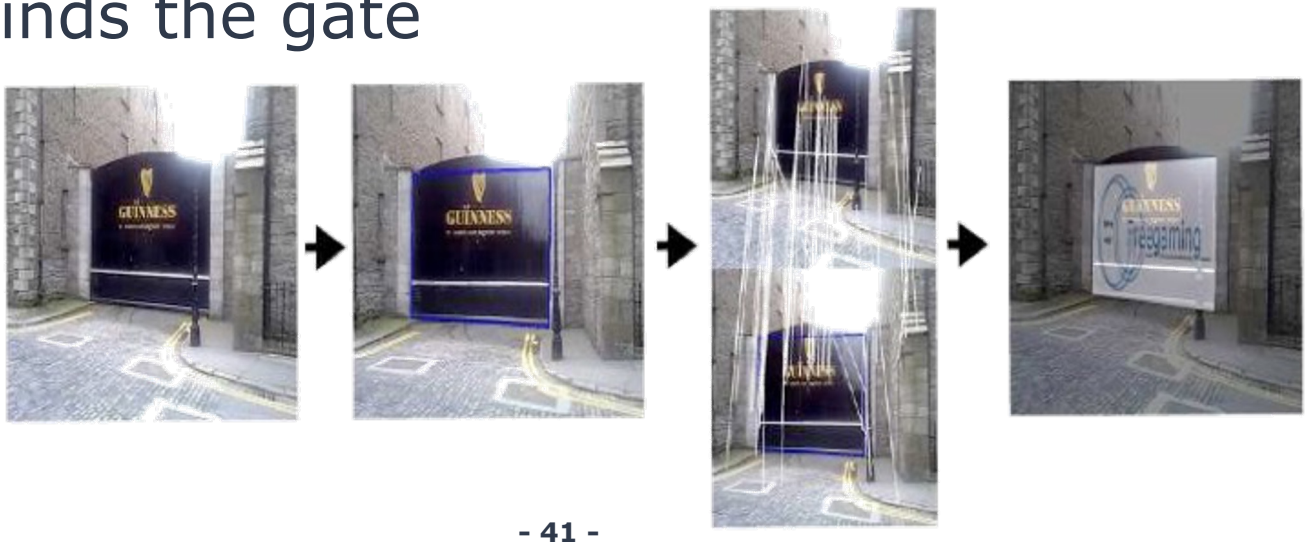


- AR does not have to use actual GPS location, it could just use the environment, but when it does (like Pokémon Go) can be used for navigation by overlaying directions on the screen
- How does AR work ? There are three kinds of image/screen augmentation:
  1. Based purely on location/compass … Pokémon Go is an example of this
  2. Based on image content/analysis … here there is something real in the camera video that is detected and when detected the screen is augmented
  3. Based on a combination of the two

- For AR based on content, these don’t care where on earth you actually are, just that your camera “sees” something the app is looking for, detects it, and responds
- This is a form of computer vision object matching

- Object-to-object matching should be invariant to size (object is near or far away), rotation, inversion, and seeing objects at an angle
- This technique called SIFT/SURF is how it is done … thousands of "interest points" in the query object and in objects in the video are matched (only some are shown in the image), lines between them are drawn and if the connections are mostly parallel lines, then it is a match

- Treasure hunts are a good example of AR on mobiles based on context (what's in the picture) and on location
- These images are of (1) Guinness gate, (2) gate detected by an AR app, (3) how the actual gate is matched against a target image in the app, and (4) AR overlays a treasure hunt clue when the user is in the right location and finds the gate



AR Treasure hunt

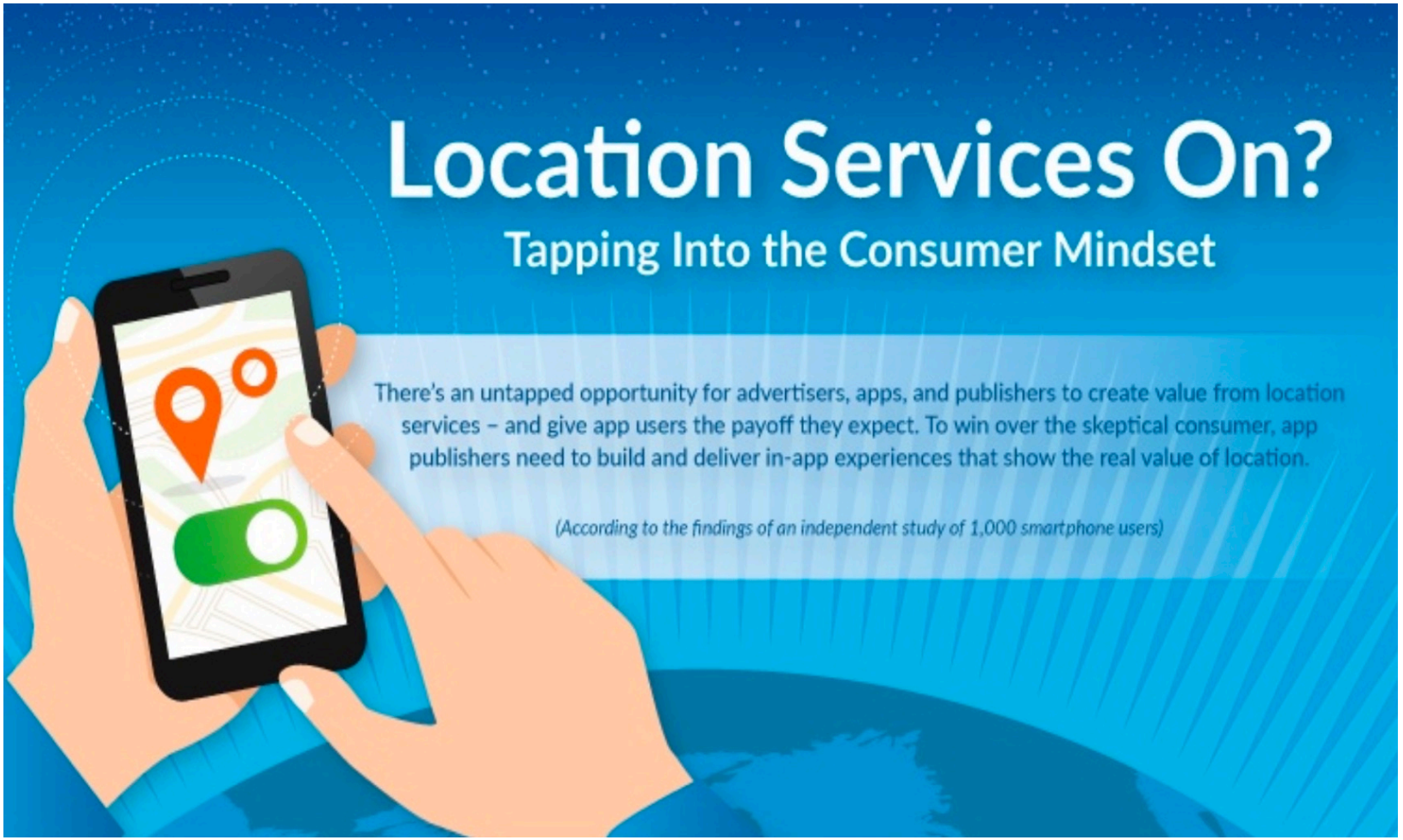
- See an example at https://www.youtube.com/watch?v=TPiG3Xrp9OY

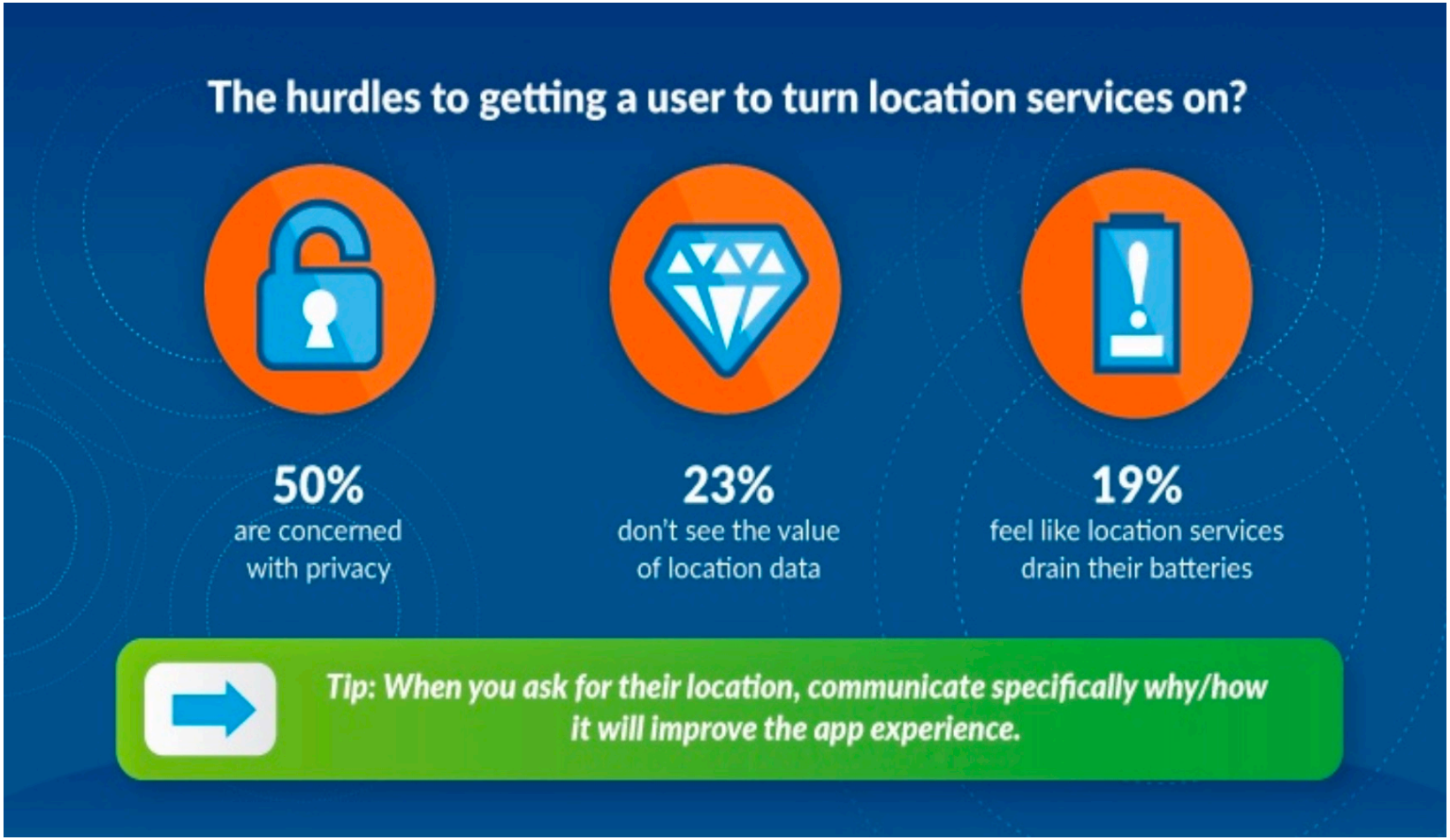
AR on mobile

- To make AR possible on phone, manufacturers adopted their processors to support fast, energy-minimising image content based AR applications, which process camera output in real time.
- AR on mobiles is now easy to do and Layar was the first (best ?) generic platform with lots of demos like Daft houses for rent, nearest bus/Luas stops, details on overhead flights
- See video at https://www.youtube.com/watch?v=ZR4eSmmPCxg

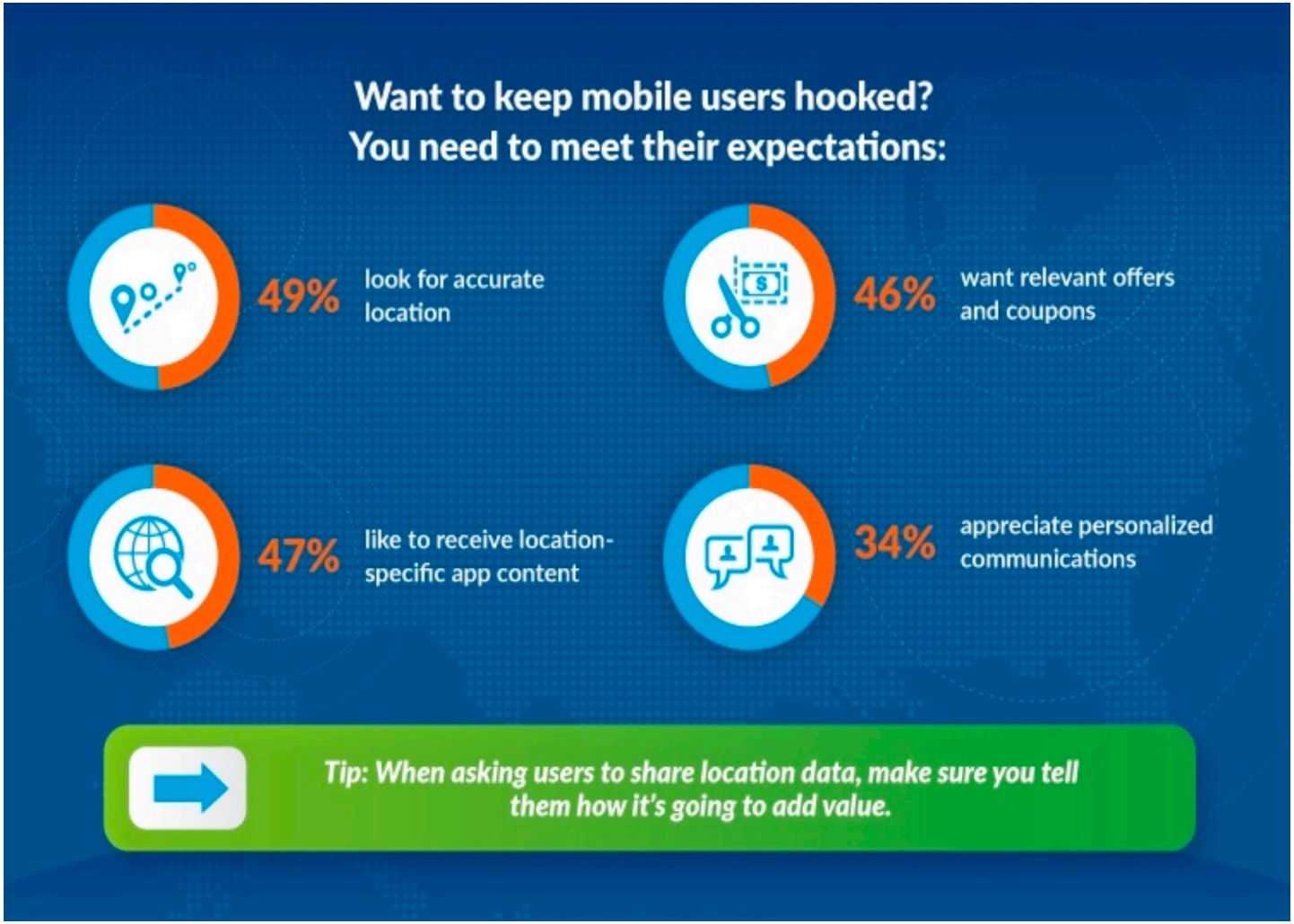
Views on LBS

- Back to LBS … what do people really think of tracking of their location on their smartphones … the following series of infographics expand on this, available at https://www.skyhook.com/blog/infographic-cracking-the-code-on-location-services-on


Location Services On?
Tapping Into the Consumer Mindset
There's an untapped opportunity for advertisers, apps, and publishers to create value from location services – and give app users the payoff they expect. To win over the skeptical consumer, app publishers need to build and deliver in-app experiences that show the real value of location.
(According to the findings of an independent study of 1,000 smartphone users)


The hurdles to getting a user to turn location services on?
50%
are concerned
with privacy
23%
don't see the value
of location data
19%
feel like location services
drain their batteries
Tip: When you ask for their location, communicate specifically why/how
it will improve the app experience.


The good news? Many consumers see the benefits of location services and opt to keep them on:
83%
say they are vital to the app
25%
want notifications about nearby offers
Tip: Make sure you combine location with contextually relevant features and offers to custom fit the app experience.

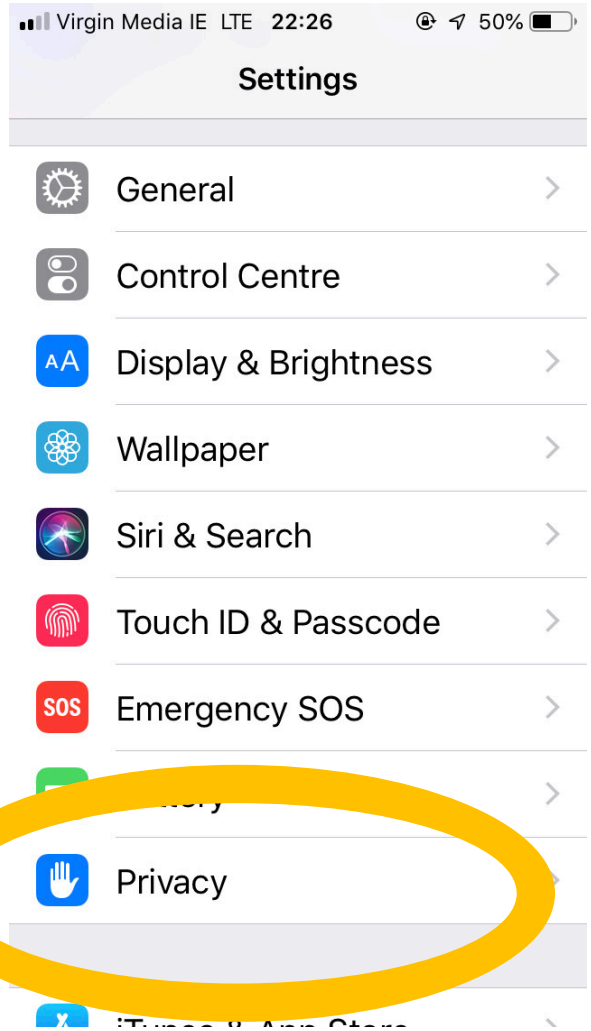

Want to keep mobile users hooked?
You need to meet their expectations:
49%
look for accurate location
46%
want relevant offers and coupons
47%
like to receive location-specific app content
34%
appreciate personalized communications
Tip: When asking users to share location data, make sure you tell them how it's going to add value.

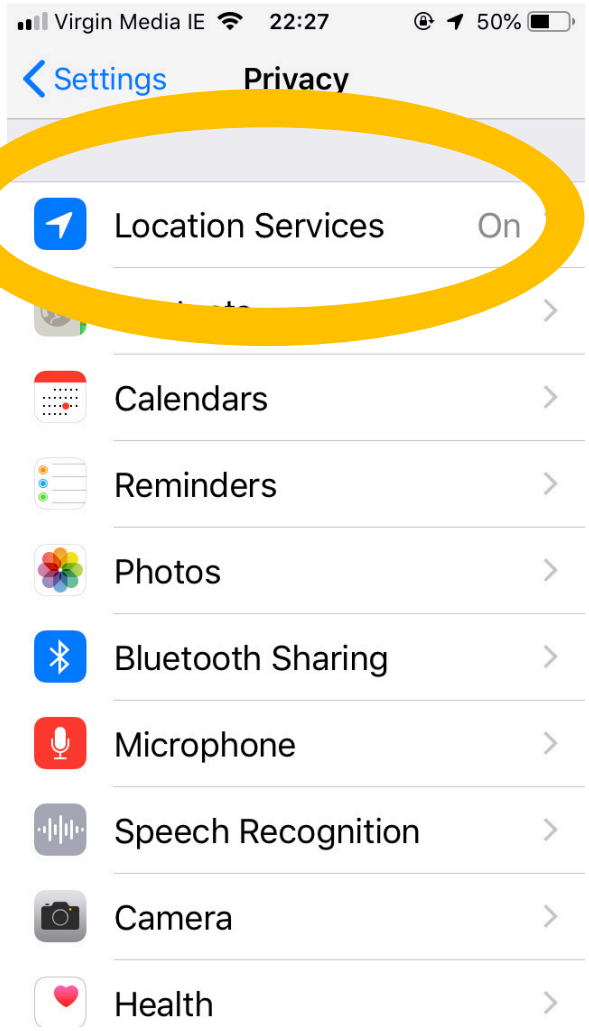
Research commissioned by Skyhook Wireless and conducted by Research Now.

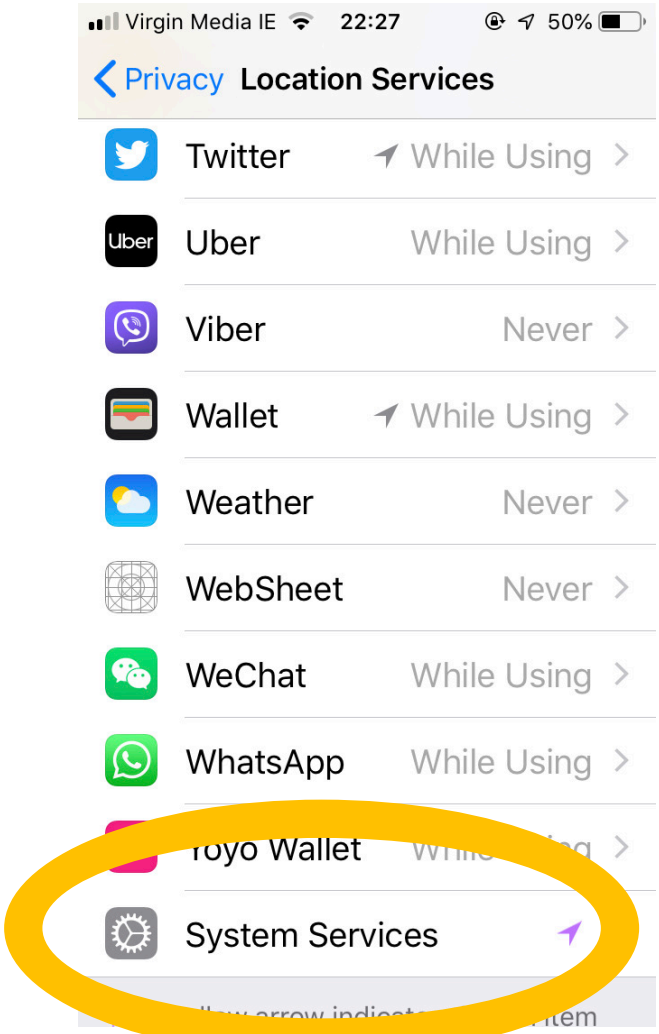
- However there are downsides to LBS, mostly its the personal data captured and the tracking that manufacturers do on us
- LBS bring challenges (e.g. privacy, ethical, and legal issues)
- Most people don’t realise how much personal information is gathered on everyday activities
- The next series of slides show how an iPhone tracks and stores your location, on the device
- Go to the “Settings” app and follow the menu options from there

Data Ownership and Privacy

- There is much media coverage about our personal data from our use of social media being used to personalise adverts for us (we see more of this in a later MOOC)
- In terms of location, both Google and Apple track our location on our phones
- This is to help improve services and it is on the phone only, but iPhone locations will be uploaded to the cloud and we have no control over it
- Here's what the iPhone tracks …


Virgin Media IE LTE 22:26
50%
Settings
General
Control Centre
Display & Brightness
Wallpaper
Siri & Search
Touch ID & Passcode
Emergency SOS
Privacy


Virgin Media IE
22:27
50%
Settings
Privacy
Location Services
On
Calendars
Reminders
Photos
Bluetooth Sharing
Microphone
Speech Recognition
Camera
Health


Virgin Media IE
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Privacy
Location Services
Twitter
While Using
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Wallet
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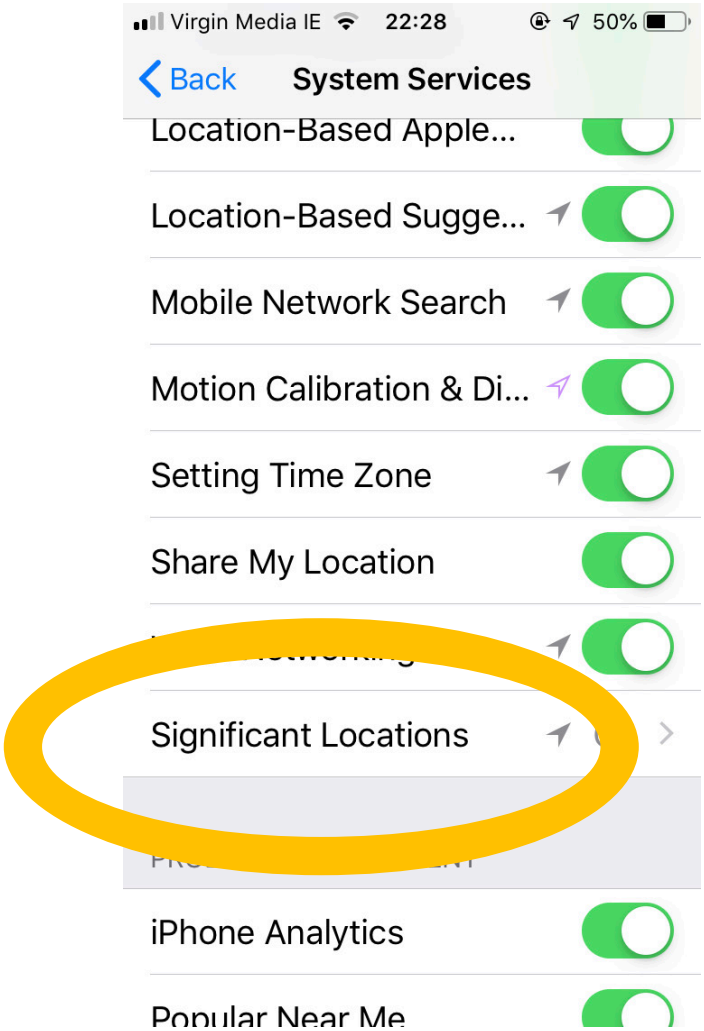
WebSheet
Never
WeChat
While Using
WhatsApp
While Using
System Services


Virgin Media IE
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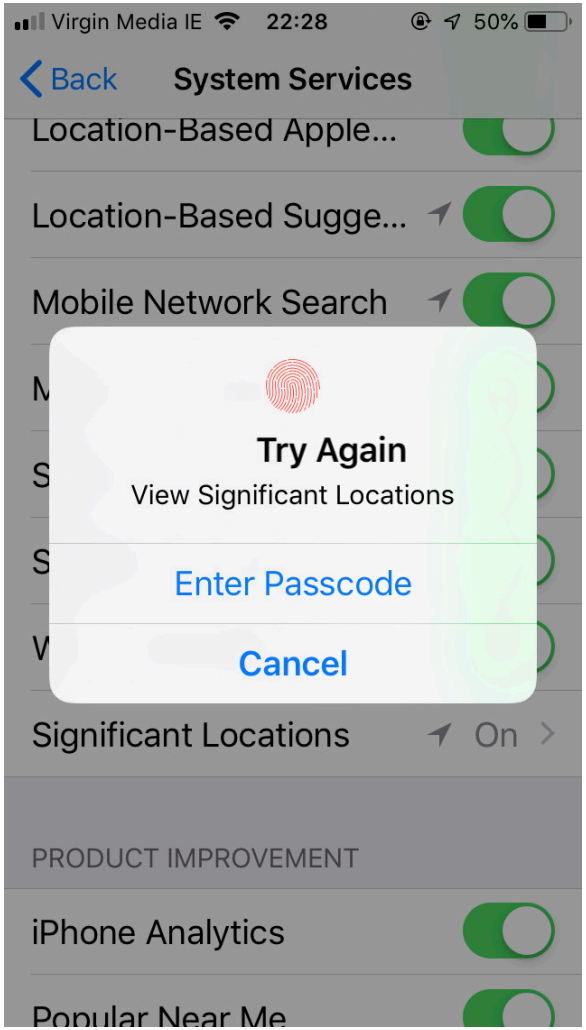
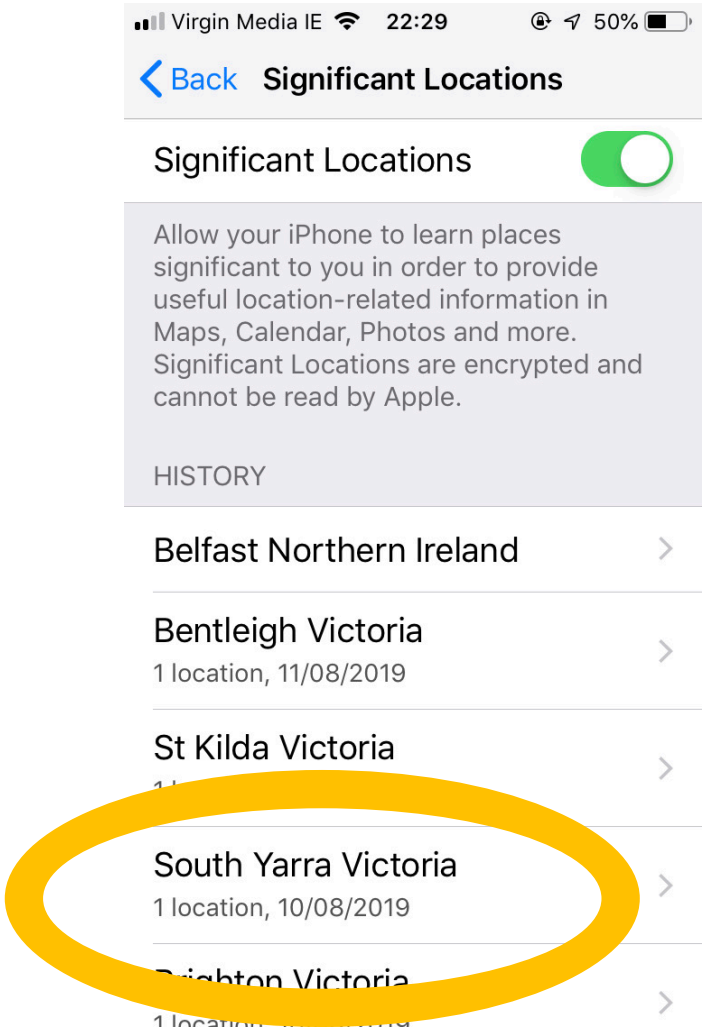
System Services
Location-Based Apple...
Location-Based Sugge...
Mobile Network Search
Motion Calibration & Di...
Setting Time Zone
Share My Location
Significant Locations
iPhone Analytics
Popular Near Me

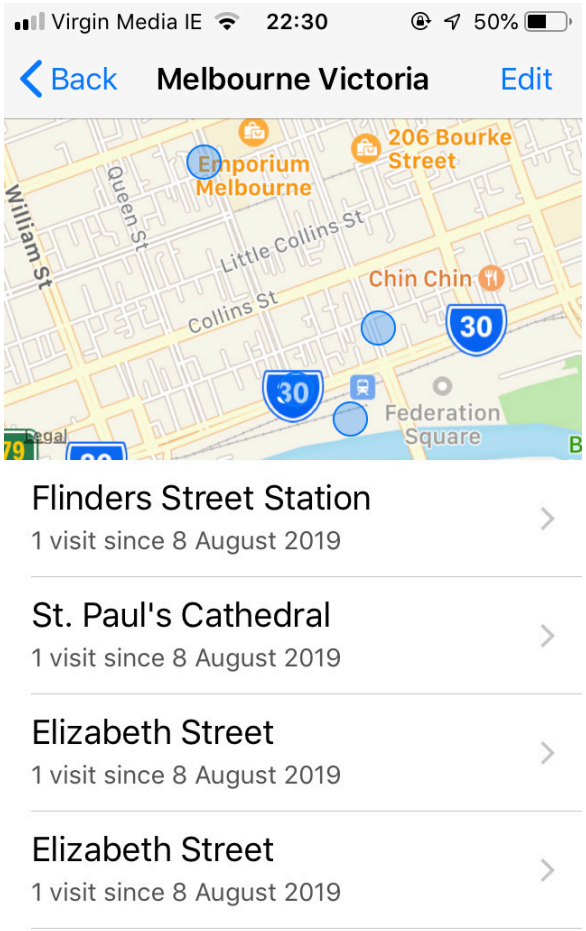
Need to give password to gain access



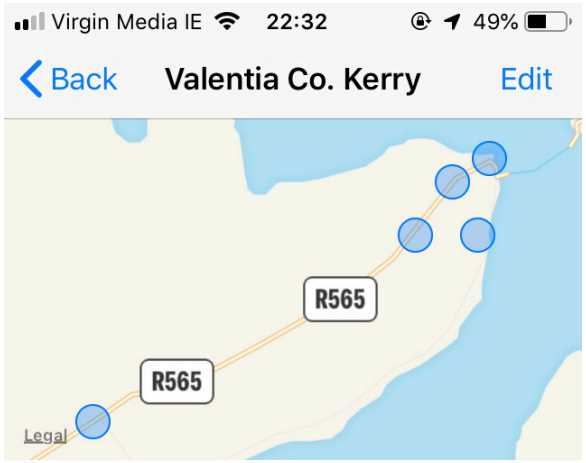
And here we are …



There’s a hierarchy of locations



Locations, dates of visits



12 An Toileán
27 visits since 25 July 2018

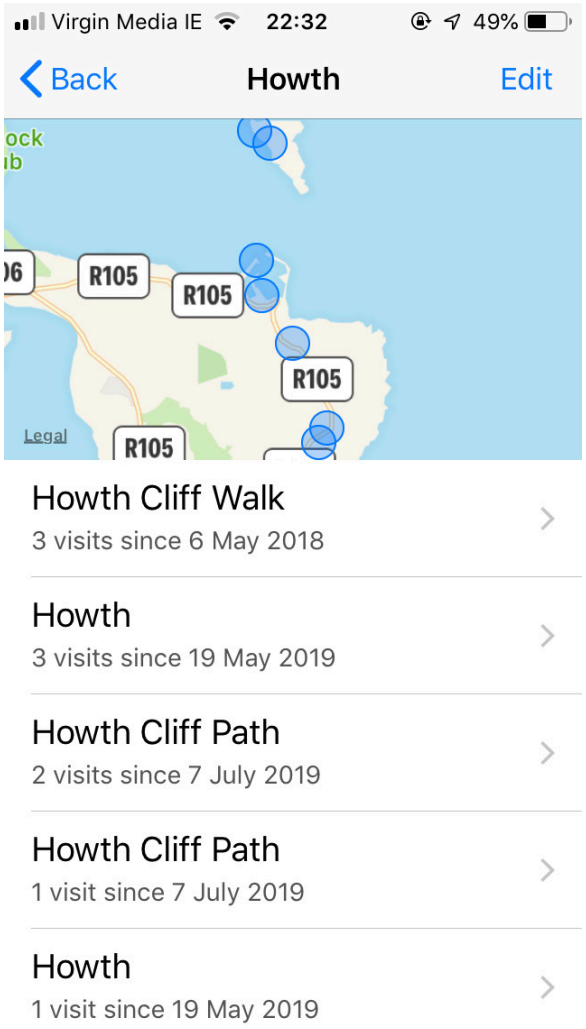
Watch House Cottages
4 visits since 24 July 2019

The Ring Lyne - Bar and Restaurant
1 visit since 30 July 2019

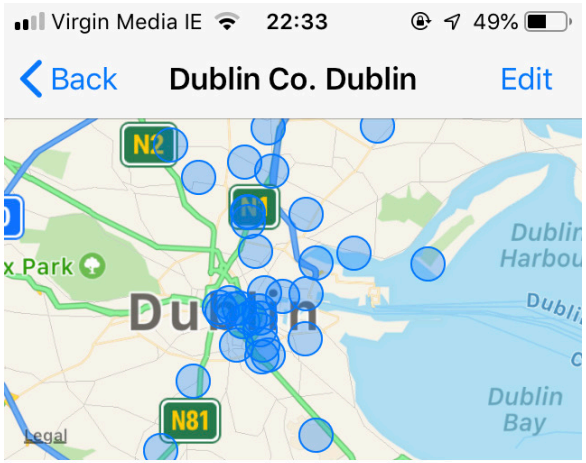
Crackow
1 visit since 25 July 2019

17 Glór Na Farraige

Going back in time to when you last cleared it



Big picture as well as fine detail



Dublin City University
62 visits since 15 December 2017

Royal Irish Academy
5 visits since 30 November 2017

University College Dublin
3 visits since 8 March 2018

Aviva Stadium
2 visits since 21 April 2018

Kimmage Road Lower
1 visit since 27 July 2019

- The iPhone “Settings” menu just presents the locations, no interactions with them, but it is easy to hack and then export all my location data from my phone to … wherever

Location in Search

- We now know how Google and other services take advantage of the searcher's actual location, especially on mobile
- Such services are for individuals mostly, except LBS gaming, even location sharing is sharing of an individual's location with another individual, its 1-to-1
- There's not a lot more that can be done for solo individual search or information finding other services for an individual except to personalise search output by location
- Beyond that we can think of collaborative search or other collaborative services
- This opens up shared searching, shared browsing, either synchronous or asynchronous and either co-located or not, but it fits into "location" as the closest form of context

Collaborative Search

- Web search can be a social activity … really.
- Have you ever been, or been subjected to a back seat searcher … you have the keyboard but somebody else telling you what to search, what to click … GRRRR !
- Search systems are for individuals – always so – never for groups yet we often search in groups either synchronously or asynchronously .. and .. there is no computational support for this in any of the search tools we use

Search Together

- Two (Jane and Bob) people want to collaborate on some task like choosing a vacation destination
- Both search the web and share results by … shouting at each other, or emailing URLs
- That is synchronous search – same time, same location – but Jane's search can't take advantage of the pages Bob has found, or vice versa

Search Together

- Bob decides to go out for pizza while Jane continues to search, Bob gets delayed so Jane goes to bed and when he does get back, Bob picks up the internet search while Jane sleeps
- This is asynchronous search – different time, same location but same search – and there are no computational tools to support this

Search Together

- Jane gets up early to go to work while Bob has a lie-on then during her lunch break, Jane picks up the search and WhatsApps Bob to do likewise … they both continue the same searchfor a vacation destination synchronously, but in different locations
- Again, no tools to support collaborative asynchronous or synchronous, co-located or remote, searching
- Any idea why this might be so ?

Search Together

- Yet we’re seeing real time (synchronous) and delayed (asynchronous) collaboration in other tools
- Google Docs, Sheets etc. allows synchronousand asynchronous editing and comments
- Skype for Business and Zoom allow synchronous collaboration and shared desktops
- Shared calendar tools, file sharing like Dropbox and Box, Slack channels and more all support remote or shared location forms of collaboration
- Yet there’s no support for shared information finding tasks.

Summary

- LBS attracts a lot of commercial interest aiming for 4A (anytime, anywhere, for anyone and anything) ‘services’
- Typically these have a very product or service oriented focus
- Huge demand for providing LBS for indoor as well as outdoor

Week 2: Sensing Human Activity

- By human activity we mean walk, drive, sit or more, what the body is doing, its movement, its position, and we also mean limb movement so jumping, waving, etc.
- Importance in niche applications like movies and games and also useful in information finding
- Based on (wearable) accelerometers and gyroscopes, or motion capture studios, or Microsoft Kinect
- Used as an interface to augmented reality for in-home shopping, for example

Kinds of Context

- Location – where you are
- **Activity – what you are doing now**

Human Activity As Context

- Capturing human activity is done using 1 or more sensors, so this is mostly about sensors and what we can do using simple sensors
- Applications are widespread - sports, ambient-assisted living, gaming, health and wellness, etc.
- Wouldn't it be great to be able to identify what a person is doing right now... and tailor our information access accordingly. Its not the primary function, but a second-order effect
- Why would this be useful?
- How can we do it?

Motion Sensing on Smartphones

- In addition to GPS, which we saw earlier, smartphones, watches, cars all have built-in motion sensors
- Accelerometers measure the acceleration of a moving body in a single direction
- Put 3 of them together, perpendicularly, and you can measure acceleration in any direction .. Left right, back forward, up down, or a combination.
- Accelerometers used to be physical devices but now they are microscopic crystals that become stressed when accelerated and the voltage coming from the crystals changes and that's what gives accelerometer values

- Gyroscopes also used to be large physical devices for keeping balance on old airplanes, now they are reduced in size and fit on circuits.
- They help accelerometers to understand which way your phone is orientated
- The magnetometer or compass measures which way the phone is pointed

More sensors

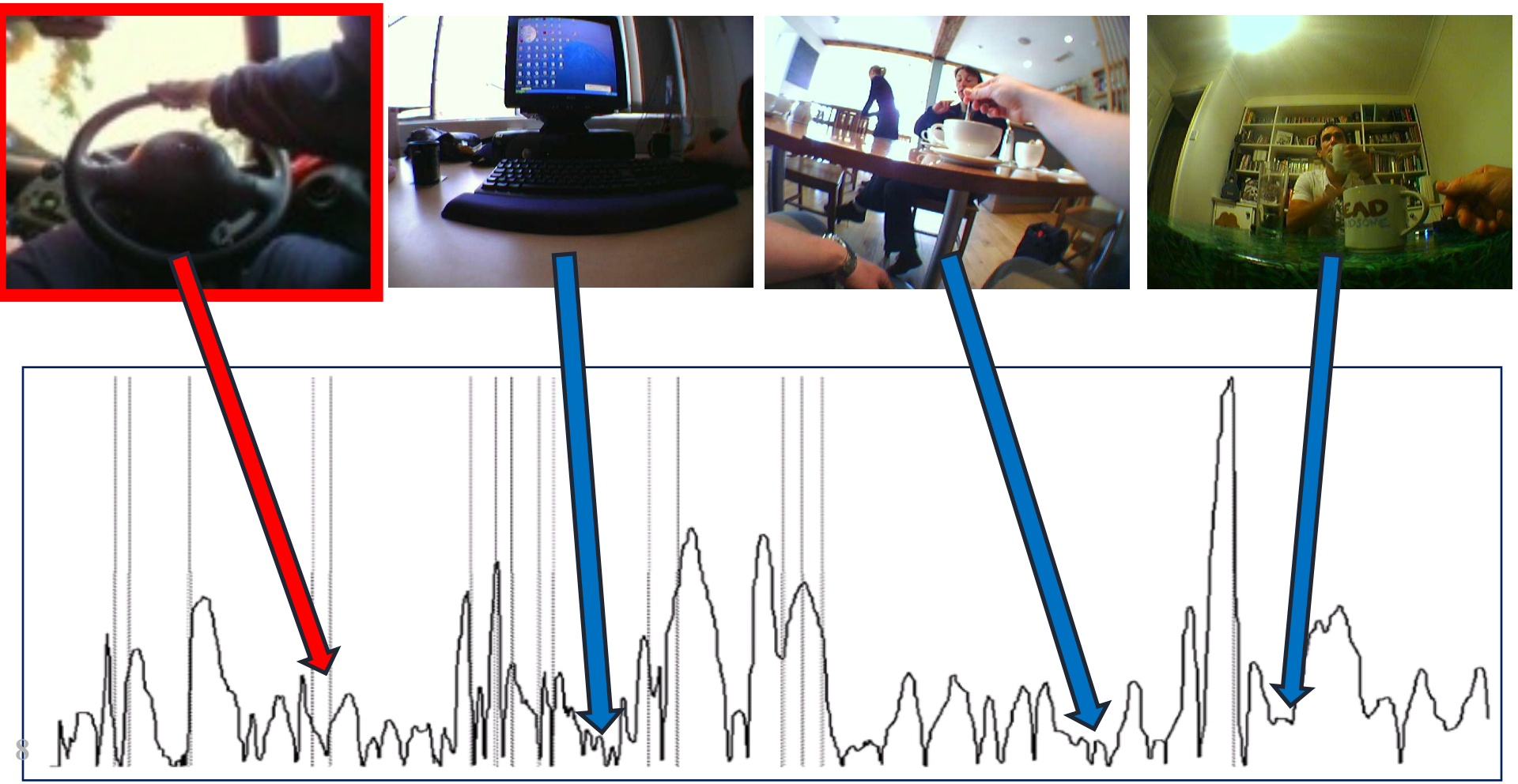
- … and it doesn't end there.
- Many phones have a **barometer**, measuring atmospheric pressure, a clue for altitude
- Others have a **light sensor**, measuring brightness
- Others have a **proximity sensor** near the speaker to detect if there's anything (like your ear) near to it.
- So from this orchestra of sensors on the phone, we can detect a lot of information

Lets look at activity classification

- You only need an accelerometer-enabled phone and some clever software … to get 98% accuracy in classifying activities !
- Walking, standing, running, driving, etc. are all detectable
- Accelerometer data is a stream of three numbers (tri axial) arriving at (at least) 1 Hz
- These numbers can be converted into activity labels using an Artificial Intelligence technique called Machine Learning
  - So what does that mean ...
- The activity labels are then validated by checking it against a groundtruth of the 'correct answers' for different activities

How to identify human activity from accelerometers?

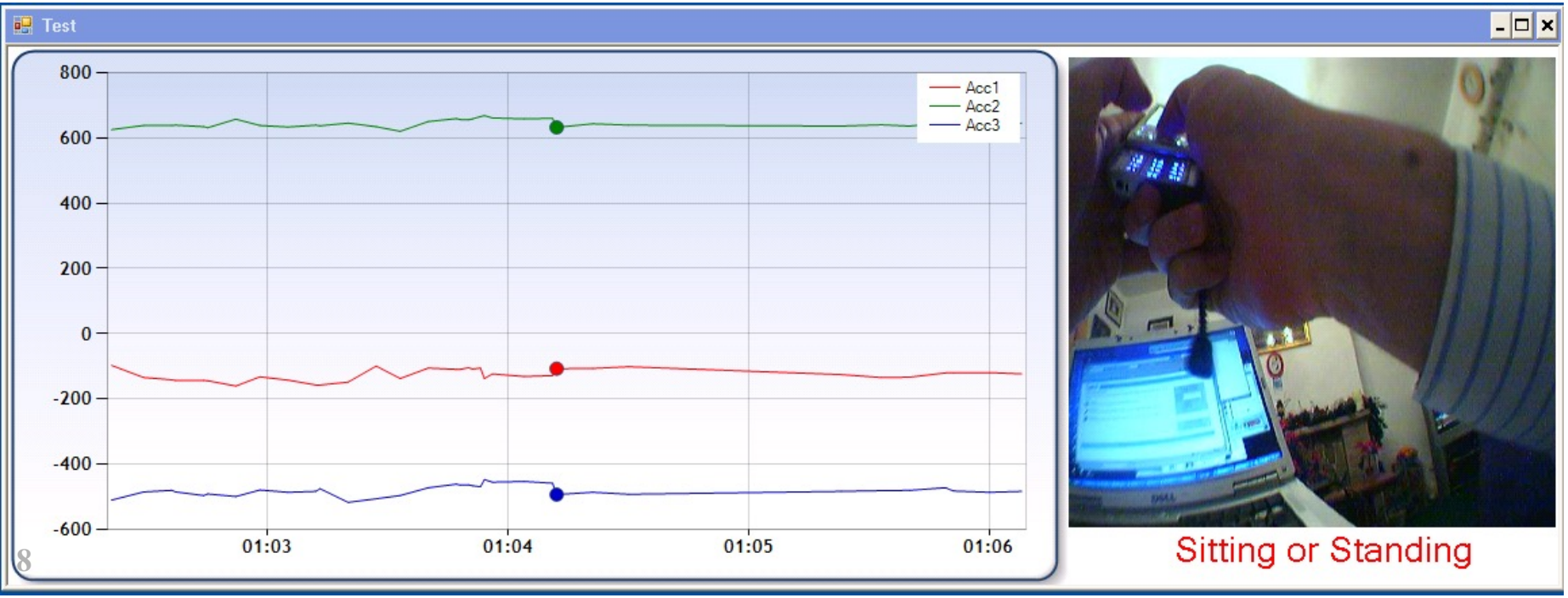
- 1 week groundtruth (132,247 acc readings)
- SVM – 39 features (mean/range/stdev of previous 1/5/20/120/300 on X/Y/Z axes)
- Precision score of 0.82 recorded after re-occurrence smoothing



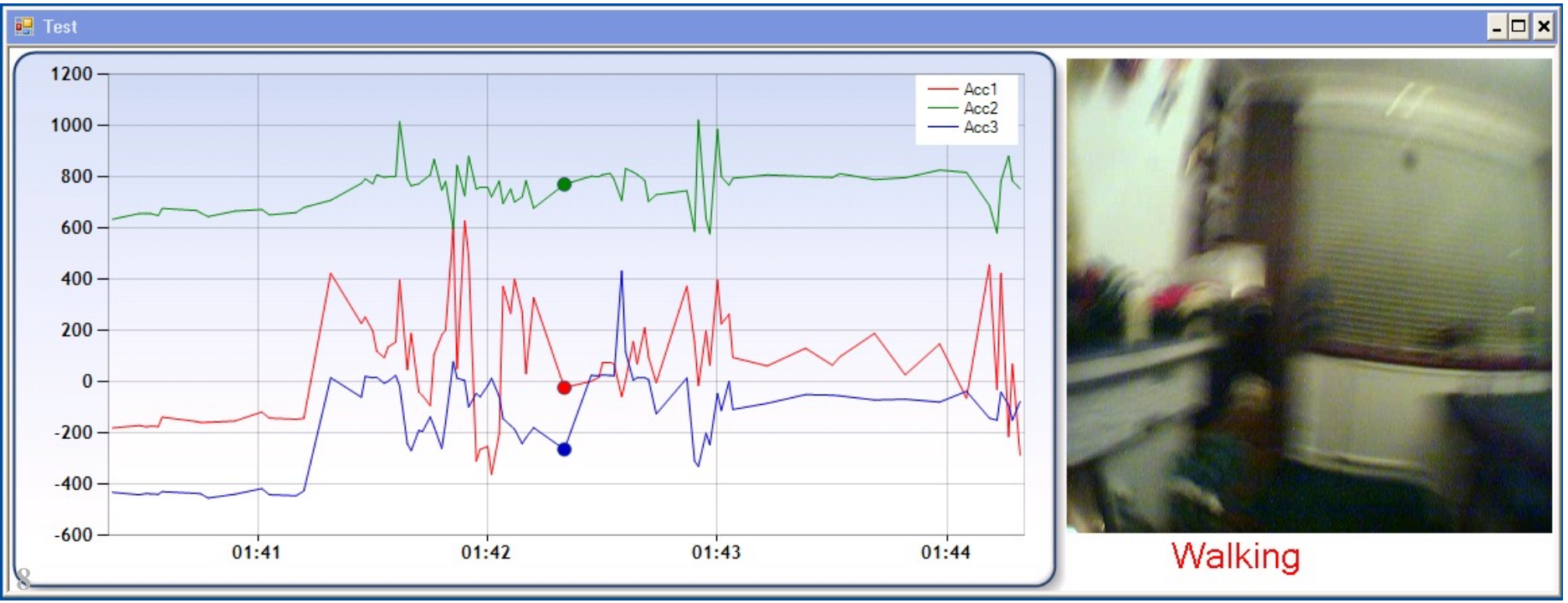
Identifying Activities

Sitting/Standing = 93% accurate

Using a range of machine learning classifiers: Logistic Regression, Naïve Bayes, SVM, etc.

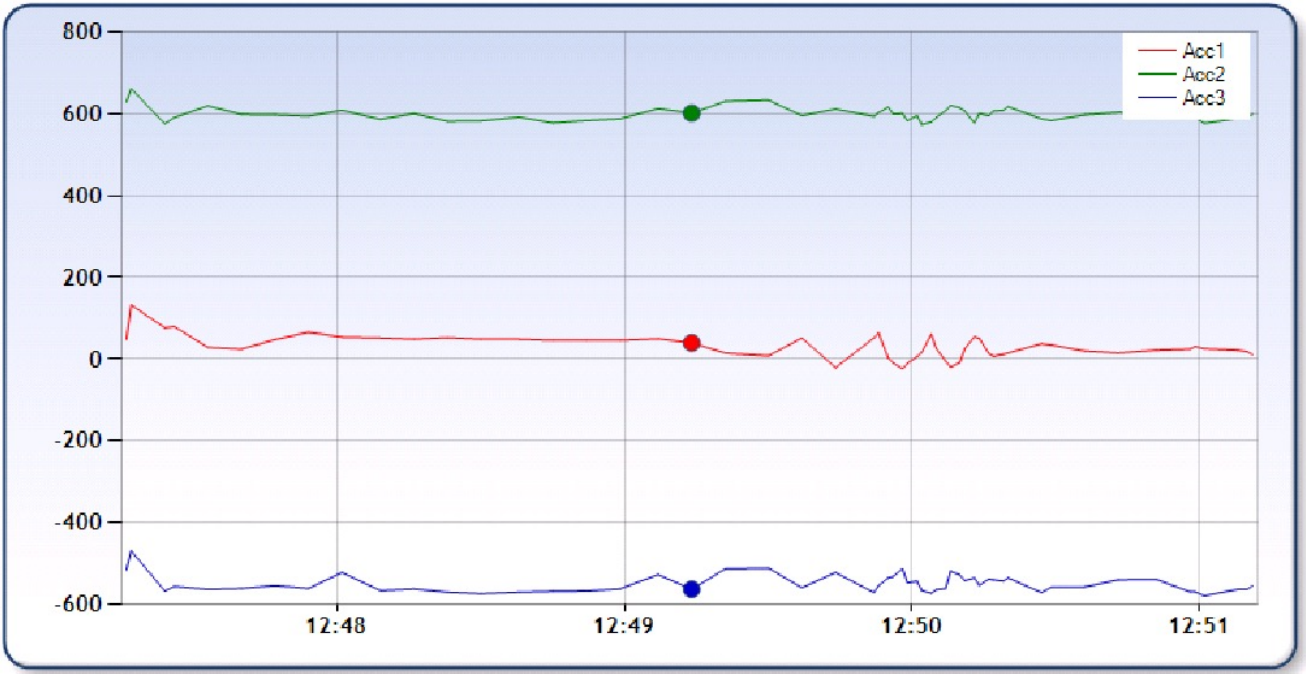


Identifying Activities
Walking = 97% Accurate



Identifying Activities
Driving = 98% Accurate

Identifying Activities
Lying down and resting = 98%
Accurate



Lying

Activity detection

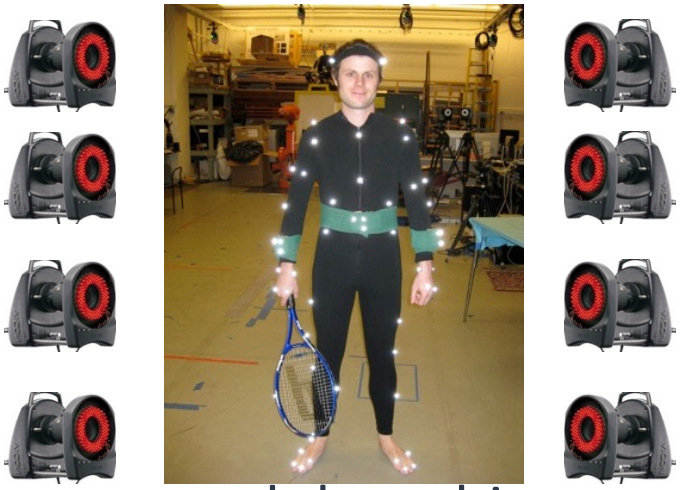
- So with a smartphone in your pocket, or a fitness band on your wrist, we can classify what you are doing, in real time
- Why would we bother ?
- Google speech on mobile uses accelerometers to detect when the phone is moved to the mouth to 'speak' queries on Android -> that kicks in Automatic Speech Recognition for a user query
- Also used to trigger SIRI on phone
- Could extend this further … knowing what the (mobile) user is doing based on accelerometer activities (and combine with location), select when to alert, what to search, etc.
- Problem with using the phone for this is we don't "wear" the phone, but we do wear the watch ?

Activity Detection - Alternatives

- The phone or the wearable are good, sometimes great, at classifying activity, but are there better techniques ?

- Yes, but the high-end approaches are very specialist, expensive, and operate in niche applications

More elaborate motion/activity capture



- Traditional approach to motion capture is a Vicon recording studio
- In this, a user wears more than a dozen "markers" reflective spheres, at the joints of limbs (knees, ankles, elbows, etc.
- A network of infra-red lights and cameras around the subject capture the markers and in real time, combine them to generate a 3D model of the user
- This is very accurate - sampling rate is 120-250Hz
- Used in movies, in sports analysis, biomechanics
- Disadvantages are that it is ….
  - Cumbersome, expensive
  - Motion confined to small area, size of a small room
  - Markers interfere with movement

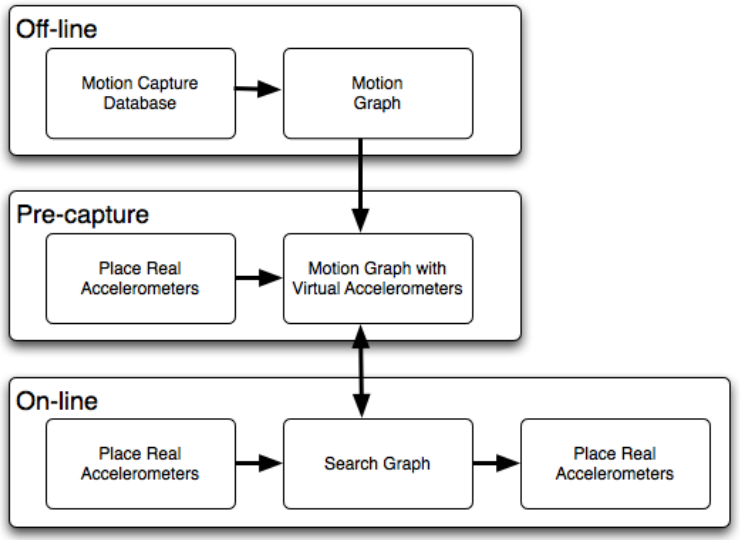
Motion Capture

- We wanted to do something cheaper and our objectives were
  - Viable, near real-time, cheap, accurate and unobtrusive
  - Naturalistic (looks real)
  - Matches real movement (as closely as possible)

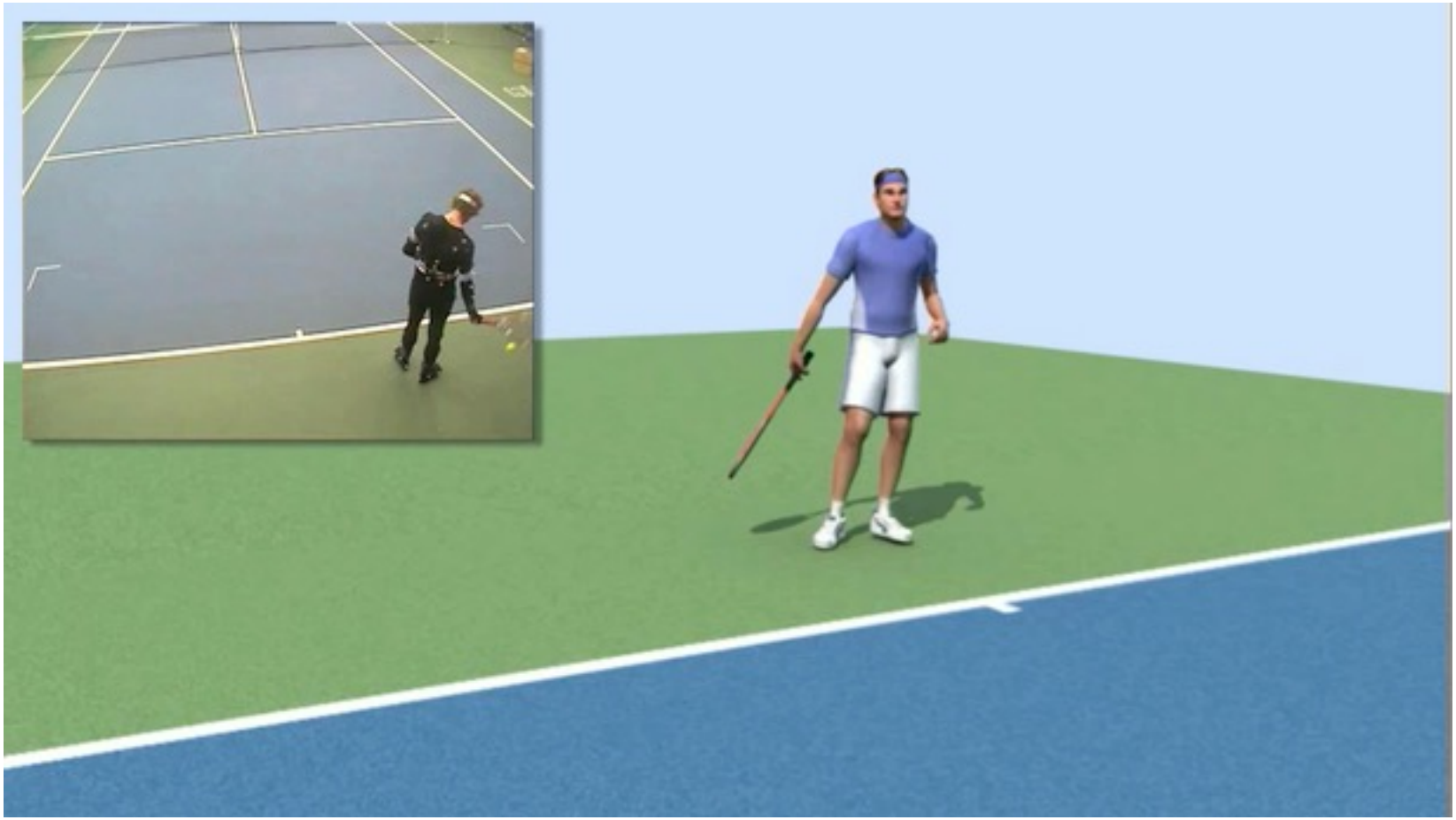
- So we came up with the following based on only 6x accelerometers (as used in your phone) worn around the body

Motion Capture, Our Approach

- Inertial sensing
  - Synthesize realistic motion from Inertial Measurement Units (IMU)
- Contextual information
  - Single low-cost camera if available
- Off-line
  - Capture prototypical movements
  - Build motion graph
- Pre-capture
  - Define IMU placement
  - Add virtual IMU data to motion graph
- On-line
  - Search motion graph
  - Match virtual & real IMU data



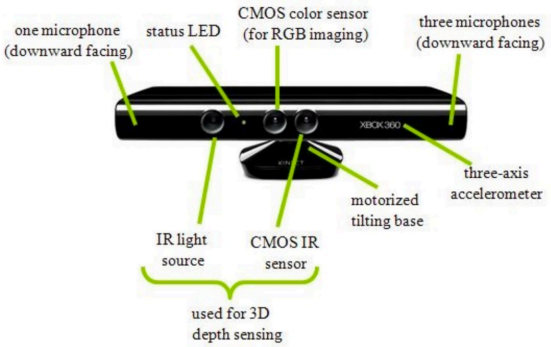
How well does it work ?



- Video shows a real person (Sam Barry, Irish tennis player, in black) wearing inertia sensors, data captured wirelessly to generate 3D model which is then rendered as a Roger Federer lookalike

Kinect

- And then came the Microsoft Kinect !
- Sits on top of a TV or computer screen and contains an integrated microphone array, visible spectrum camera and IR-based depth camera
- Intended to be a proprietary interface to the X-Box gaming console but it was quickly hacked, so Microsoft gave up and released an API so anyone could use it for anything



Figure

Caption

Fig. 2. Microsoft Kinect sensor

- Kinect was released by Microsoft to connect to X-Box so there are many X-Box games with Kinect interfaces where platers' motion is captured
- Kinect targeted healthcare apps
- It targeted exergaming

Microsoft Kinect

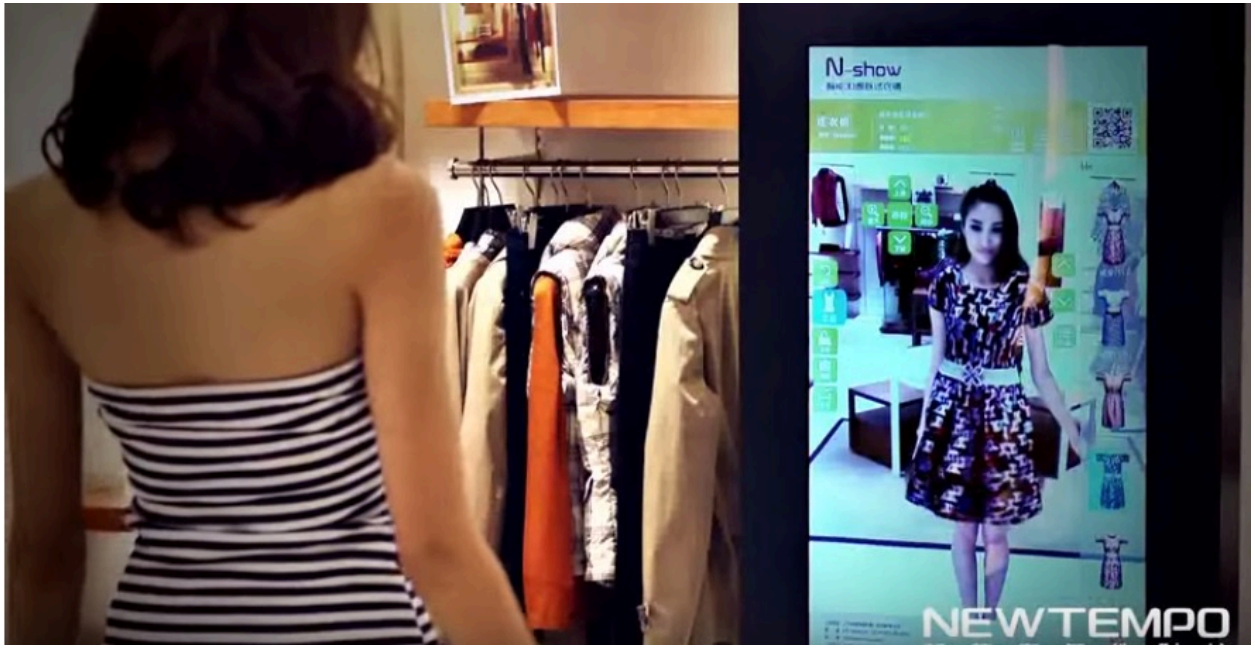
- Kinect is a form of AR
- Works by sending out patterns of dots in invisible spectrum light, and then picks them up with a camera
- https://www.youtube.com/watch?v=dTKlNGSH9Po&feature=related
- Using this, Kinect knows how far you are from the camera (depth map) and can augment the video camera image on the screen
- One example app is the virtual dressing room where you can "try on" clothes …

Robust Virtual Mirror

- There is a crude form of AR in shopping – see JCPenny teen on Moodle and t-shirt and shoes videos
- Working towards a virtual dressing room equipped with a Virtual Mirror and a Clothing Advisor
- Several issues that are of interest for such a scenario:
  - Robust real-time tracking methods to ensure that the virtual clothes follow the movements of the user
  - Methods and algorithms for realistic rendering of virtually textured clothes
  - Image processing techniques for scene analysis
  - Texture and shape based clothing retrieval

DCU

- Details at https://www.youtube.com/watch?v=59VUkMahcLI



Clothing Advisor

- This is actually a form of location-as-context which disregards GPS location altogether but uses human motion
- So could we take this further and search for clothing from a catalog for use in a virtual mirror ?
- Yes, and for this need an interactive segmentation tool, or an automatic one, and then use features from segmented shirt in search
- Colleagues in Singapore are characterising cities by types of clothes worn by general population, based on streetview !

Texture-based retrieval results

- Query :

Top 5 retrieved results:

Texture-based retrieval results

- Query :

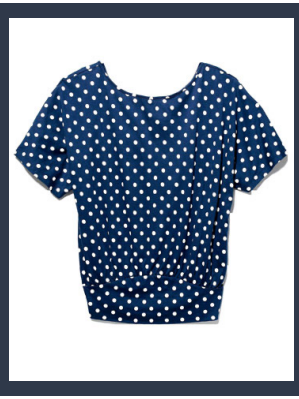
Top 5 retrieved results:





Colour-based retrieval results

Query :



Top 5 retrieved results:





Kinect

- Best hacks …
- #10 virtual dressing room captures depth of subject and wraps a 3D non-deforming model of clothes around the subject, ours deforms the clothes = more natural
- #9 (wall) we did this for NMI treasure room (award-winning at MM2011)
- Play the others and be inspired !
- All revolve around sensing what you are doing, now

Summary

- Human motion and movement will need to be captured for high end applications like movies and elite sports
- Human motion and movement will also be needed for low-end applications like using your phone, for which in-built accelerometers and gyros will be sufficient
- Human motion and movement for games is pretty much solved with Kinect
- Now all we need are applications that use human motion.

Week 3: Sensing the Body

- Here we cover the technology behind wearable sensors measuring heart rate, respiration, GSR, EEG, movement
- These have applications like …
  - Noting HR during the day during exercise or sports, combine with location for health apps
  - Logging sleep and sleep quality
  - Polygraphs
- Then we look at examples of pooling personal sensor data including the body, location, activities .. Raises issues of data ownership, GDPR, double-dipping on the advantages of data capture

Sensing the Body - Physiology

- Our physiology is the set of outward signs that our body gives constantly, to indicate what state our bodies are in.
- For example
  - when we perspire its an indication we're too hot and we need to cool down;
  - when we've goosepimples on our arms it means the environment is too cold for us and we need to preserve heat hence the goosepimples;
  - when our breathing is fast it means we're extending ourselves and we need to get more oxygen into our blood streams because we're exercising, or we're tense

Sensing the Body - Physiology

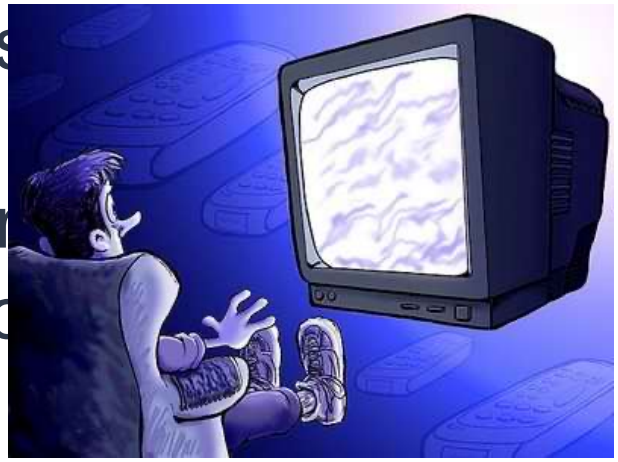
- Sensing the body usually means using some form of wearable sensor
- Sometimes it can mean taking samples of body fluids like perspiration, urine, eye tears, blood or interstitial fluid and analysing this chemically
- Wearable sensors are cumbersome and interfere as our bodies are a hostile environment for sensors … we sweat thus interfering with contact between sensor and the skin, we move so sensors don't stay firmly in place unless they are stuck on like plasters

Sensing the Body - Physiology

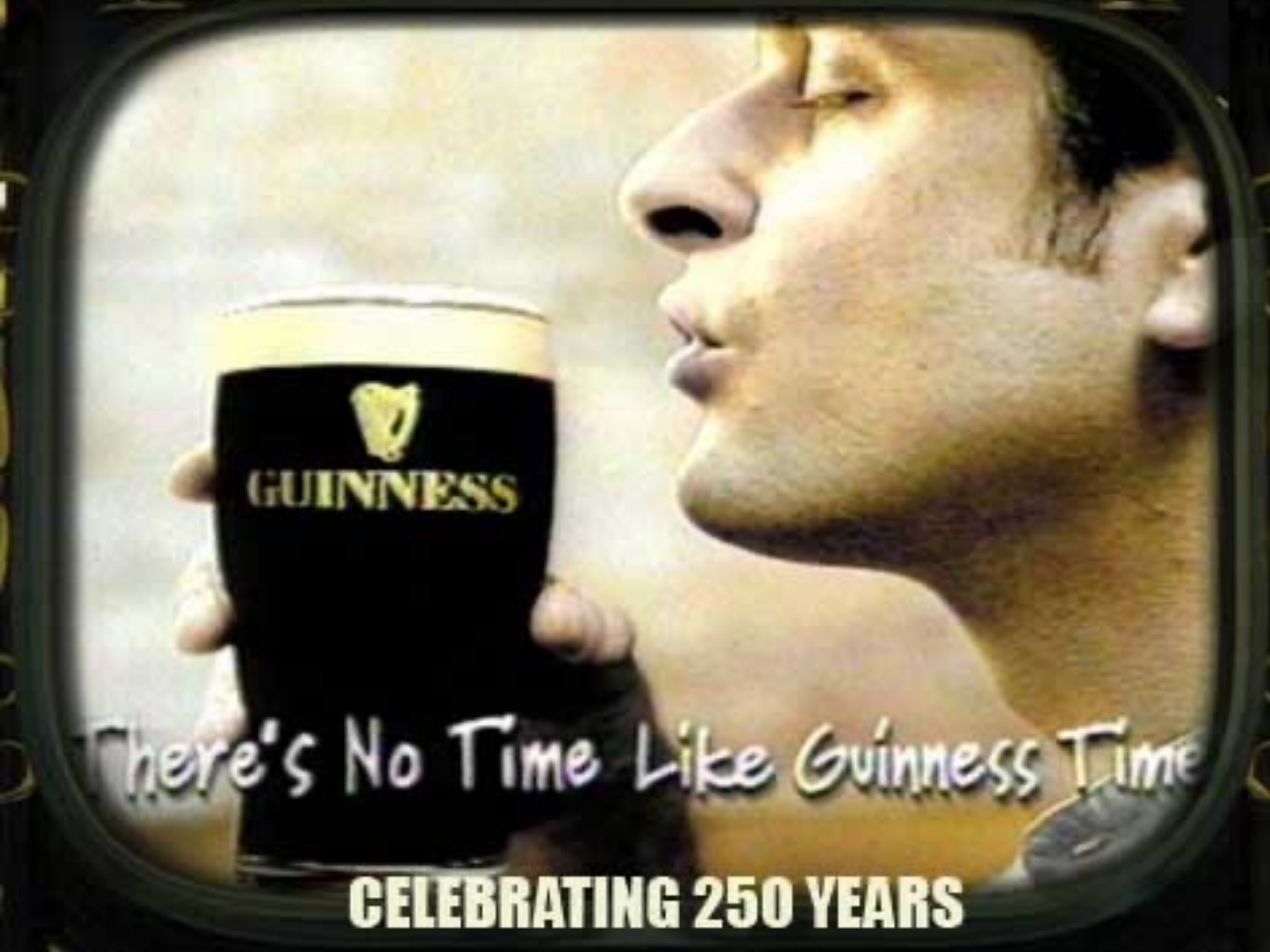
- Mostly, and the main reason we sense our bodies, is for health reasons,
  - we monitor our heart rate when we exercise
  - we track our movement so as to count our exercise or number of steps taken in a day
  - older people at home and lone workers in forests and remote areas wear fall detectors to detect when accidents have occurred
  - the hard of hearing use hearing aids and some people have their heart rates regularised with implanted pacemakers, etc.
- While health and wellness reasons are the main reason, there are others also, like measuring our reaction to advertising material (just as an example)

Sensing the Body - Physiology

- We can sense and measure the body's physiological reaction as we experience something, some stimulus like watching a movie or seeing a proposal for a new TV advert
- In such cases we see (it is usually seeing because when we see something we have a near-instant reaction whereas when we hear, taste or feel something it takes s body to react) the new stimulus some physiology signals as a pr how good or emotional or impac the stimulus actually is

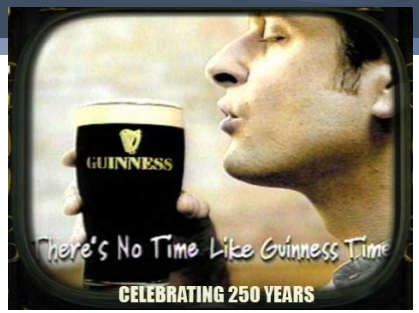


- Lets see some examples …. (see slide note)
- We'll now see a series of images, each of which will (probably) induce some emotional reaction from you.
- Lets see them …


GUINNESS
There's No Time Like Guinness Time
CELEBRATING 250 YEARS


مجموعة ورقات البريدية
Group.Waraqat.Net

- Each one of these is from an advert for a popular drink in Ireland.
- What did you feel when you saw each one of them ?
- A sense of Irishness, pride, a sense of taste/quality, sense of excitement with the rugby picture ?
- The goal of the advertiser in this case and the feelings/emotion/reaction they want to induce in the observer are joy, pride, memory/nostalgia



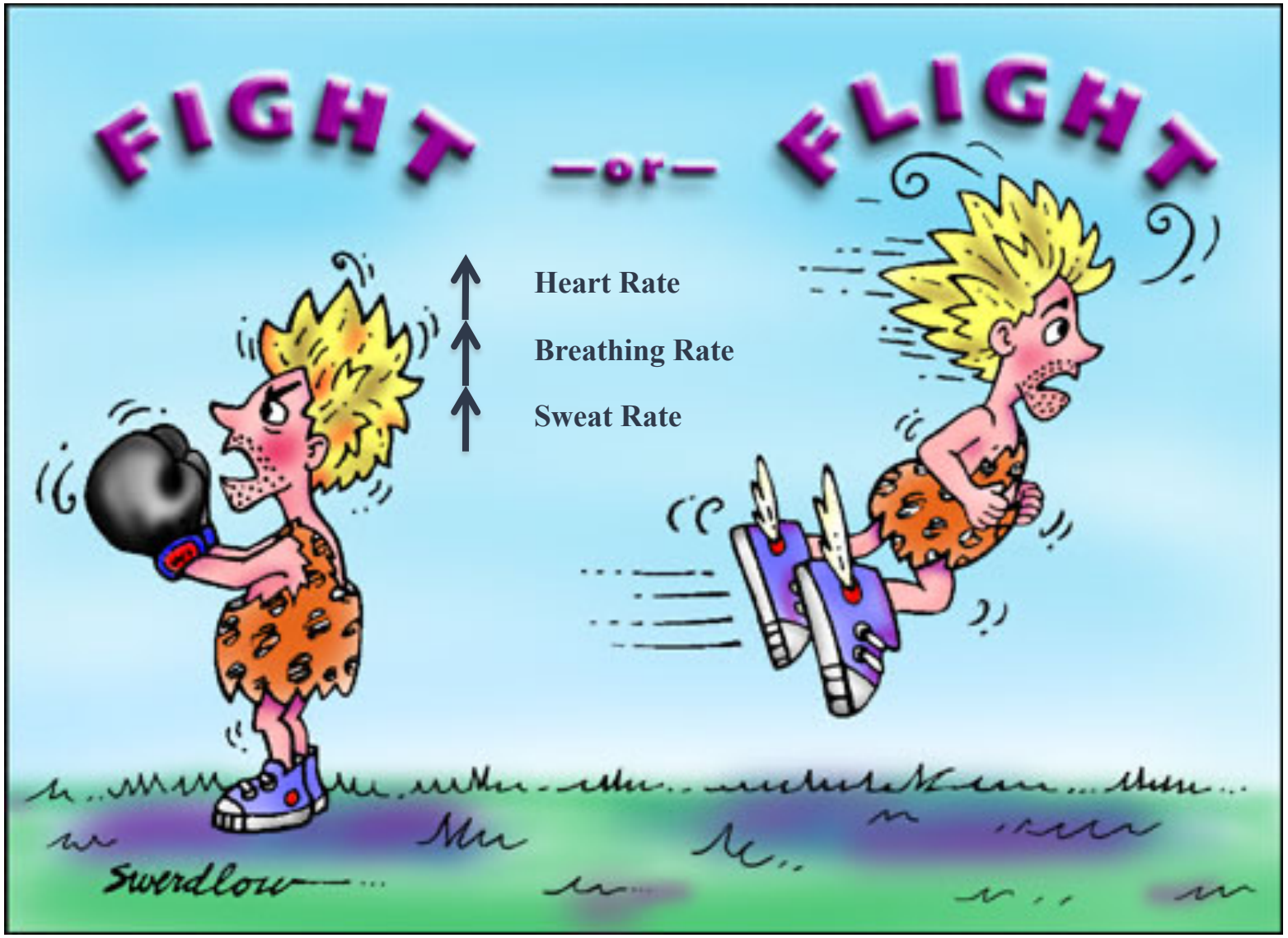
- These adverts are different … they induce a sense of … cute !
- They’re meant to make you smile, you may even have laughed a bit (go on, admit it)
- You get a warm fuzzy feeling inside when seeing these

- When advertisers want to measure the impact of their adverts they measure the reaction of subjects (like you and me)
- The traditional approaches to this are to use
  - Questionnaires, easy and can be done at scale
  - Self-reporting relying on people reporting back themselves
  - Interviews with subjects one-on-one
  - Focus groups or meetings with small groups and a structured discussion

- Problems with these include
  - A time lag between seeing the stimulus and having to describe the reaction afterwards
  - Memory – not being able to remember exactly and to what intensity you connected with the stimulus
  - Subjective judgments – one person might be a hard judge and slow to rate highly whereas another might be more generous, for the same content
  - Difficulty in verbally describing their emotions/response … remember in MOOC-1 where we discussed vocabulary and memory where we may not have the words or the language?

- So this begs the question of whether there are valid and objective measurements of psychophysiological responses to a stimulus … i.e. can we measure our physiology and how it changes when we experience a stimulus
- Our bodies have evolved a basic (sympathetic) nervous system which reacts to an unexpected stimulus in one of two ways … we're either going to fight, or flight, and our physiology reacts

(see text in note)



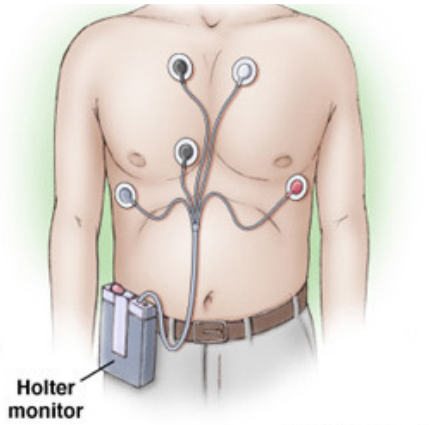
Measuring Heart Rate

- Heart rate can be measured by
  1. feeling the pulse at wrist or temple
  2. listening to the chest
  3. sensing the electrical pulses via electrodes
  4. Sensing minute changes in blood flow via photoplethysmography

- (1) and (2) are ambulatory, for emergency response while (3) and (4) can be embedded in wearable sensors

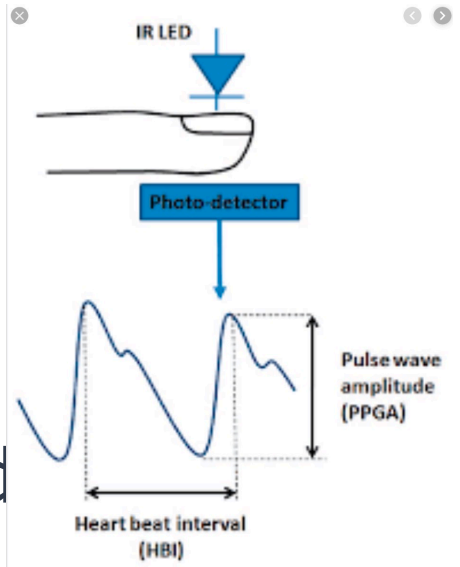
Measuring Heart Rate

- Sensing HR electrically needs electrodes placed on the body like in a holtar monitor, a hospital intensive care unit or a consumer-level wearable as a chest strap connecting to a watch (but the watch itself is not measuring heart rate here)



Measuring Heart Rate

- Measuring HR using photoplethysmography (PPG) is an optical technique measuring blood flow changes based on shining an LED into the skin and sensing colour changes using a second LED which reads the light form the first LED
- Used on watches like Apple Watch where you see 2 LEDs flashing (green) light and 2 LEDs "watching" for changes in light



Measuring Heart Rate

- Heart rate is fairly straightforward, the measure is the number of heartbeats per minute (bpm)
- It is regulated by our autonomic nervous system and changes as follows:
  - Sympathetic activity like exercise leads to increased HR
  - Parasympathetic activity like yoga relaxing or a trained athlete before start of a race leans to reduced HR
- Heart rate variability (HRV) is beat-to-beat variation within a time window and is an indicator of wellness

Measuring Blood Pressure

- Blood pressure (BP) normally rises and falls throughout the day but persistently high is bad, long-lasting is called hypertension
- BP normally measured by a health practitioner as its **two** numbers, pressure when it beats, and between beats, and uses a cuff around the upper arm
- BP changes slowly, not instantly, so it’s a longitudinal measure
- Smartphones already have a wide array of sensors inside, but can't measure BP — at least not yet

Measuring Blood Pressure

- To begin BP measurement, use a blood pressure cuff like one of these

DCU

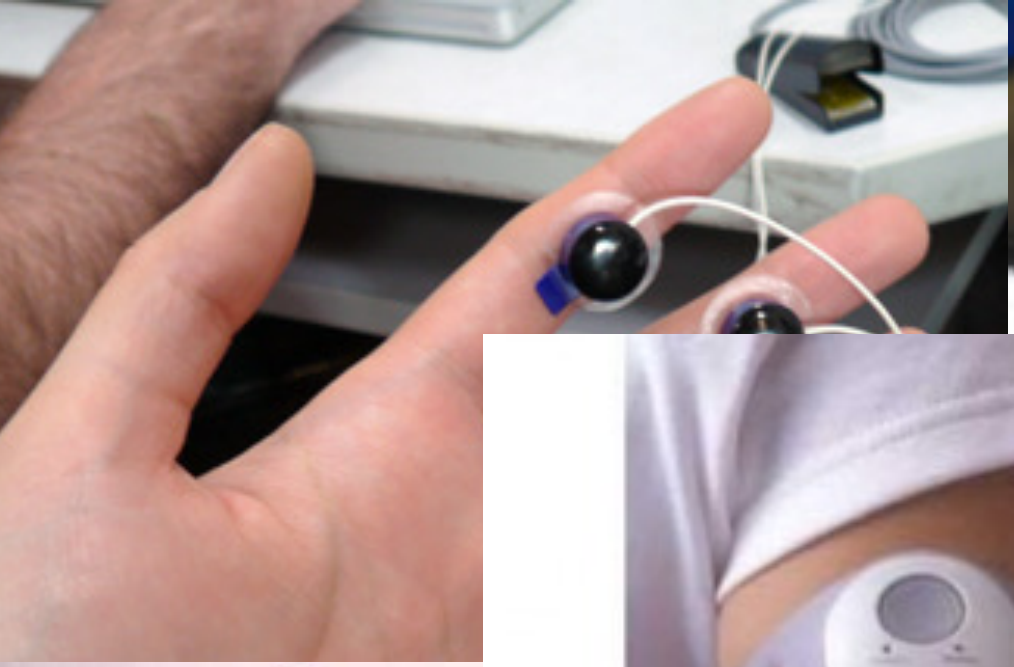
Measuring Respiration

- Respiration is a really good indicator of the body's state, but really difficult to measure.
- Respiration rate is breaths per minute but these could be deep, or shallow, so also need the volume of air breathed
- Gold standard is a face mask (awkward, cumbersome) but wearable vests that measure expanding/contracting chests are now available

DCU

Measuring GSR

- Galvanic Skin Response (GSR) measures our skin's response to (mostly) emotional stimuli like stress
- Appears as sweaty palms and elsewhere and we can sense this by measuring the electrical conductivity of the skin (when its wetter it conducts electricity better)
- Not the same as perspiration caused by over-heating





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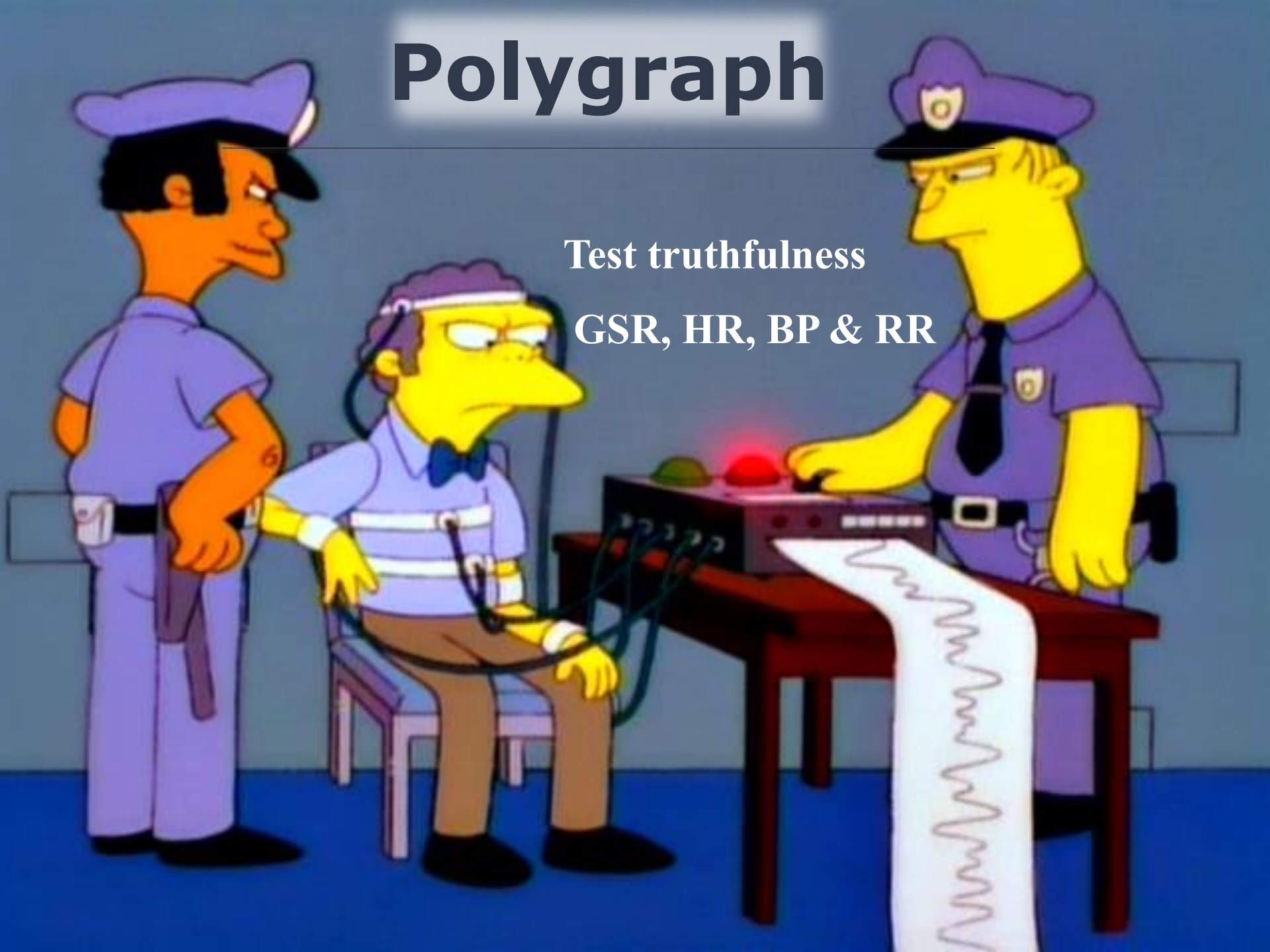
Polygraph

- One (popular, common) use of sensors together is a polygraph
- Measures several physiological indicators such as BP, HR, respiration, and skin conductivity while subject is asked and answers a series of questions

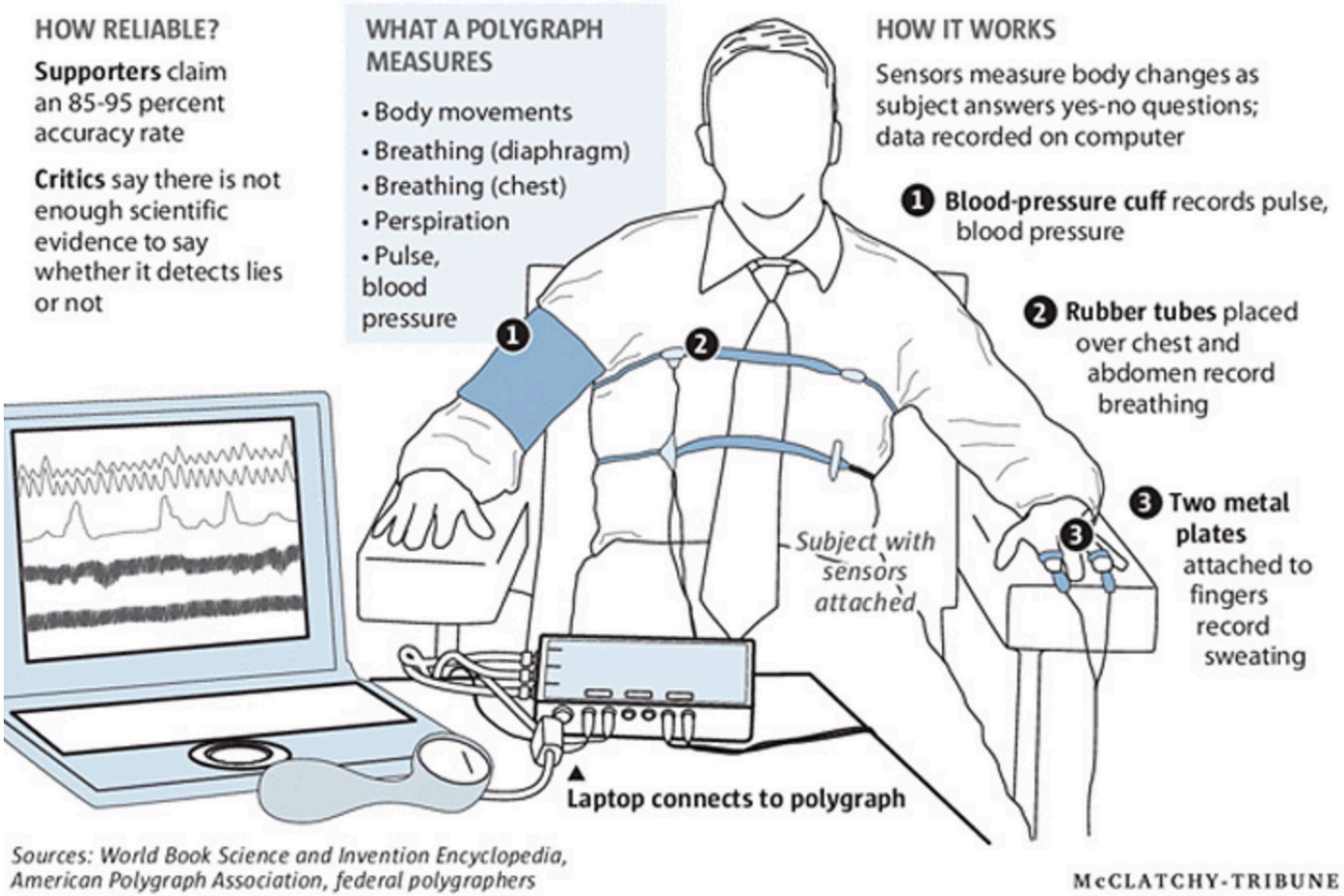
Polygraph



- From ”The Simpsons”…. https://www.youtube.com/watch?v=a1pWCkW95W0

Do polygraphs detect lies?

Polygraph, or "lie detector" exams, continue to be used by law-enforcement and government agencies for various screenings even though most criminal courts ban polygraph evidence.



- What does all this tell us …

- … we can measure record different aspects of our physiology and use that data to analyse human responses to stimuli or normal daily human activities, sometimes in real time, using portable and wearable technology
- It is specialist and niche, but not for long
- Lets look at one such activity … sleep

This is your life

79 YEARS
28,835 DAYS

The one activity you spend most of your life doing is sleep. But how does it compare to work, socialising and laughing? The average human spends roughly 79 years, or 28,835 days on Earth. Each bead in this jar represents one year.

IN BED	WORK	SCREEN TIME	EATING	HOLIDAYS
ROMANCE	SOCIALISING	EXERCISE	SCHOOL	THE REST

Sleep Explained

- Sleep is “active”, our brains do not shut down and are almost as active, cataloging memories
- Sleep 5 stages – wake, relaxed wakefulness, light sleep, deep sleep and REM sleep
- Starts from N1, goes through N2 to N3 (deep) and then back up towards REM sleep, there is an ordering
- The first sleep cycle is usually shortest at 70–100 minutes. Later cycles are 90–110 minutes.
- If you sleep for 8 hours, you have 5 full cycles

Sleep Explained

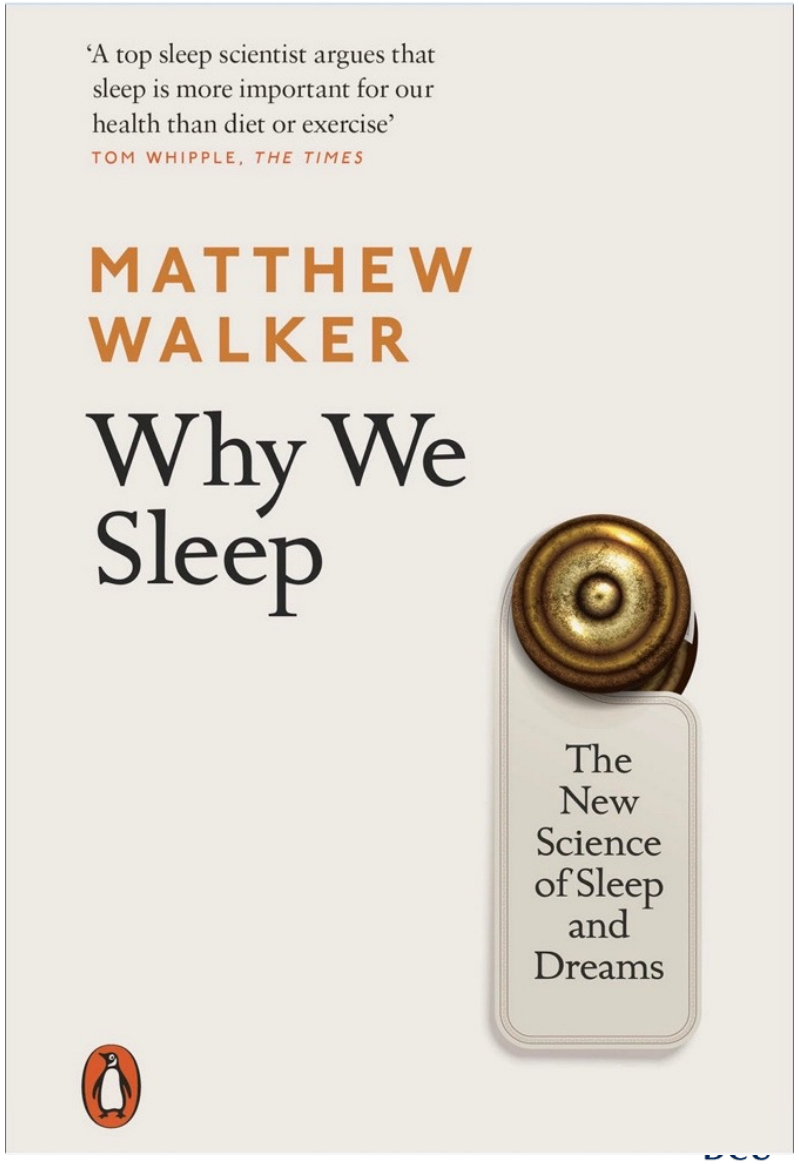
- Each phase has characteristics
  - REM – body paralysed, HR, RR increased, body temperature drops, vivid dreams, brain active, towards latter end of the night, memory consolidation
  - N1 – conscious of surroundings, hypnic jerks
  - N2 – brief arousals, decreased HR, RR
  - N3 or deep sleep – slowest HR, RR, difficult to wake and then groggy

Why is sleep important ?

- It is believed that during sleep we re-live (parts of) our day, deciding which parts are more/less important and worth remembering
- Insufficient sleep makes you more stupid, fatter, unhappier, poorer, sicker, worse at sex, more grumpy, more likely to get cancer, Alzheimer's and more likely to die in a car crash ! Who says … see book on next slide.
- Recent years have focused on this, we're more aware, partly because we ourselves can now measure it, exploiting its structured, predictable, and characteristic nature
- **Orthosomnia -** preoccupation with perfecting sleep data

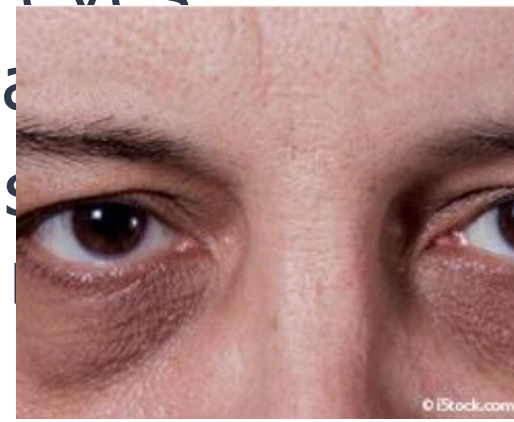
Why is sleep important ?

- This book has done a lot to highlight its importance



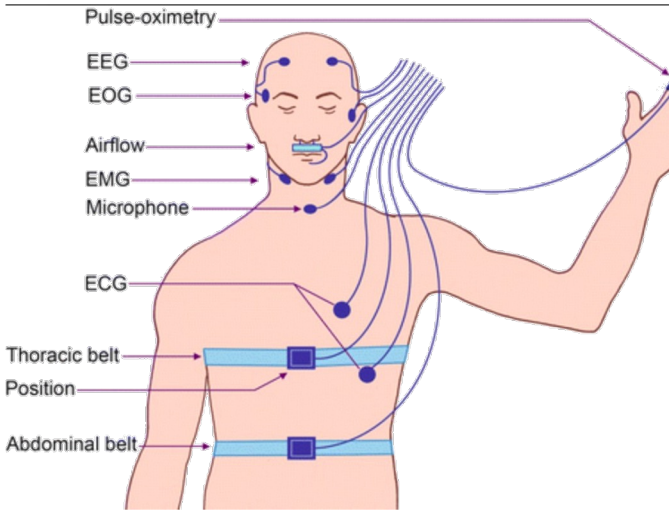
Sleep and Appearance

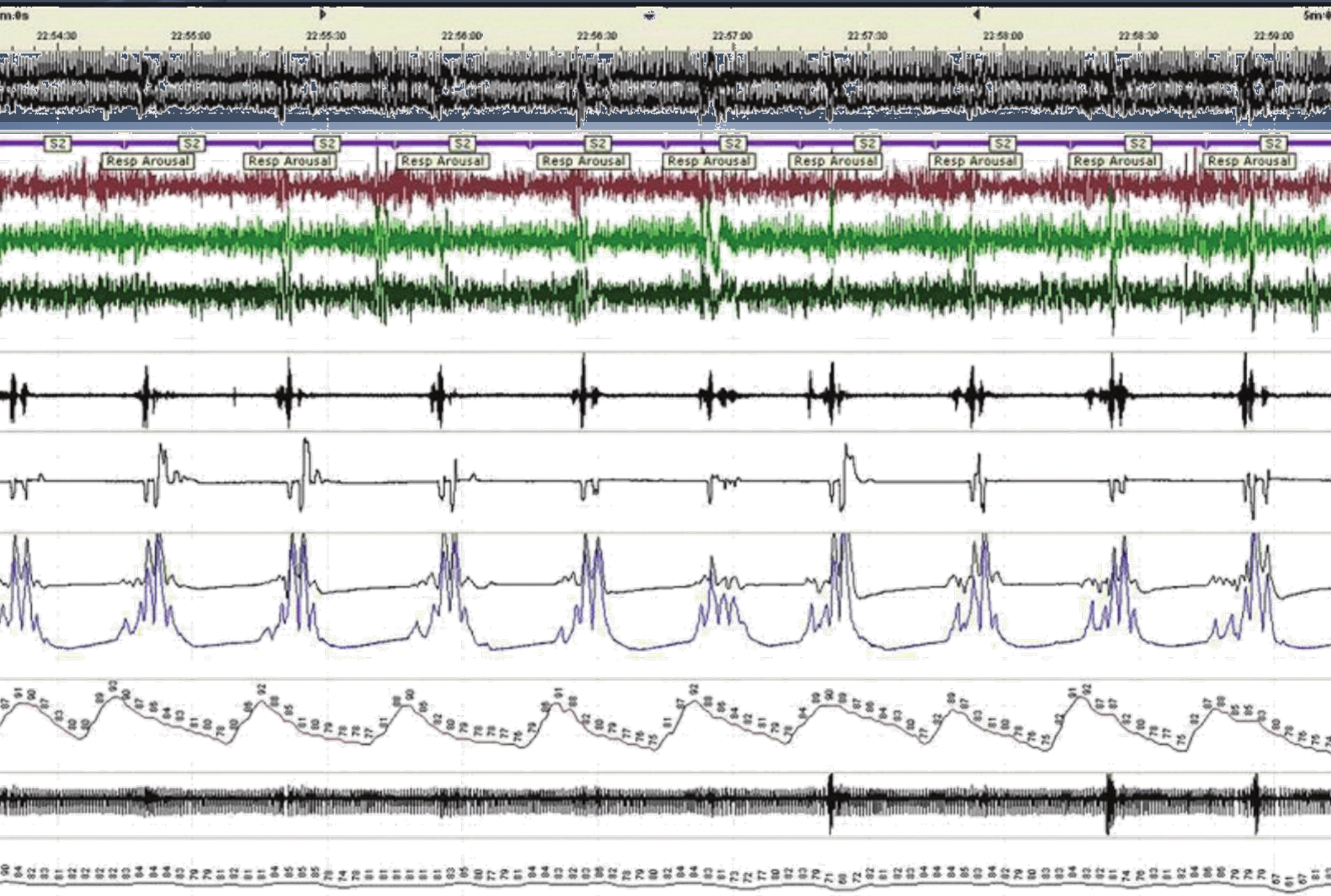
- Insufficient sleep leads to reduced blood flow to the skin in the face, so complexion is drab, ashen and reveals dark areas
- Leads to dark circles under the eyes topical creams used to camoufla
- Also more wrinkles because less collagen produced, puffy eyes, "glow"
- … and … you don't look happy



Measuring Sleep (Properly)

- Sleep labs record EEGs (electroencephalograms, recordings of brain activity), body and eye movement, HR, HRV, RR, Oxygen saturation, etc.
- They pool all these into a polysomnograph for an holistic overview of sleep, which looks like …





nutes trace of polysomnography in stage 2 sleep revealing reccurent episodes of central and some mixed apneas leading to marked
rations and arousals.

Sensing Sleep – Our Options

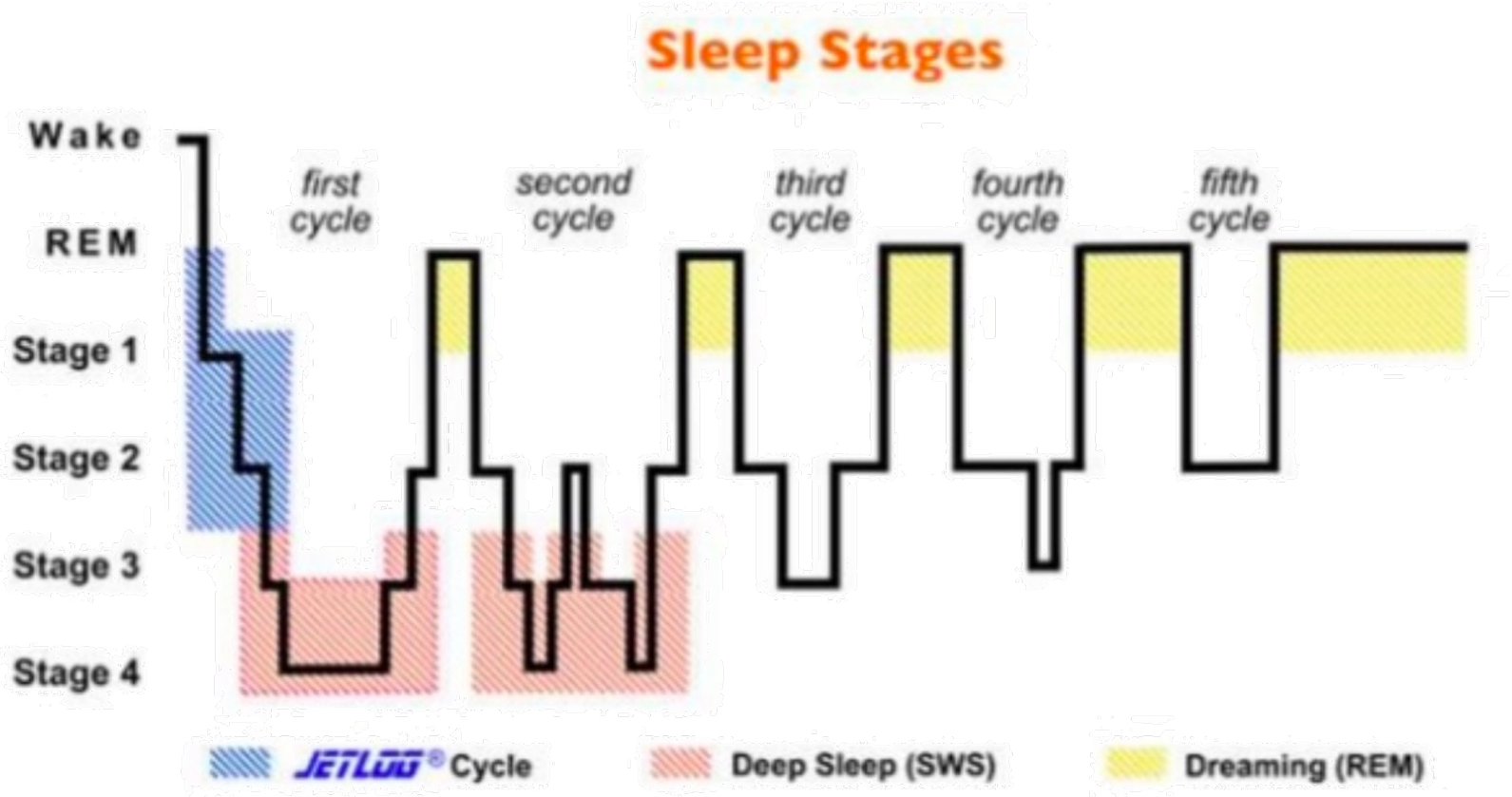
There are consumer-level techniques for measuring sleep which are being used by ordinary folks .. like me !

1. Phone apps
2. Wrist-worn accelerometer devices
3. Movement radar or sonar
4. The Ōuru ring

Each of these uses a subset of sensors to map the sleeper into different phases of sleep and then depending on completing the cycles, and time spent in deep (restorative) sleep, they can "score" your night's sleep.

A night's sleep is presented as a hypnogram

Presented as a Hypnogram



1. Smartphone Apps

- How do they work ? Phones record different things depending on where they are placed ..
  - Movement (if in the bed, under the pillow)
  - Microphone (if beside the bed, actually listening to your breathing whether its deep and slow, or fast and shallow)
  - Sonar – inaudible frequency emitted by the phone's speaker and listened to by the phone's mic, picking up your movement and respiration, just like bats navigate !
- There are many available apps, some are freebies, some are paid
- SleepScore, Sleep Cycle, Pillow, etc.

2. Wrist-worn Accelerometers

- Examples are FitBit, Jawbone, Withings, LARK, etc.
- These "just" do movement but directly from the arm, so more accurately than phone apps
- They then sync with smartphone and upload data to the cloud for processing

3. Sonar / Radar

- Developed by an Irish SME BiancaMed which sold it to ResMed which developed the “S+” and was first to market
- A box beside the bed emits very low levels of transmitted radio-frequency power acting as sonar to detect in-bed movement
- Contactless, measures your motion, plus from the phone it logs room temperature, brightness and noise level (yes, your phone is listening to you as you sleep)

4. The Ōura Ring

- From a Finnish start-up, a (finger) ring with in-built accelerometer and gyroscope and also measures body temperature, and heart rate
- HR sampled using IR spectrum light from 2 LEDs at 250 Hz so able to do much more than wrist-worn HR sensors
- Contactless battery charge lasts 7 days, data capacity 6 weeks
- Low power Bluetooth download to phone

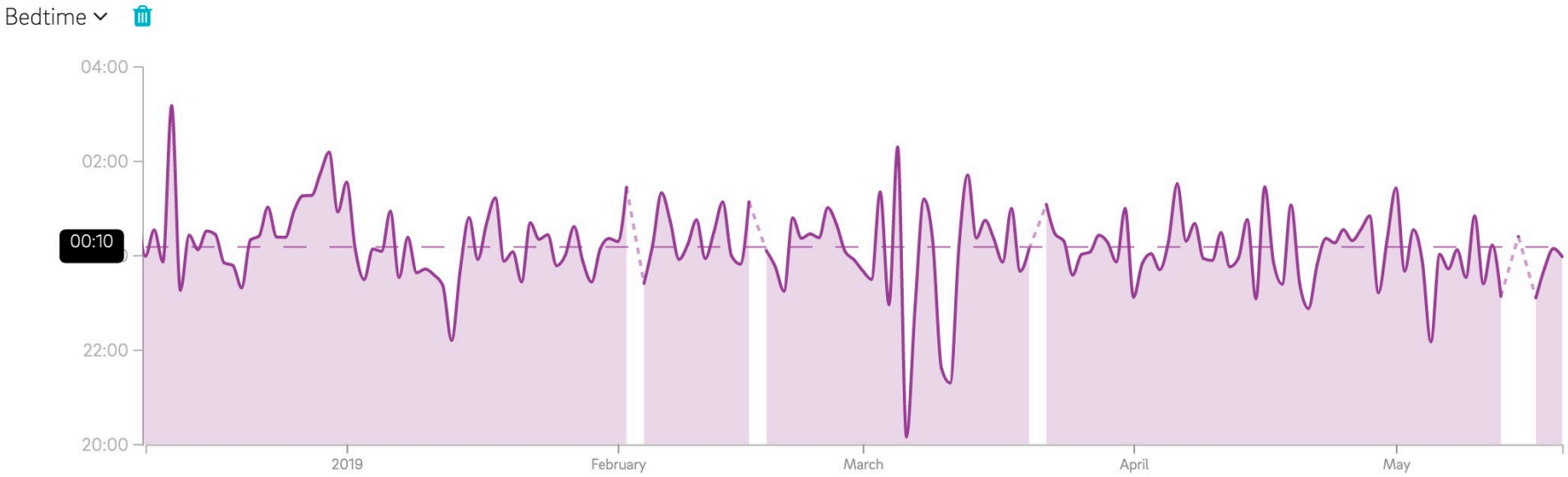
ŌURA

Accuracy of sleep tracking ?

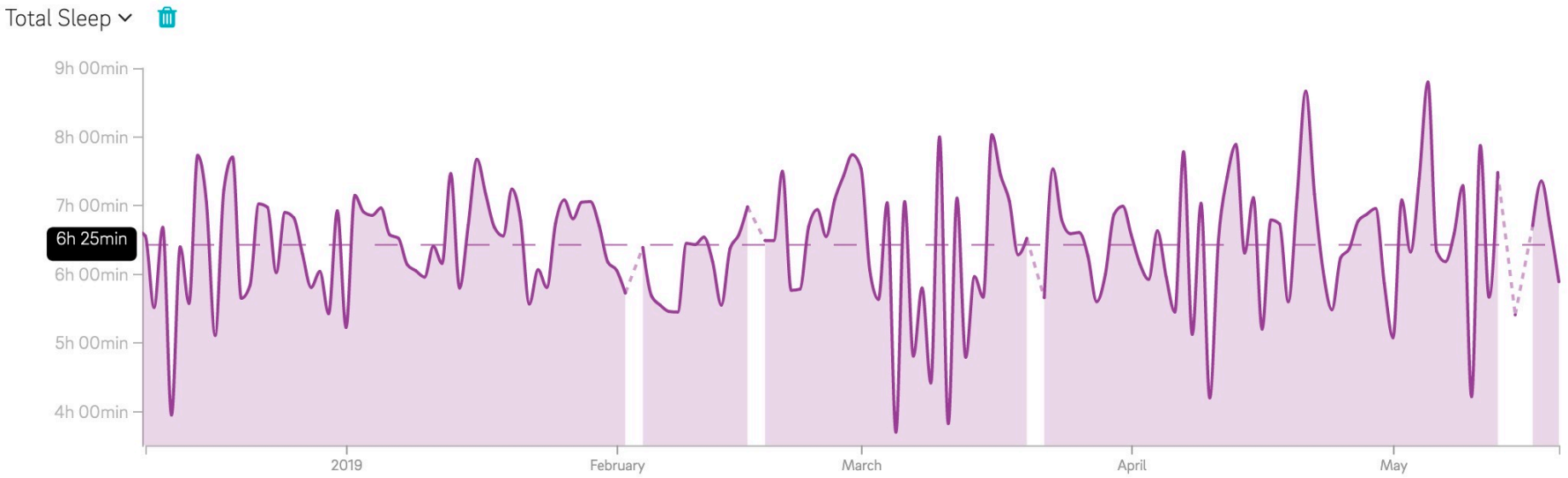
- Consumer grade wearables like the ones we've een are not sleep labs, they use a proxy for an orchestra of sensors !
- Each individual sensor will have errors (movement, sweat, etc.)
- The algorithms to compute "sleep efficiency" are opaque and proprietary

And what about Alan's Sleep ?

- Here's a sample of summary data over 6 months … gaps are when I was travelling

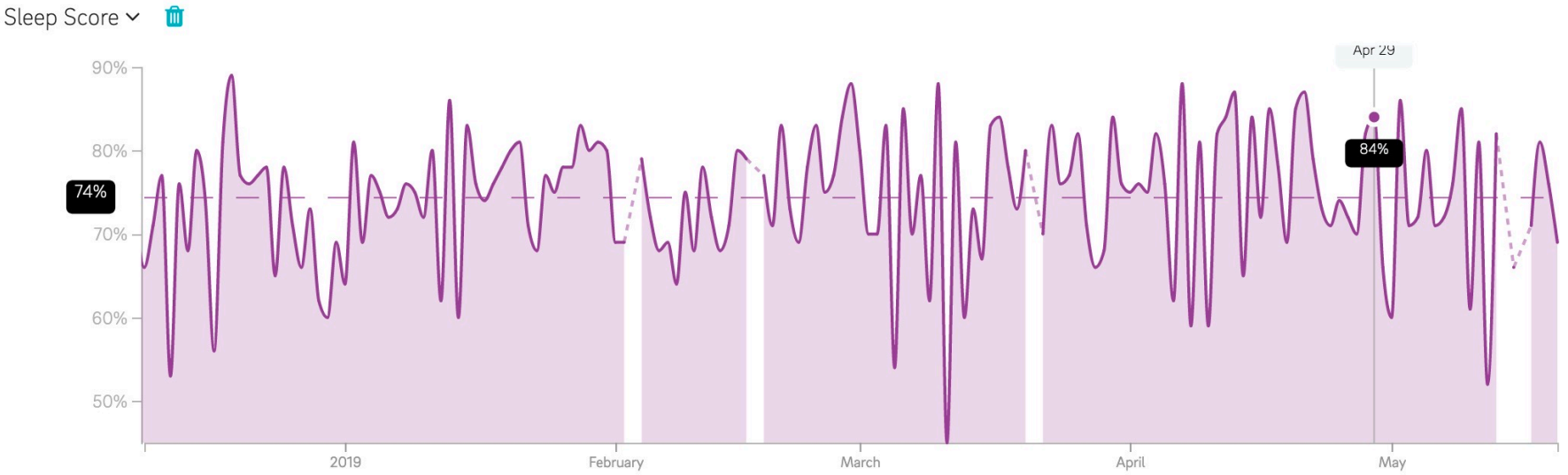


And what about Alan's Sleep ?



DCU

And what about Alan's Sleep ?



So what to do with this information ?

- Some use it to inform or influence day-to-day activities
- Some look at trends, but the trends don't say a lot because other factors influence those trends (travel, vacation, stress, colds and flu, sports events, etc.) and we can't see those.
- That's because sleep apps, activity apps, health apps, all work independently of each other, not synchronised
- So there is not a lot we can actually usefully do with our own sleep data or any other lifelog data
- We can't easily integrate it or re-purpose it and because it reports day-at-a-time information its difficult to get useful longitudinal analysis.

Aggregating health sensor data

- There are two ways in which we can pool or aggregate individual wearable sensor data for some benefit

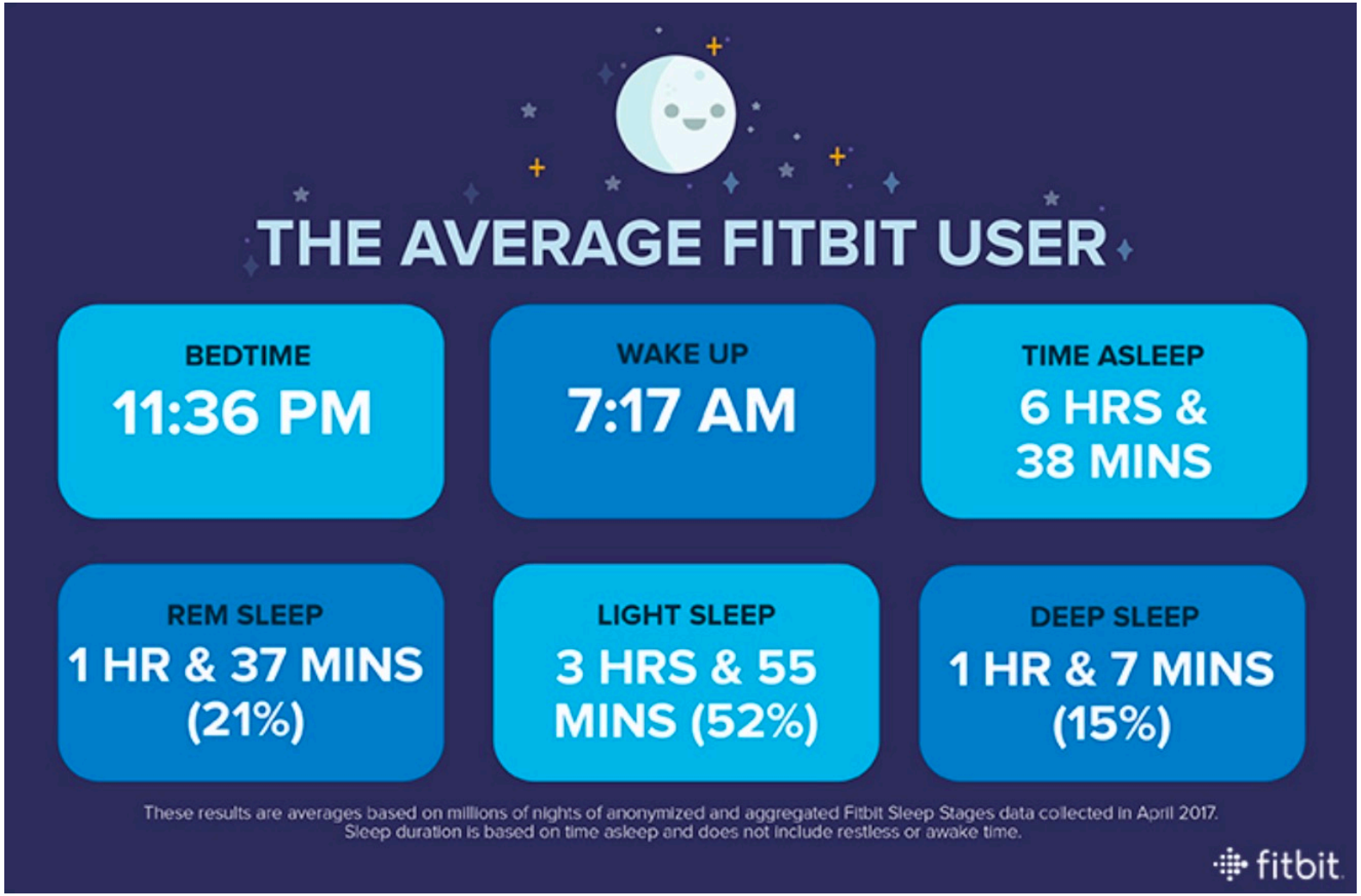
1. We can aggregate our own personal data with data from other users, across a population
2. We can aggregate our own personal data from different apps/sensors

Population-level Analytics from Pooled Individual Data

- Almost all vendors who allow us gather individual data, get value from pooling anonymised data
- Let's look at 4 examples

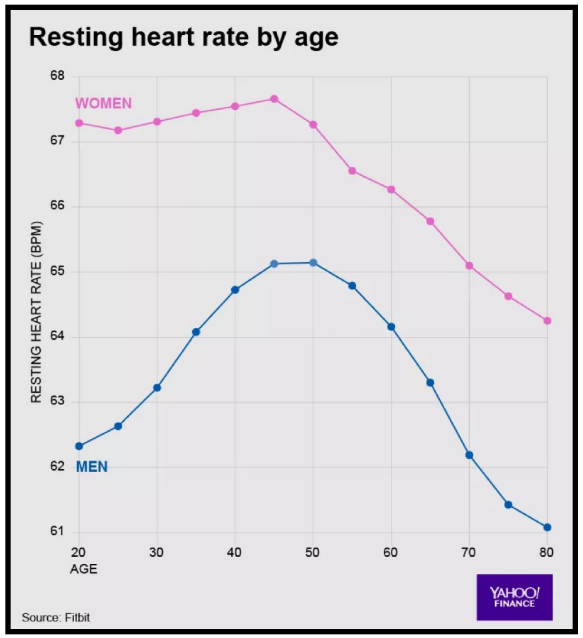
Population-level Analytics from Pooled Individual Data

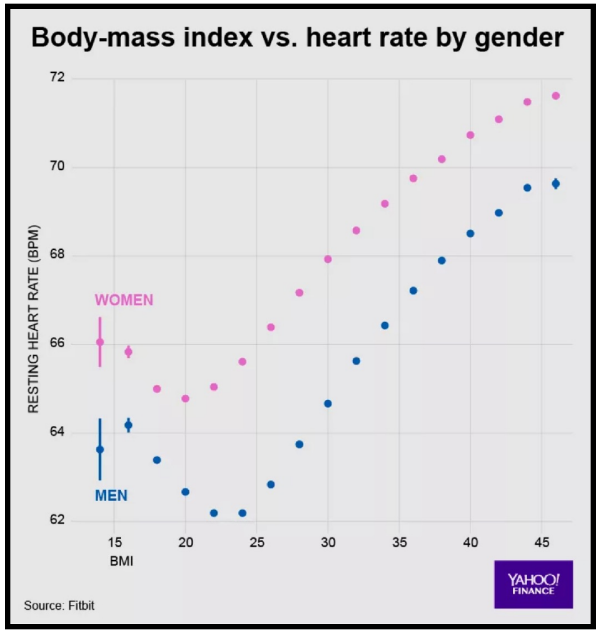
- Fitbit – wearable wrist-worn activity logger and sleep recorder
- Fitbit mined 150B hours of heart rate data, gathering statistics from millions of sleep nights and discovered the following

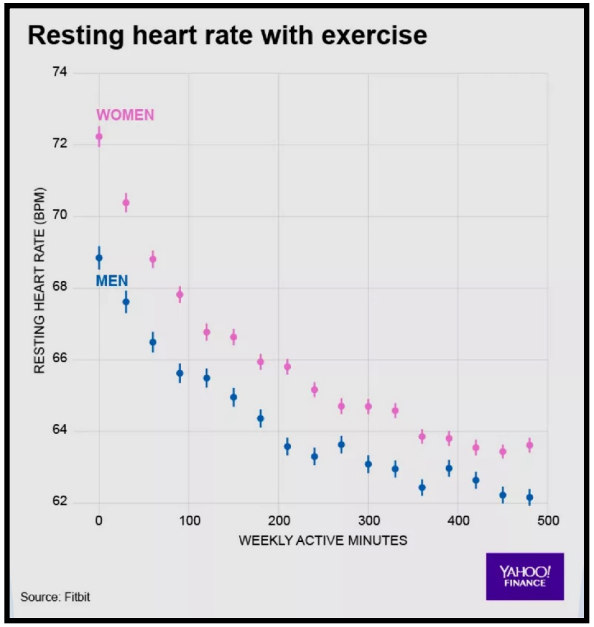

THE AVERAGE FITBIT USER
BEDTIME
11:36 PM
WAKE UP
7:17 AM
TIME ASLEEP
6 HRS & 38 MINS
REM SLEEP
1 HR & 37 MINS (21%)
LIGHT SLEEP
3 HRS & 55 MINS (52%)
DEEP SLEEP
1 HR & 7 MINS (15%)
These results are averages based on millions of nights of anonymized and aggregated Fitbit Sleep Stages data collected in April 2017.
Sleep duration is based on time asleep and does not include restless or awake time.
fitbit

- Some fitbit devices also record heart rate, so they mined that to correlate resting heart rate (a wellness indicator) with body-mass index (a weight indicator), age, and amount of exercise
- They found insights that cardiologists were not aware of

Resting Heart Rate is an excellent indicator of overall health.







https://finance.yahoo.com/news/exclusive-fitbits-150-billion-hours-heart-data-reveals-secrets-human-health-133124215.html

fitbit®

DCU

Population-level Analytics from Pooled Individual Data

- 23andMe is a DNA testing company who's catchphrase is to allow you to "meet your genes"
- From a saliva sample they synthesise your DNA and search it for DNA markers which
  1. Reveal your ancestry
  2. Report your Genetic Health Risks (whether you have genetic variants associated with increased risk for certain(+200) health conditions) and Carrier Status (detect genetic variants that can cause inherited conditions)

Population-level Analytics from Pooled Individual Data

- 23andMe provides benefit to the individual (gene markers) but even more benefit when data is pooled in order to connect relatives and determine actual exposure risk to diseases based on population analysis

Population-level Analytics from Pooled Individual Data

- Earlier we mentioned Strava for running/cycling using a smartphone or watch to record runs or bike rides
- It logs (GPS) location and from that it gives time, pace, elevation gain and profile, power output (bike), calories, map .. All very useful and interesting for each individual
- But when our data is is pooled, its even more useful

Alan Smeaton – Ride

6 0

5:31 PM on Sunday, July 28, 2019

Lighthouse climb x3

Add a description

21.30 km	1:22:55	524 m
Distance (?)	Moving Time	Elevation

124 W	615 kJ
Estimated Avg Power	Energy Output

With someone who didn't record? Add Friends

STRAVA LABS
View Flybys ›

	Avg	Max
Speed	15.4km/h	62.6km/h
Calories	686	
Elapsed Time	1:25:55	

Show Less

Strava iPhone App

Bike: Endurance Bike

TOP RESULTS

View all

- **PR** on Valentia Island Return from Lighthouse (7:52)
- **2nd fastest time** on Valentia Island Return from Lighthouse (7:53)
- **2nd fastest time** on Feaghmaan Climb - Valencia - Steep Part (6:38)

- Community-created segments are short (or long) parts of runs/cycles where participants can challenge others, or mark their own personal performances on those segments (next slide)

Valentia Island Return from Lighthouse

1.45km 109m 7%

4	7:52	11.1km/h	211W	833	—

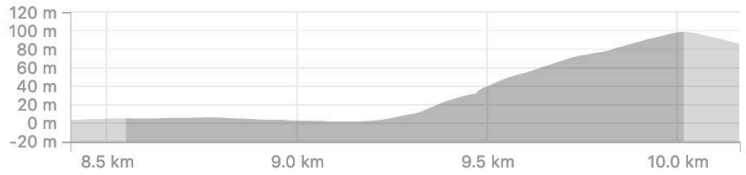
7:52

This Effort

7:52
Moving Time

Analyze	Set Goal
Compare	
Improve your time	

	AVG	MAX
Speed	11.1km/h	28.1km/h
Cadence	0	0
Heart Rate	—	0 bpm
Est Power	211W	—
VAM	833	
Elev Diff	109m	



Top 10

All-time

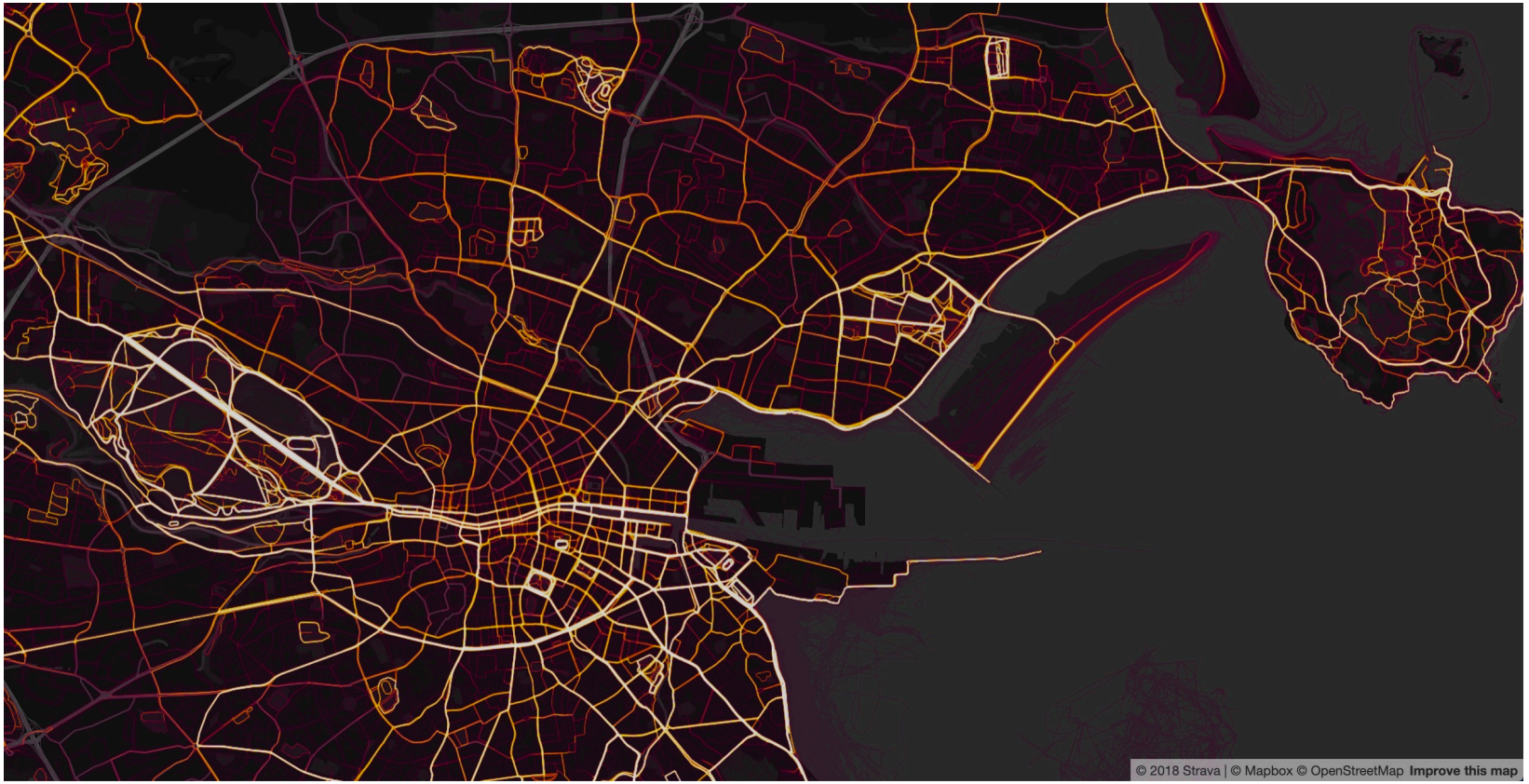
Your PR 7:52
15 /82

	Athlete	Time	
1	Patrick Clifford	5:48	15.0km/h
2	Matt Whelan	6:01	14.5km/h
3	Aidan G	6:03	14.4km/h
4	David Power	6:25	13.6km/h
5	Declan Doorly	6:37	13.2km/h
6	Robert Downey	6:52	12.7km/h
7	Colin Lacey	6:57	12.6km/h
8	Patrick Gallahue	7:08	12.2km/h
9	Rose Holland	7:09	12.2km/h
10	Damien Keaney	7:12	12.1km/h
			...
14	Damien Twohig	7:24	11.8km/h
15	Steve Kiely	7:52	11.1km/h
15	**Alan Smeaton**	**7:52**	**11.1km/h**
17	James Cruickshank	7:58	11.0km/h
18	Alan Bolster SWCC	8:03	10.8km/h

View full leaderboard

- Strava Global Map is an anonymised heatmap of run/cycle routes takenb by all Strava users over previous 2 years, updated monthly, showing areas where people run/cycle
- Next slide is DCU campus, Albert College Park stands out clearly
- Slide after that is running in Dublin, Phoenix Park main avenue is a clear hotspot

Strava Global Heatmap

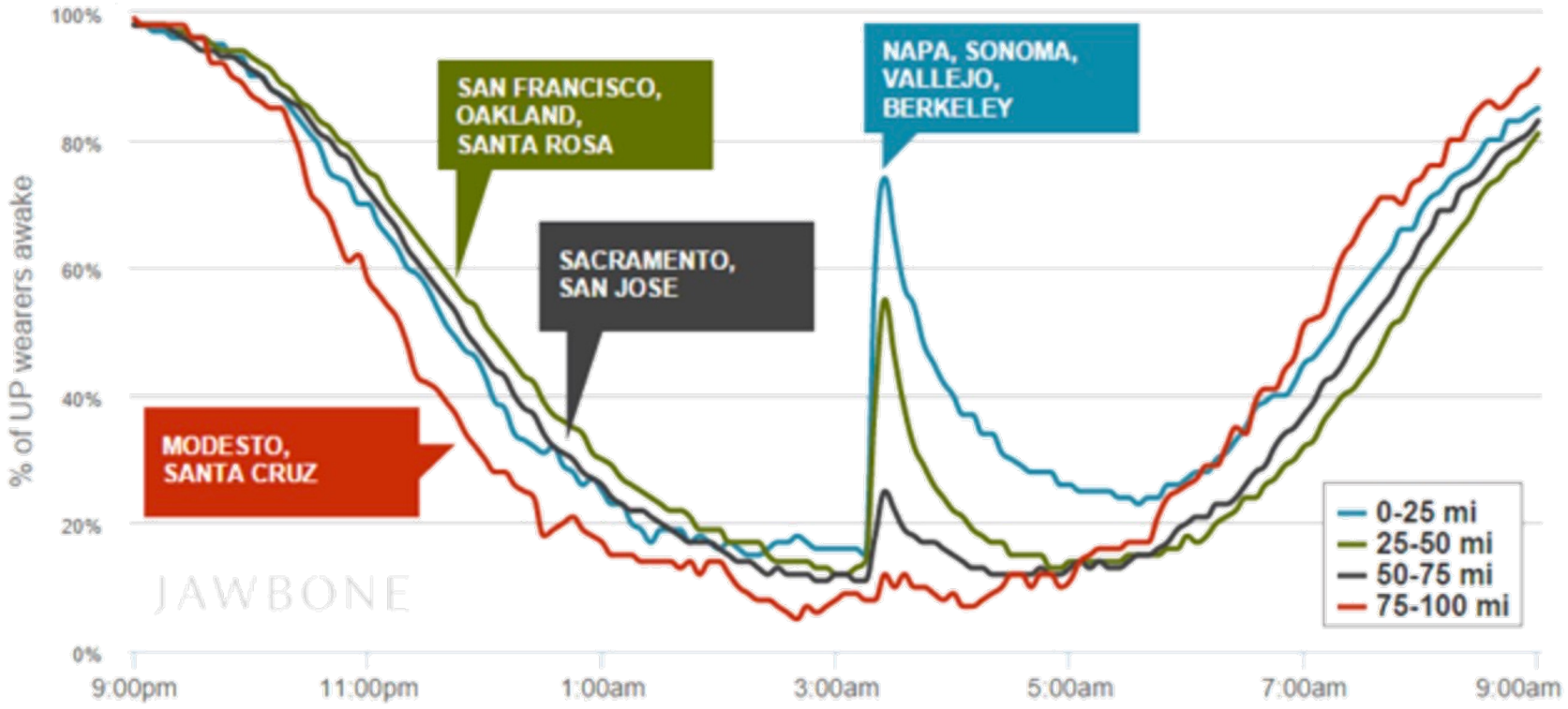

© 2018 Strava | © Mapbox © OpenStreetMap Improve this map

Population-level Analytics from Pooled Individual Data

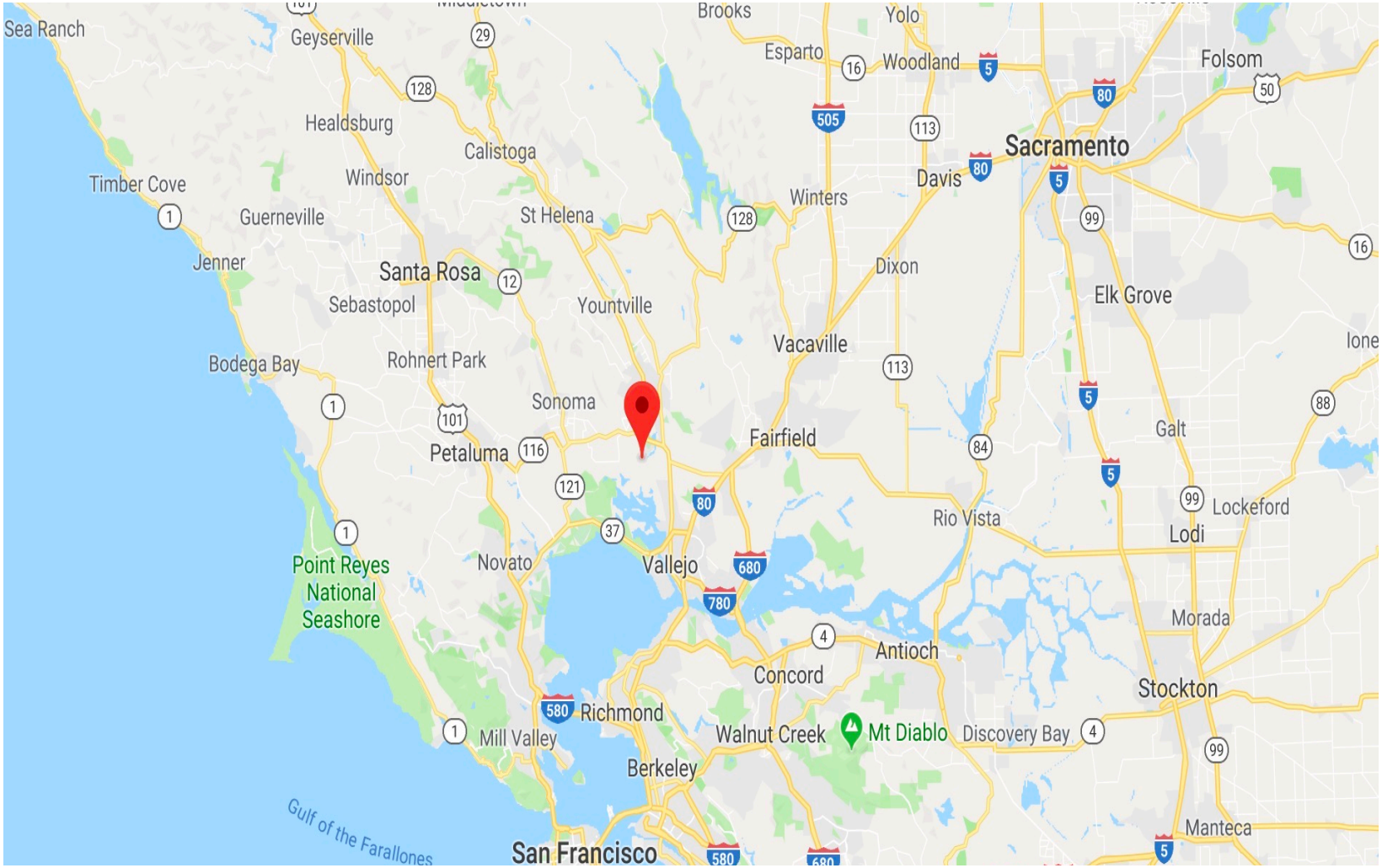
- Jawbone Up is a wrist-worn activity and sleep tracker
- In 2014 a 6.0 earthquake hit Napa Valley in Northern California
- Jawbone mined the sleep data of those using their wearable to determine the % of people in each area woken by the earthquake
- The theory is the stringer the quake in a given area, the greater % of people who will wake up

2014 – Northern Calif. 6.0M Earthquake

% people who woke up correlates with distance from epicentre



DCU


Sea Ranch
Geyserville
Brooks
Yolo
Esparto
Woodland
Folsom
Healdsburg
Calistoga
Sacramento
Timber Cove
Windsor
Davis
Winters
Guerneville
St Helena
Jenner
Santa Rosa
Dixon
Sebastopol
Yountville
Elk Grove
Vacaville
Bodega Bay
Rohnert Park
Sonoma
Galt
Petaluma
Fairfield
Rio Vista
Lockeford
Lodi
Point Reyes National Seashore
Novato
Vallejo
Morada
Antioch
Concord
Stockton
Richmond
Walnut Creek
Mt Diablo
Discovery Bay
Mill Valley
Berkeley
Manteca
Gulf of the Farallones
San Francisco

Aggregating our own Personal Data Across Sensors

- So what about aggregating our own data, across different sensors and apps (as opposed to same sensor aggregated across people)
- Best example of this is Apple HealthKit

Aggregating our own Personal Data Across Sensors

Apple HealthKit

- Consolidates health data from iPhone, Apple Watch, third-party apps
- Activity, Sleep, Mindfulness, and Nutrition
- “You are in charge of your data”
- “The Health app lets you keep all your health and fitness information under your control and in one place on your device. You decide which information is placed in Health and which apps can access your data through the Health app”

Aggregating our own Personal Data Across Sensors

- Apple HealthKit is not the only one though …
- Another is dacadoo, though the revenue model for this is different

dacadoo

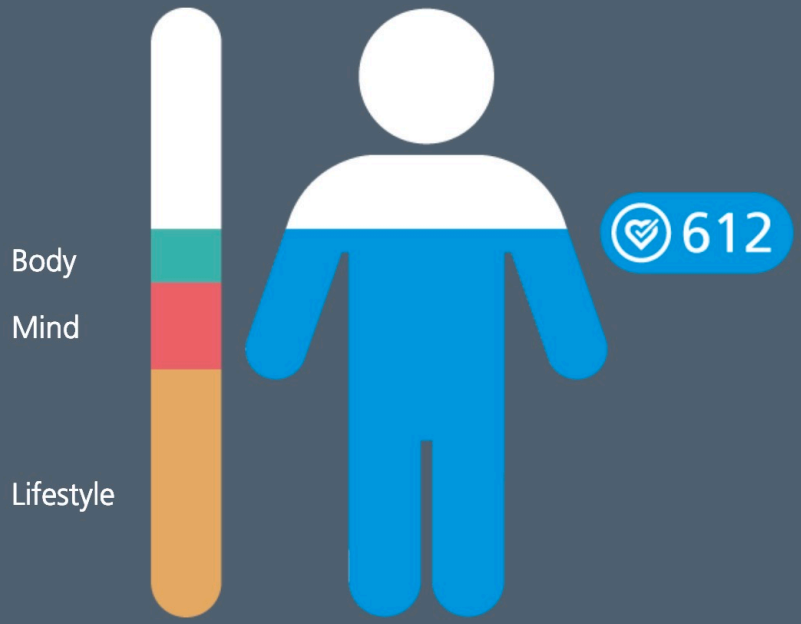
Measure your health with the Health Score

dacadoo

The Health Score Explained

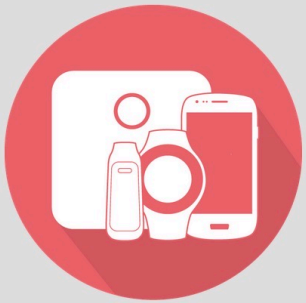
dacadoo measures your health with the Health Score and engages you to actively manage your health and wellbeing in an easy and fun way. The Health Score is a scientifically calculated number from 1 (low) to 1,000 (high) and it is based on who you are (body), how you feel (feelings) and how you live (lifestyle). When tracked over time, it offers a good directional indicator of how your health is evolving.

Find out More



dacadoo

dacadoo is Easy, Fun & Engaging!



1. Track

Track exercise, nutrition, stress, sleep, body values and mental wellbeing.

2. Health Score

Get your personal Health Score, the real-time indicator of your health and wellbeing.

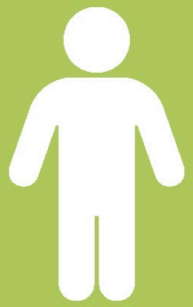
3. Engage

Remain active and engaged with personal feedback, rewards, friends and gaming features.

dacadoo

You Control Your Data

Data Security
All your data on dacadoo is securely protected, using state-of-the-art cryptographic methods to store your data in a data center in Switzerland with logical and physical security.



You

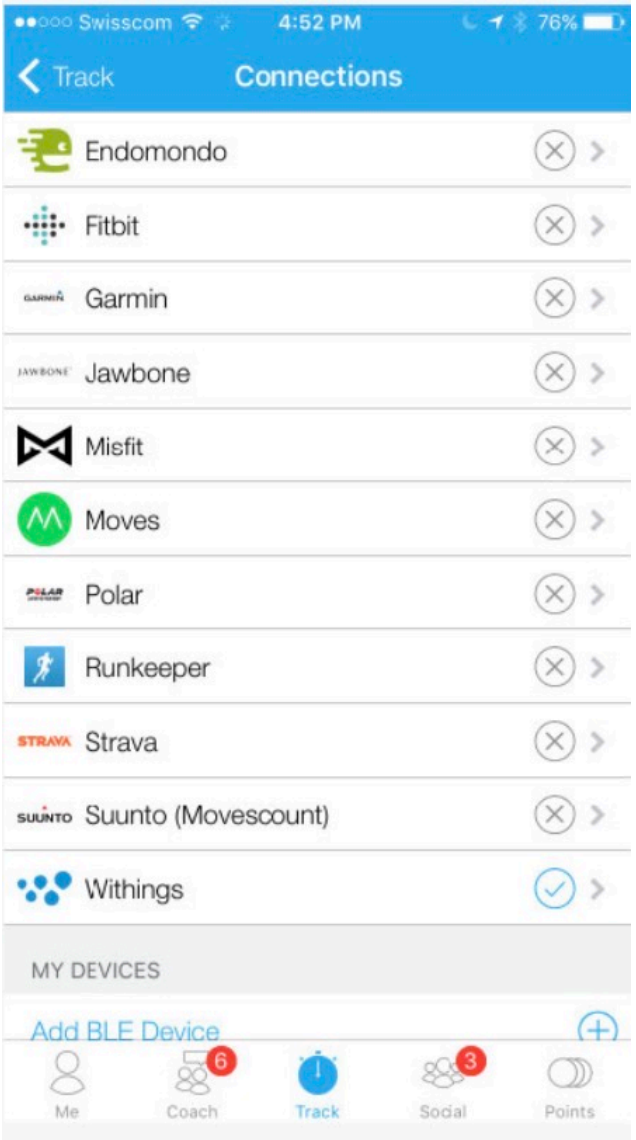
Data Privacy
dacadoo complies with data protection and privacy laws (GDPR, HIPAA). As a user, you decide what you want to share, and what to keep private.

dacadoo

Supported Devices and Apps

dacadoo

- Revenue stream is corporate
- Employer signs up as a service to employees, employees use it, employer gets healthier (more productive) staff



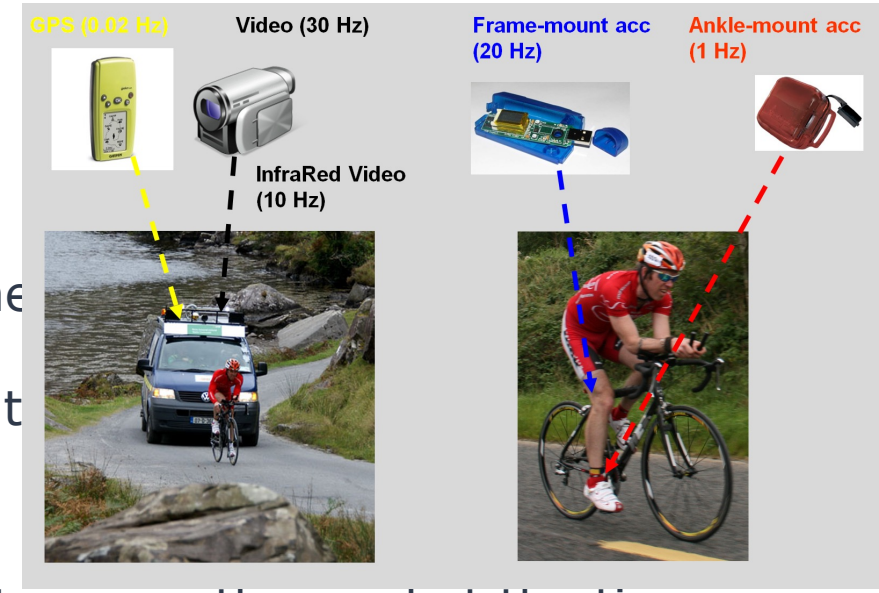
Another Example of Combining Across Sensors

- Another example of how to combine the sensors together, work we did for the *Race Around Ireland* cycle race
  - Non-stop, 1,350 miles, solo or team of 4, some hills, mostly flat;
- Strategy and pacing are key to completion
  - When to rest, how to pace, who to race, recovery;
- Human performance scientists interested in
  - How the human body recovers, how to maximise performance over 4/5-day endurance race, what recovery techniques work best.

Sports - Cycling

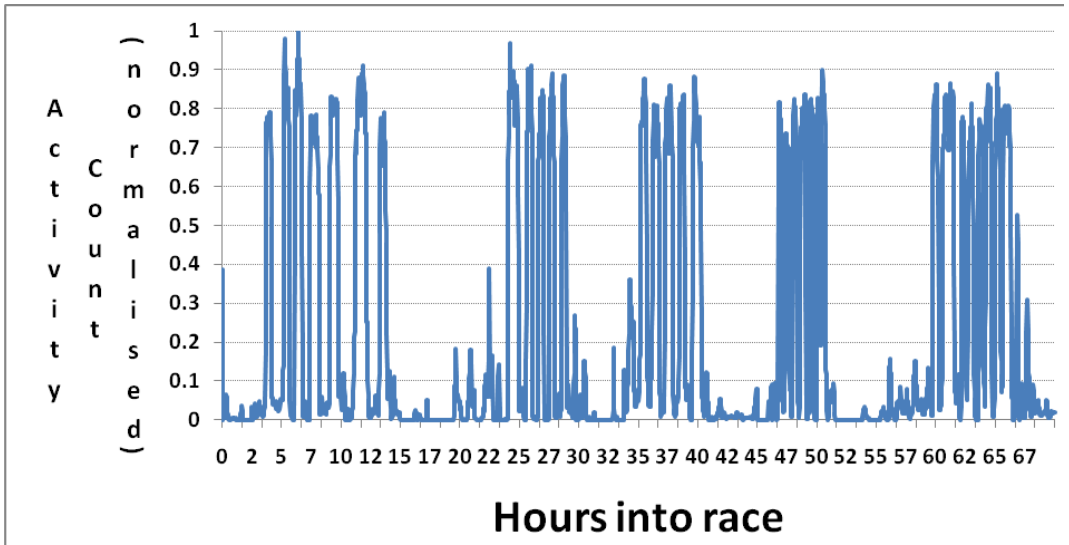
So we instrumented a team of 4 cyclists with sensors

- On Body …
  - Heart rate, GSR, respiration, fluid intake, food intake, sweat analysis, blood analysis, massage,
  - Ankle-mounted WIMU gives cadence, cycle/rest times
- On Bike …
  - WIMU gives yaw and roll of the bike, when cyclist is in/out of the saddle
  - Power gauge gives power output
- Environment …
  - A van followed whichever cyclist was on the road at the time, 24 hous a day for 5 days, recording weather, wind, temperature, road surface, wet/dry, day/night and also did video tracking of the cyclist



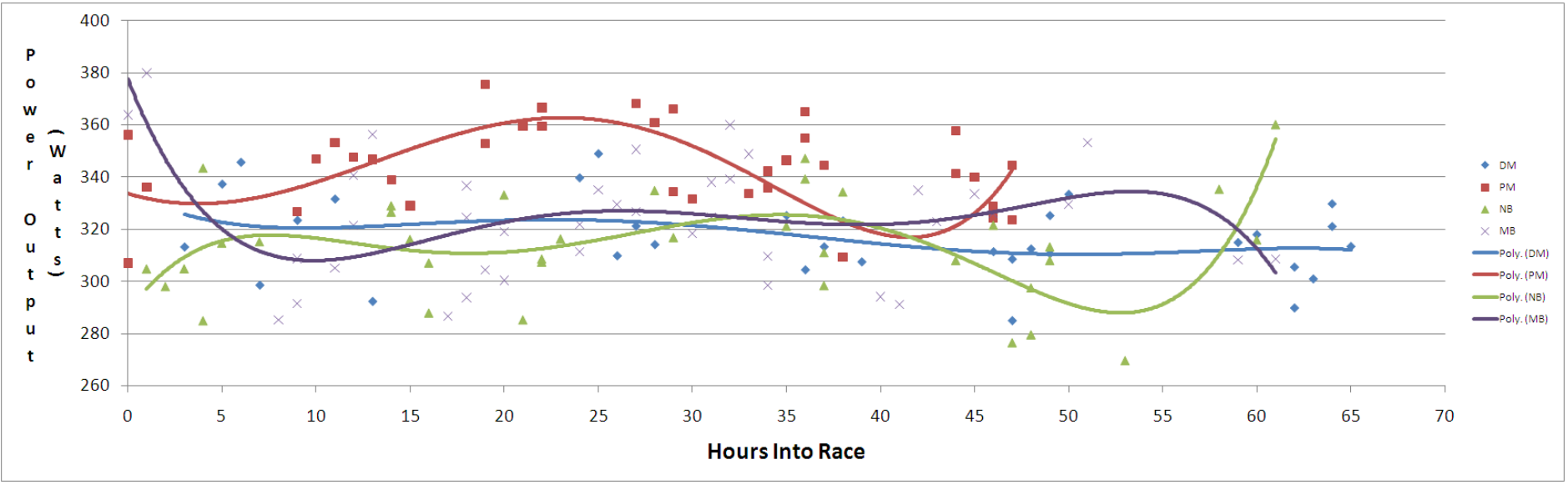
Sports - Cycling

- We aggregated all this data for each of 4 cyclists in the team to study their performance (degradation) over time and the impact of different recovery techniques
  - Insights into endurance performance



Sports - Cycling

- This was their aggregated effort, aggregated from multiple sensors:



Week 4: Sensing the Brain

- The structure of the human brain … neurons firing … electrical signals which we can sense with EEG
- EEG kit and an outline of some variations of it
- What can EEG be used for
- Localising areas in the brain to see what areas are active

- Pareodolia
- ERPs P300
- BCIs

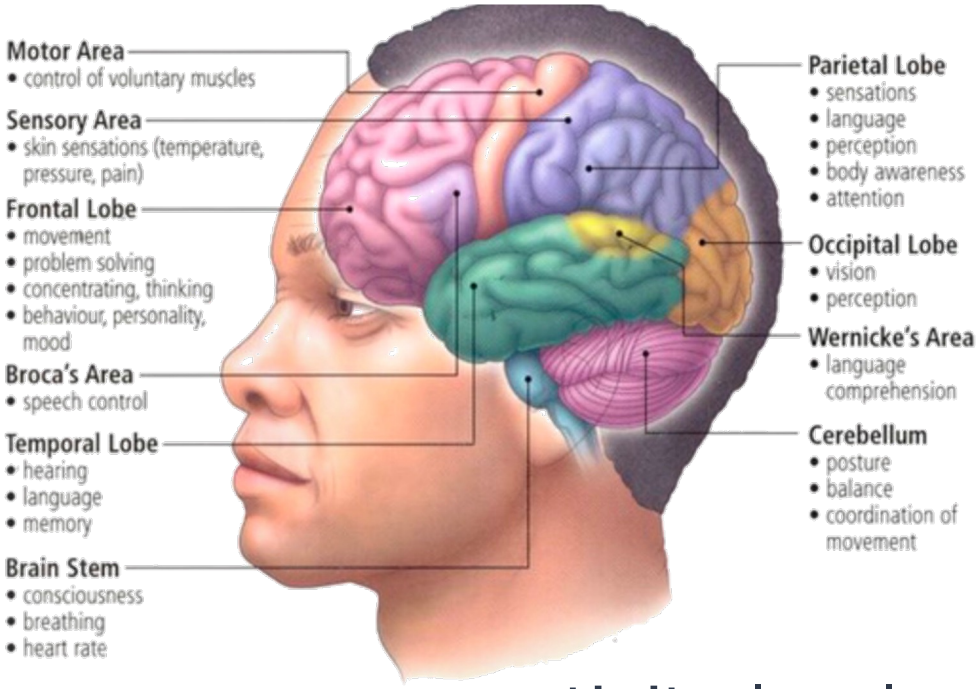
- In MOOC1 we looked at the human brain and memory and forgetting
- We also referenced the human brain when covering sleep and how EEGs which measure brain activity form part of polysomnographs
- Now lets look at the structure of the human brain and how it works and how we can sense it

The Human Brain

- 1.5kg, or 2% of our body weight, made of 86B neurons (grey matter) connected by trillions of connections (synapses) which transmit electric pulses as messages
- This architecture of huge number of simple connected processors, is now realised as good for solving very complex problems, like vision, and learning
- (That's why we have deep learning and "AI")
- The brain is responsible for executive functions both autonomic (heart, breathing, digestion, etc.) and voluntary, in addition to executive functions like self-control, planning, reasoning, memory and abstract thought.

Human Memory

- The brain has been coarsely mapped so we know which areas are responsible for which kinds of function



- So if we can measure activity levels at given points in the brain, we know what kind of "work" the brain is doing

Human Memory

- Like the Human Genome Mapping project which ran 1990-2003 and who's task was to map the sequence of DNA base pairs that made up the human DNA, there is a brain mapping project, announced by Obama in 2013, to create a dynamic picture of the functioning brain, value $100M
- Dwarfed by the EU's €1.5B Human Brain Project, 2013-2023, largest scientific EU project ever, 100 Universities with the following 6 themes:

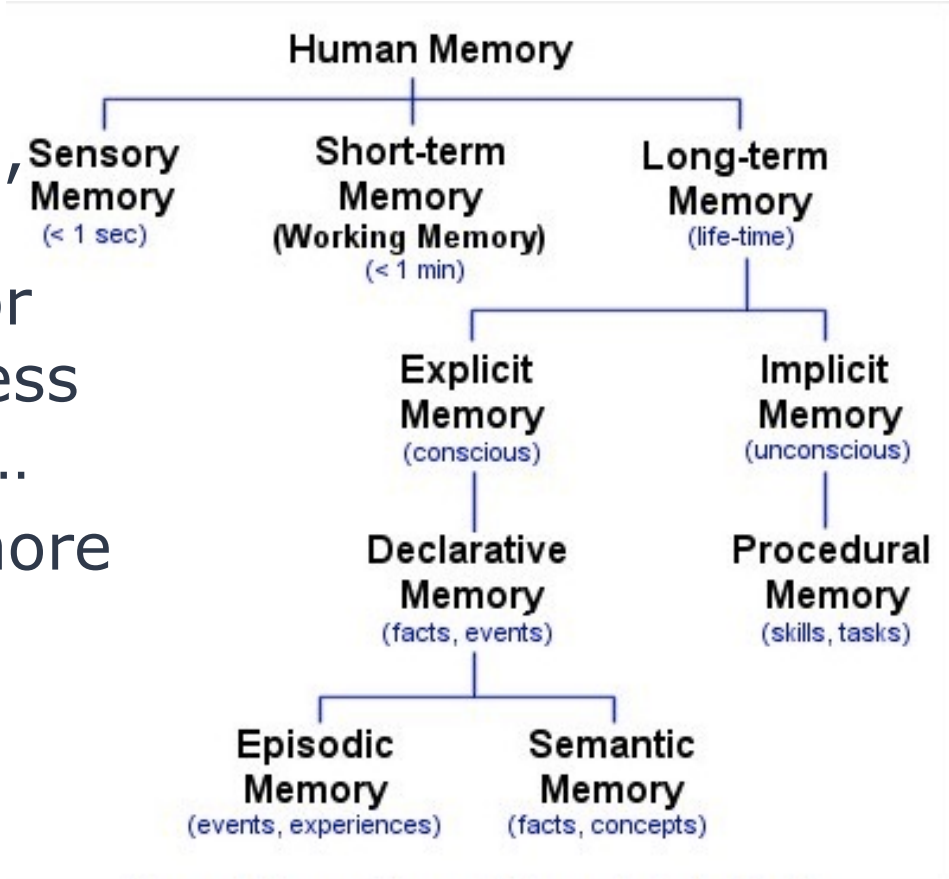
Human Brain Project - Structure

- Neuroinformatics (access to shared brain data)
- Brain Simulation (replication of brain architecture and activity on computers)
- High Performance Analytics and Computing (providing the required computing and analytics capabilities),
- Medical Informatics (access to patient data, identification of disease signatures)
- Neuromorphic Computing (development of brain-inspired computing)
- Neurorobotics (use of robots to test brain simulations)

- We know the brain consists of simple but massively parallel processing
- Each of the 86B cells in the brain connects to 000's of others via neurons
- The overall brain "orchestrates" (but without a conductor) activity by sensing messages from cell to cell along neurons
- Brain activity is actually electrical charges sent from one cell to another, measured in milli-volts
- Such is the scale of the activity, it represents sophisticated processing like thought, consciousness, control over the body, and as we saw earlier, memory

Human Memory

- As a re-cap from earlier MOOC on memory …
- Sensory – short term, rapid decay unless refreshed, passed to…
- Short-term if attentive, the "post-it" note, usually only 7 items, or chunks, discarded unless consciously decide to …
- Long-term memory, more permanent, this is our interest



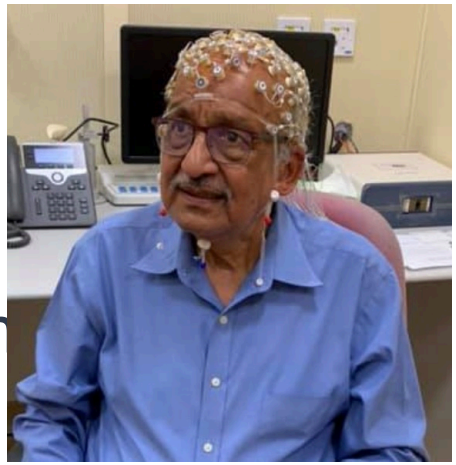
Types of Human Memory: Diagram by Luke Mastin

Brain Activity

- So if brain activity is “only” firing neural circuits, can we “listen” to this by sensing the electrical activity ?
- Yes of course
- BCI (Brain Computer Interface) is a communication channel capable of operation entirely on neural signals
- Many sensing technologies exist:
  EEG, nIR, MEG, PET, ECoG, Local Field Potentials, fMRI
- Each offers its own interaction paradigms and capabilities but we are interested in EEG

EEG

- EEG stands for Electroencephalography and it involves the detection of electrical signals generated by the brain on the scalp
- Non-invasive, requires N sensors on and in contact with the scalp where an amplification unit digitises the tiny electrical potentials generated by the brain
- The "N" can be as small as 1 or 2 but they're not much use so 32, 64, 128 (as in image) or even 256 nodes are used, plus a couple on the ear and on the chin as "ground" (to complete the electrical circuit)

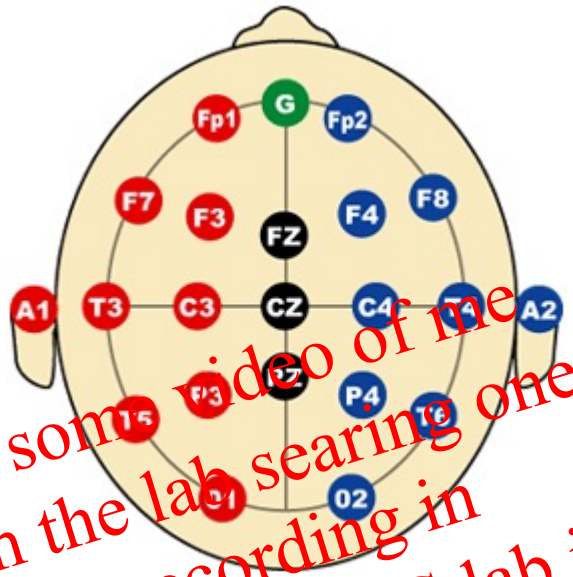


EEG

- Some more examples of EEG

EEG

EEG nodes (electrical sensors) are placed on the scalp according to a Universal placement standard, shown here, so there is consistency



I can add generate some video of me or somebody form the lab searing one of these, needs some recording in School Nursing where the EEG lab is … it'll look cool ;-)

EEG – What to Measure ?

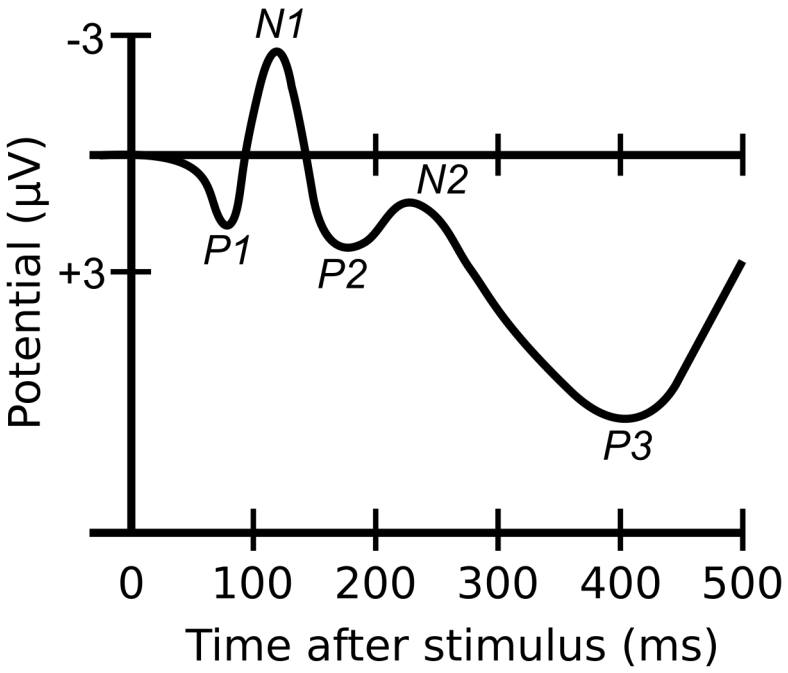
- In MOOC 1 we looked at measuring attention levels and showed, anecdotally, how attention level correlates with memory recall
- We showed that in the video clipped below, where we used a simple 2-node EEG
- So we can use EEG to measure attention in a way that is similar to "listening" to the amount of "traffic" in the brain, not localising it or determining where in the brain, just how active the brain actually is
- But we can do more when we determine where in the brain, the activity is, so we use many nodes and even triangulate to pinpoint the places in the brain where the greatest activities are

Brain Functioning

- The brain works in different ways to store and recall memories, make decisions, formulate language, make a decision, create an idea, initiate a movement, etc.
- Understanding these processes is the leading edge of neuroscience
- One brain function that is well understood is our reaction to external stimuli (not thoughts or ideas we might have but things we see, hear, feel)
- These are called Event Related Potentials or ERPs

ERPs

- We are interested in ERPs (Event Related Potentials) electrical responses at certain scalp points, generated by the brain in response to stimuli such as an image, sound, touch, taste…
- There are several known ERPs including P1, N1, P2, N2 and P3 which occur 100, 170, 200, 250 and 300 milliseconds (approx.) after the stimulation



ERPs

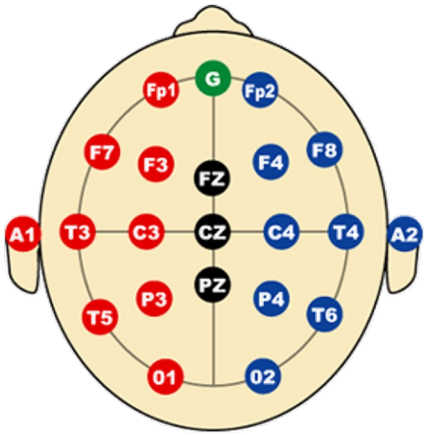
- What is important is knowing the time of presentation of the stimulus, so sound, taste, video are not good for this
- An example, is an image, presented on a screen
- Every time you see a new slide or change of image in this MOOC, it generates an ERP in your brain, and it is reflective/indicative of your visual and interpretative processing … namely the fact that milli-voltages on your scalp are generated and could be recorded is an indication that you have actually seen, as opposed to eyes glazed over, the images
- There are ERPs related simply to visual changes (i.e. there's a new image), while other ERPs are related to specific concepts or elements of the image (i.e. depend on what's in the image)

A Face

Image: Niall Carson via PA Images

The N170 ERP

- The last screen was a face. You might recognise it, you might not, it doesn't matter because whether you know who it was or don't, just seeing a face elicited an N170 ERP (negative at 170ms), discovered in 1996, in certain parts of your brain (unless you were mindwandering or asleep and didn't actually see the face, so pay attention !)
- It was probably around your occipitotemporal area, slightly to the right side, between Pz and P4
- If you had a couple of EEG nodes there then 0.17 seconds after seeing Michael D's face on your screen, they would have detected a voltage change



ERP

- Regardless of what I told you to do, or whatever you are doing so long as you are paying some attention to what you're seeing, there will always be a N170 ERP when you see a face, about 0.17 seconds after seeing it, there's an electrical pulse
- We call this type of ERP exogenous – it occurs regardless of your internal mental state or perception
- When we see faces that aren't really faces they just look like faces, its called "pareodolia" and it's a consequence of our evolution … we are social animals, we are always looking for other people to meet and talk to
- We see faces in the patterns of bushes, or leaves, or even when we look at clouds

ERP – P3

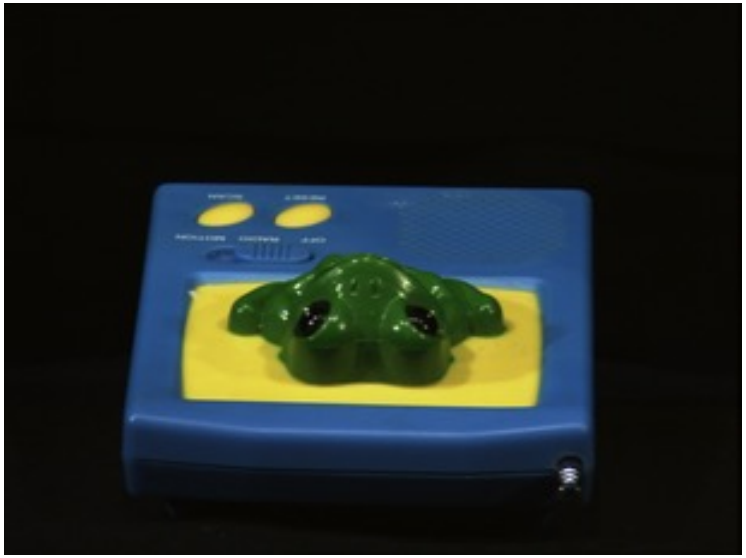
- In addition to exogenous ERPs there are endogenous ERPs too !
- These ERPs are sensitive and modulated by your internal cognitive state with regard to things like expectation .. in other words we "wind you up" and get you ready to see something, then when you see it you have an endogenous ERP because you're expecting something to happen, and it does
- These tend to appear 220ms after you see something and one of these of importance is the P3 or P300 (same thing, P3 as shorthand for P300) ERP
- Lets make one in your …

P300 elicitation

- We’re going to show a series of images, about 1 second apart, and you are to look out for the CocaCola can like the one below, from among the following images.
- When you see it, as quick as you can, clap your hands.

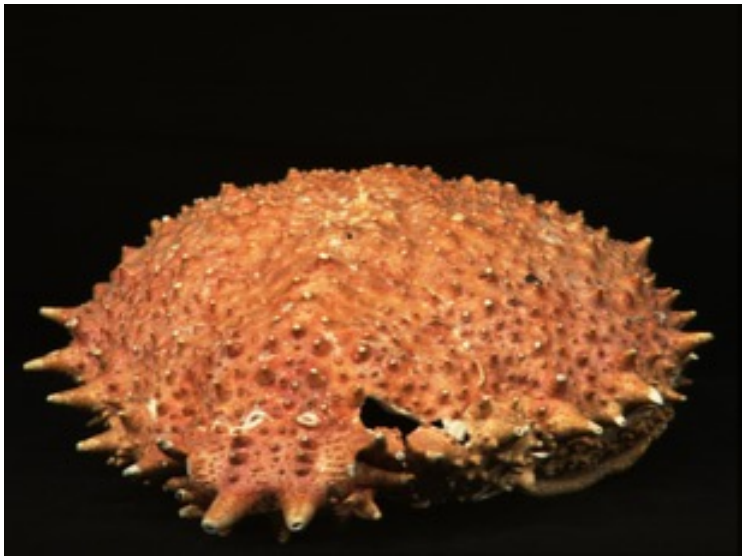
P300 elicitation

P300 elicitation



P300 elicitation

P300 elicitation



P300 elicitation

P300 elicitation

P300 elicitation

P300 elicitation

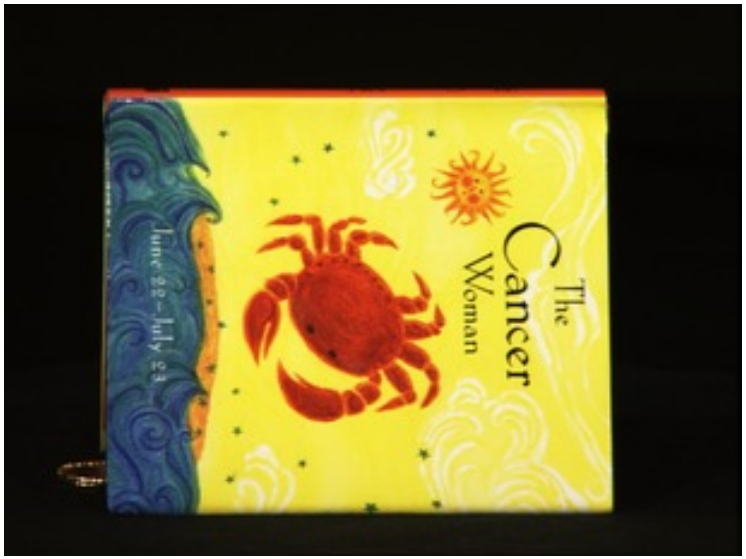
P300 elicitation

P300 elicitation

P300 elicitation

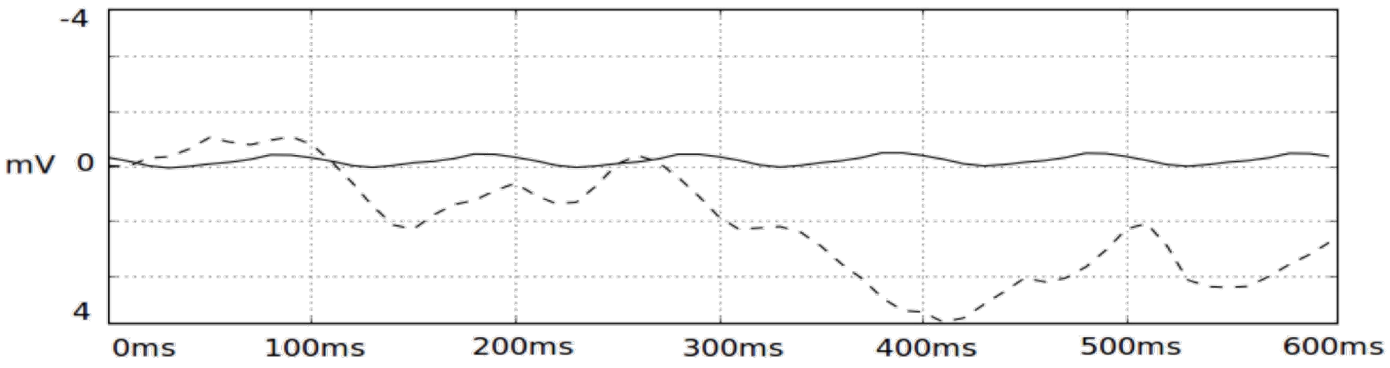
P300 elicitation

P300 elicitation



P300 wave

- When you saw the Coke can, it generated a P300 wave like the dotted line below, and when you saw something that wasn't a Coke can you flatlined, like the solid line below.
- Thiswas generated over your parietal brain areas, so top and back of your head



- In experiments, when we do this we average it over many recordings, not just one.

P300 wave

- There's nothing special about the Coke can. It's just that you did not know when it was going to appear, and since I told you to look out for it, its appearance caught your attention, you recognised it
- I could have as equally used any object that you may be looking for or expecting
- So there is an idea that when searching for images, we can have a BCI interface based on using EEG sensors to detect when you see something you recognise
- Researchers (like us) are working on this kind of interface

EEG

- So what about BCI ?
- It can be used to measure attention levels and to measure reaction to (visual) stimuli … an uncontrollable and natural reaction
- And what does that get us ? When EEG becomes less intrusive to use – and it will – then we, or others, can ”tap into our brains”, in real time, perhaps to sense what we are thinking.
- Sci-Fi ? Maybe, but it’s the ultimate form of sensing the human, and it’ll happen in our lifetime.