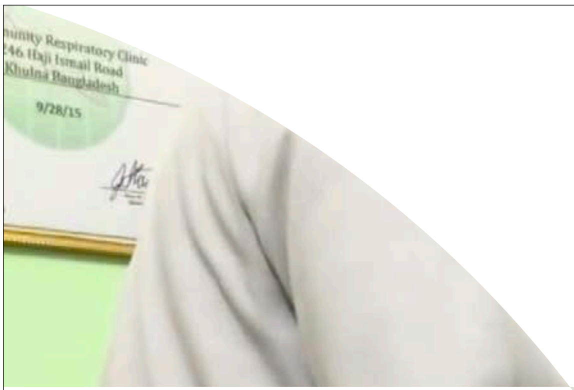
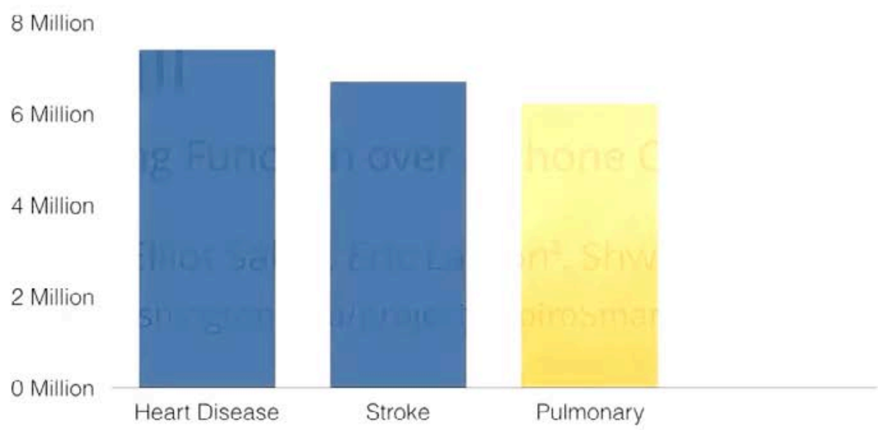
mobile health in context



mobile health & activity monitoring
spring term 2023 ETH Zürich
prof. christian holz siplab

Leading Causes of Deaths per Year



VOICE OF:
Mayank Goel, Computer Science & Engineering

for new participants: course overview

fully hybrid course

11	lectures	(in-person, but also recorded; not always 90 minutes)
2	weeks break	(Easter, Sechseläuten)
1	exercise	(accompanying the semester)
4	reading assignments	
1	end-of-term exam	(Semesterendprüfung)

course repository (recordings, assignments, links, …)

- https://go.siplab.org/mhealth2023
- user: mhealth2023, password: PuntaNizuc

contact

- everything through Moodle
- https://moodle-app2.let.ethz.ch/course/view.php?id=19753

for new participants: exercise

weekly exercise Q&A sessions

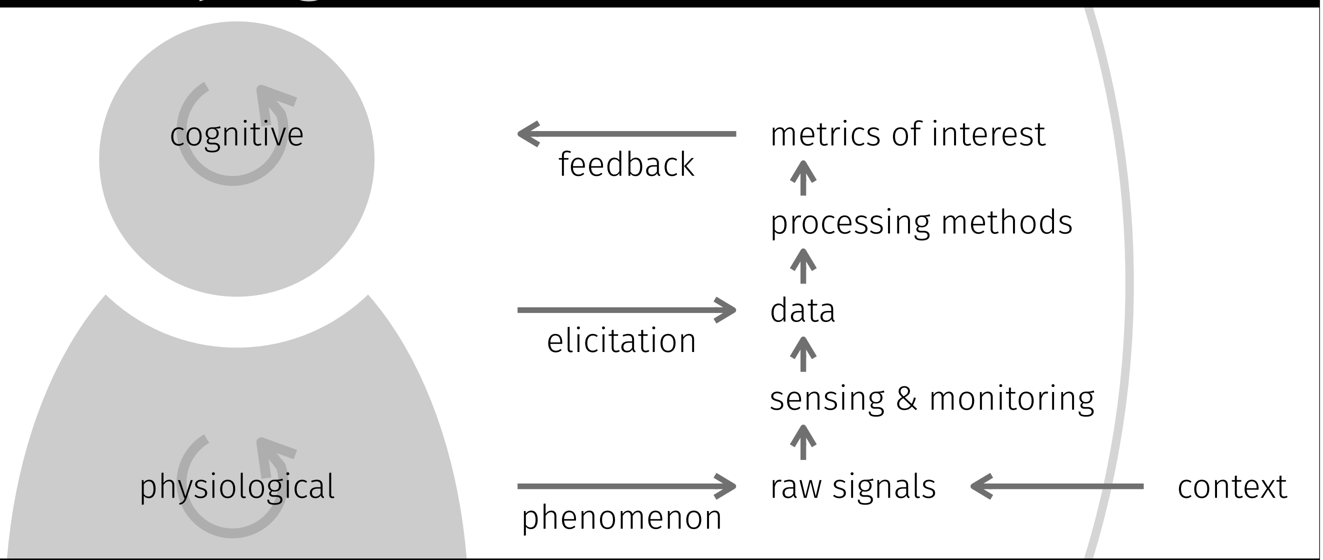
- Mondays 1–2pm in-person (CAB G 57)
- tutorials, Q&A, feedback (also based on your input)
- attendance **optional**
- Week 3: online tutorial (➭ next week)
- Week 4: starting optional in-person sessions

announcements and communication

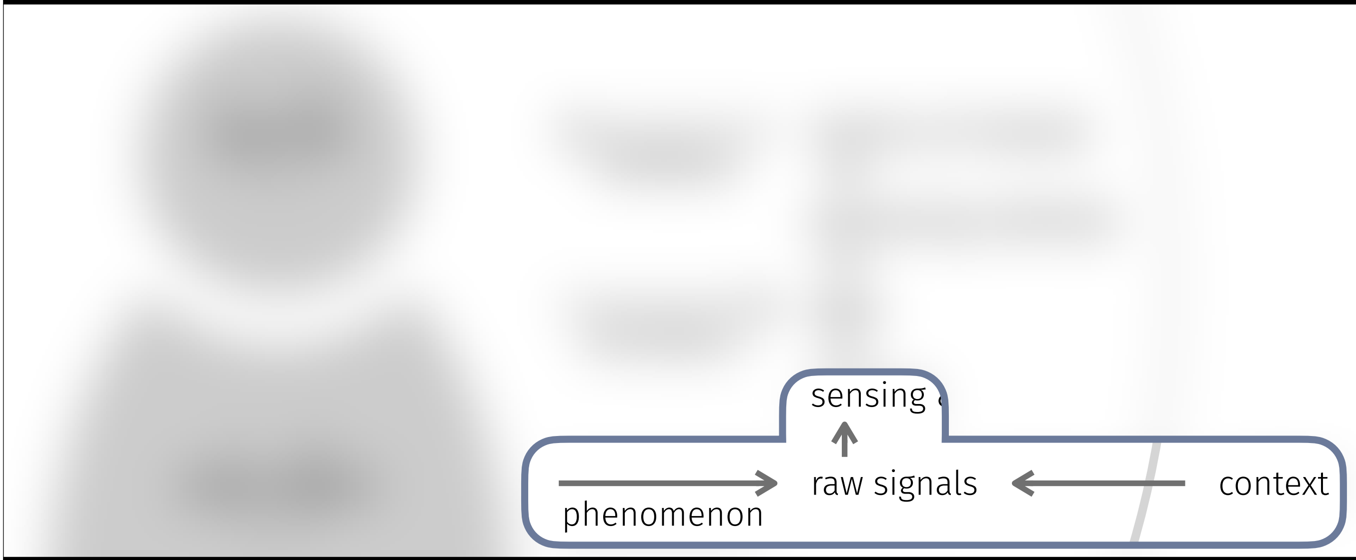
- TAs will announce important bits on Moodle
- Q&A also through Moodle

➭ https://go.siplab.org/mhealth2023

today's goals



today's goals



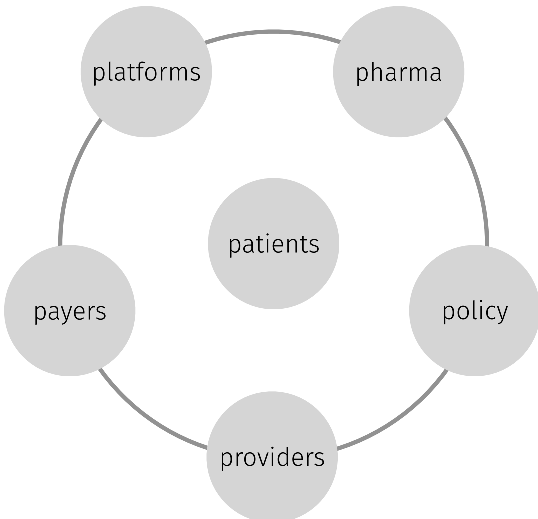
precision medicine

the goal and what's needed

precision healthcare

goal: provide precisely targeted and
highly personalized diagnostics and therapeutics to patients

fundamental assumption: information is digital, available or obtainable



6 p's of healthcare

quick recap

1) patients

improved safety and fewer side effects

greater likelihood of responding to therapy

confidence in response

improved quality of life

outcome: lifetime gained

2) providers

reduced trial and error approach

facilitated and optimized treatment solution for patient

unnecessary therapy excluded, saving treatment procedure-related time

supports improved individualized physician-patient relationship

access to valuable clinical trial samples and data through connected care

collaboration with pharmaceutical companies

3) pharma

innovative, differentiated medicines portfolio broadened

improved efficacy leads to longer treatment duration

focused clinical development

potential for faster regulatory approval

including orgs or collaborations with consumer companies
to transition to continuous care alongside diagnostics appliances

4) policy and regulators

legal and financial framework

improved patient benefit/risk ratio
through drug-companion diagnostic solution

better efficacy and safety of new medicines

opportunity for simultaneous evaluation process for drugs and diagnostics

5) payers

better healthcare solution through improved outcome/cost ratio

efficient use of resources

effective allocation of funds

6) platforms

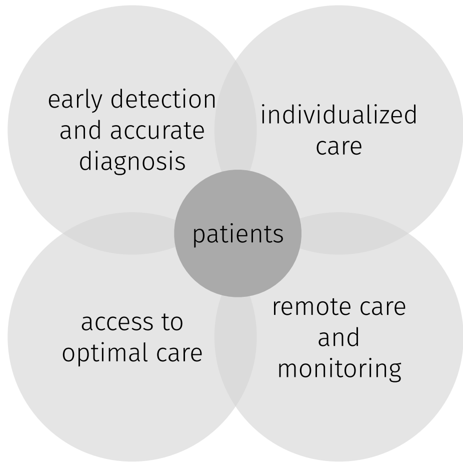
distributed backend systems that implement standards

better integration of services, communication, and certification

central hubs for data exchange

increasingly offering “AI services” to leverage data insights

precision healthcare



overall aims

- provide precisely targeted and highly personalized diagnostics and therapeutics to patients
- reactive, predictive, local & remote, short-term & longer-term
- advance from sickcare to healthcare

➪ “triple aim”: better outcomes, lower costs, better experiences

fundamental assumption: information is digital, available or obtainable

what to work on?

what problems should we focus our energy on?

often tempting to

- solve the ‘coolest’ problem
- use the newest gadget or latest technology

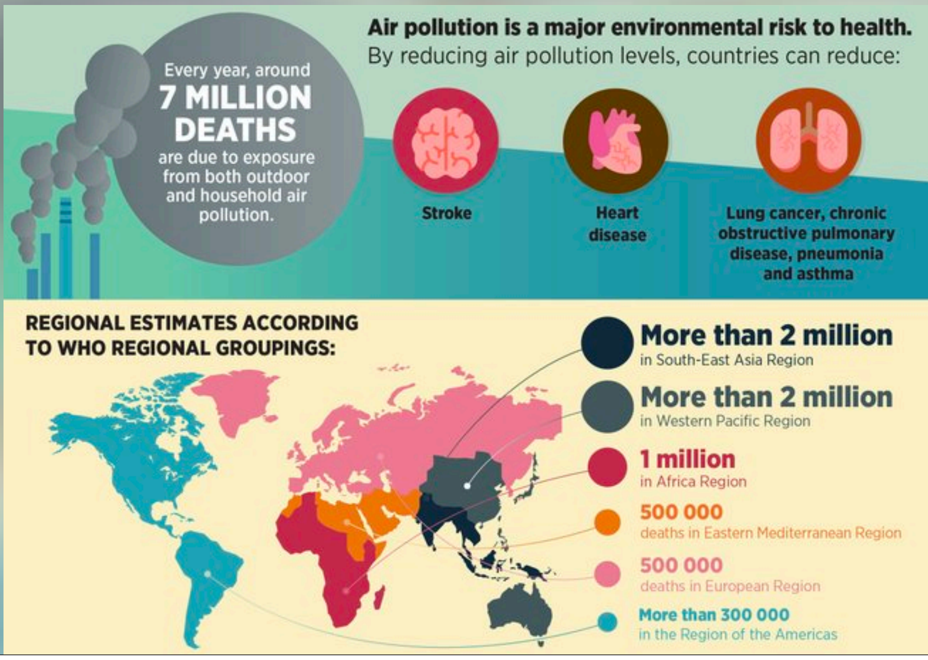
…but should focus on the biggest problems

10 biggest threats to health worldwide

according to WHO 2019/2020

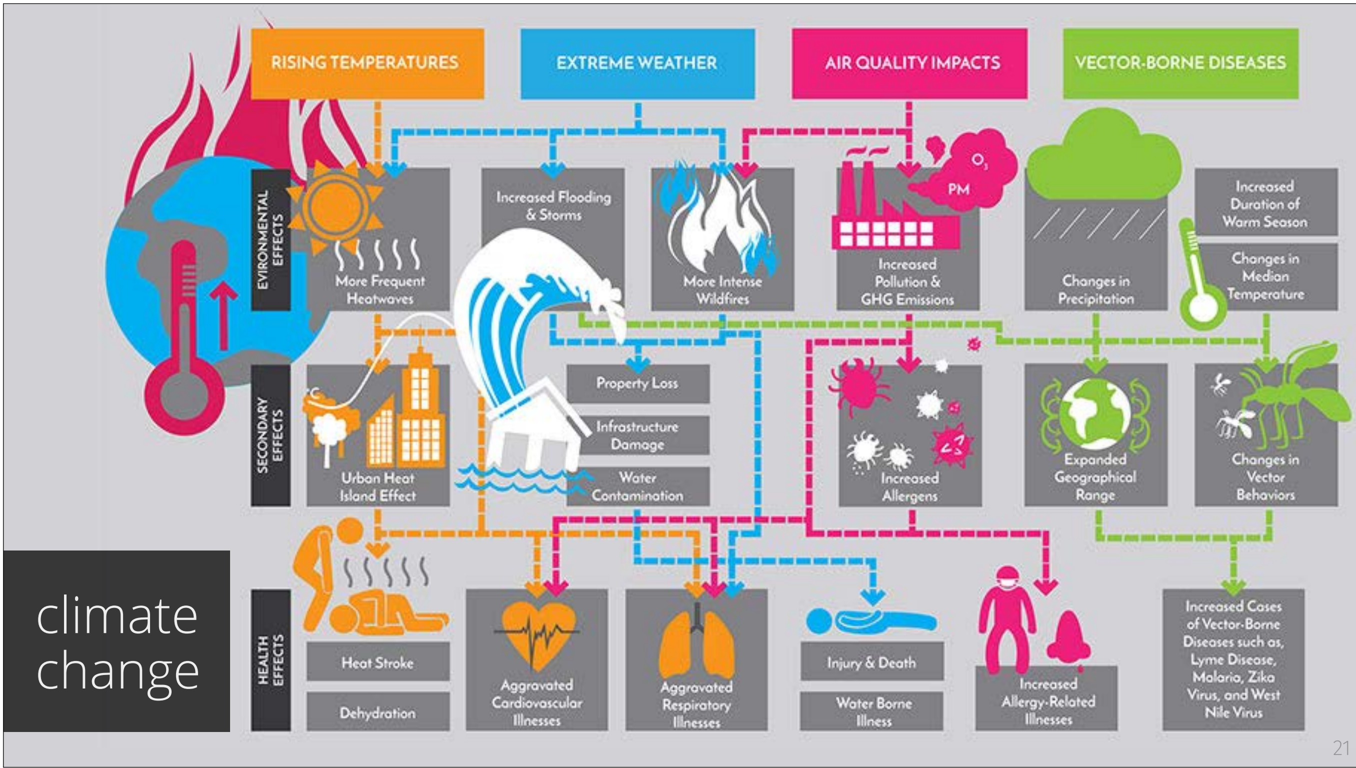
https://www.advisory.com/daily-briefing/2019/01/28/global-health-risks

1) air pollution and climate change



"the silent killer"

climate change



2) noncommunicable diseases

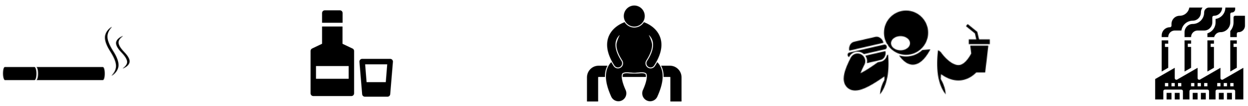
70% of deaths worldwide

- diabetes
- cancer
- heart disease

15 million premature deaths
largely in low- & middle-income countries (LMIC)

5 risk factors

- tobacco use
- alcohol use
- physical inactivity
- unhealthy diets
- air pollution



3) Influenza

a global pandemic…

in 2019, WHO said this is inevitable

➪ might be #1 right now

world’s defenses are only as effective as the weakest link
in any country's health emergency preparedness and response system

4) fragile and vulnerable settings

22% of world’s population lives in fragile settings

fragile settings

- lack access to basic health care
- poor health services

state of crisis: prolonged famine, conflict, population displacement, drought

5) antimicrobial resistance

overuse of antimicrobials in

- people
- animal for food production
- environment

if overuse continues

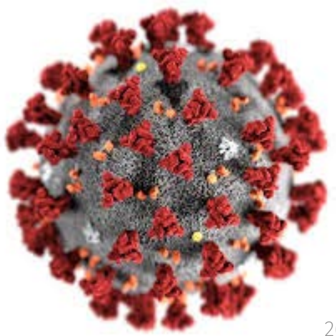
- antimicrobial resistance will worsen
- infections considered treatable may become completely resistant
  (e.g., tuberculosis, gonorrhea, pneumonia)

6) high-threat pathogens

current watchlist:

- Ebola
- Zika
- SARS
- “disease X”
  (any unknown pathogens that can cause an epidemic)

COVID-19 is likely on the next list in the future



7) weak primary care

according to WHO, primary care is

- consistent
- accessible over a patient's life time

many reasons for lack thereof

- unaffordable
- inaccessible
- noncomprehensive care

may stem from

- lack of resources
- lack of connected health care and exchange

8) vaccine hesitancy

vaccinations prevent 2–3 million deaths per year

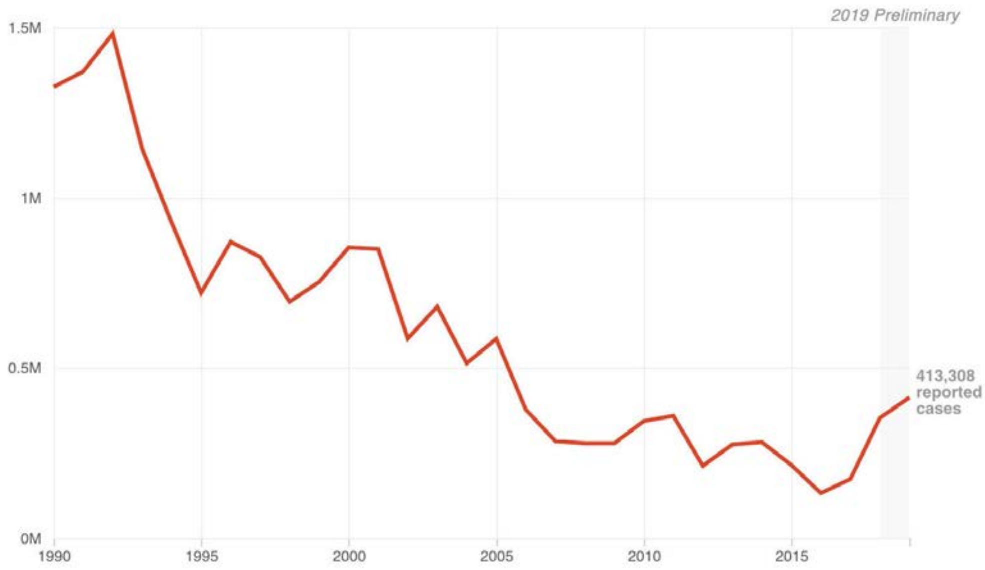
➪ one of the most cost-effective ways of avoiding disease

BUT could potentially prevent another 1.5 million if more were vaccinated

hesitancy slowly becoming a trend

- more and more people challenging the safety of vaccines
- many start to question the necessity of vaccines

8) vaccine hesitancy: measles



https://www.npr.org/sections/goatsandsoda/2019/12/05/785177595/

9) Dengue

mosquito-borne illness

- infects 390 million people each year
- 40% of the world at risk
- kills up to 20% of people with a severe form of the disease

origin

- rainy seasons in countries with tropical climates
- potential future spread to temperate climates

10) HIV

spread

- 37 million people worldwide affected
- 1 million people die from HIV/AIDS annually
- 22 million living with HIV on treatment using antiretroviral medication

risk population may be excluded from potentially life saving health services

how can computing help?

1) air pollution and climate change
2) noncommunicable diseases
3) Influenza
4) fragile and vulnerable settings
5) antimicrobial resistance
6) high-threat pathogens
7) weak primary care
8) vaccine hesitancy
9) Dengue
10) HIV

where may computing help?

where do you see the largest potential for the **promise of digital health?**
90-second brainstorming—talk to your neighbor!

mobile health in context

(rough) categories of mobile health

1. education, reminders, and data management
2. population health
3. physiological signals
4. momentary state assessment
5. continuous health management

1. education, reminders, data management

communication capabilities as a key capability

support existing practices for healthcare management

- improved access to health information
- multimedia guidebooks for remote medical decision-making

better patient access to healthcare and assessment

- reminders for medication adherence and clinic visits
- digital forms for facilitating data entry

1. education, reminders, data management

example: maternal deaths
in low- and middle income countries

often due to delays in health-related
decision-making as a result of adverse events

opportunity:

- SMS can be used to create communication
- party hierarchy: mother-infant pair,
  community health works, health facility,
  central database, emergency ambulance

Ngabo et al. '12: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3542808/

2. population health

track trends within and across communities

understand population-level trends and link to context

- urban mobility and access to green space
- epidemic monitoring and contact tracing
- community-level predictors of long-term health

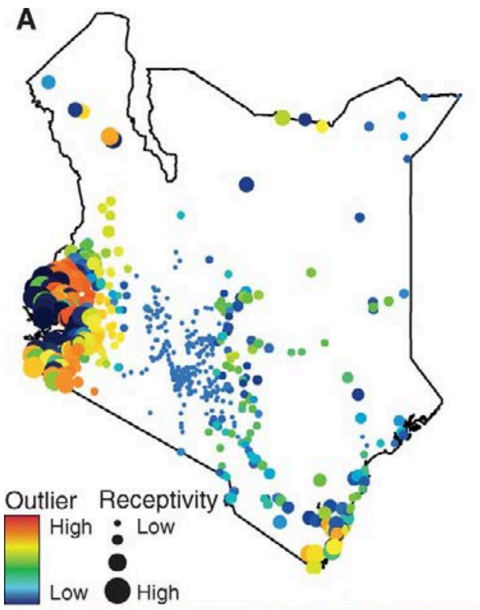
2. population health

example: malaria transmission

- identify the “sources” and “sinks”
- map human travel to
  improve malaria control in Kenya

opportunity: approximate travel from

- smartphone mobility data
- but also feature-phone data
  (i.e., cell tower connections)



Wesolowski et al. ’13: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3675794

3. physiological signals

assess real-time indicators of health that apply to the population at large

vital signs

- body temperature
- heart rate (HR) (dependent: heart rate variability, stress)
- respiratory rate
- blood pressure

other signs

- oxygen saturation (SpO_2)
- maximal oxygen consumption (VO_2 max)
- step count
- gait speed and stride length

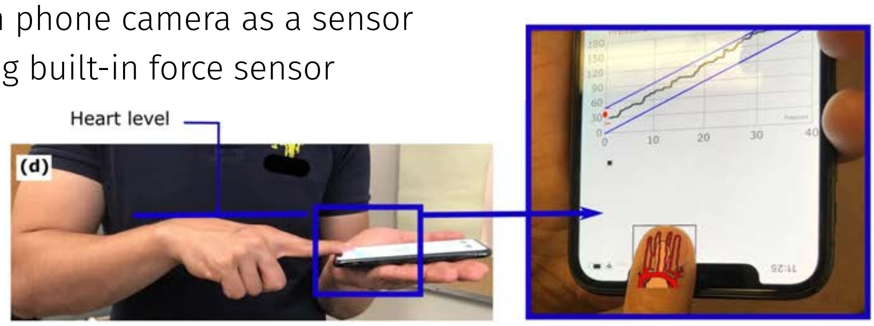
3. physiological signals

example: phone-based blood pressure monitoring

- blood pressure naturally varies throughout the day
- one-time measurements are likely confounded

opportunity: commodity sensors in mobile phones

- obtain reflections from phone camera as a sensor
- measure pressure using built-in force sensor



Chandrasekhar et al. '18: https://www.science.org/doi/abs/10.1126/scitranslmed.aap8674

4. momentary state assessment

means to objectively assess symptoms

measurement through phone-based guidance

- go through explicit procedures with their phone (e.g., perform a gesture, take a selfie)
- data processing either on the phone or transmitted to health facility/provider

many medical tasks replicable

- finger tapping task for fine motor control
- timed up-and-go (TUG) walking task for mobility
- vital sign assessment
- picture of skin lesion for skin cancer identification

4. momentary state assessment

example: neonatal jaundice

- can lead to fever and seizures
- subjective and difficult to identify for parents

opportunity: smartphone camera

- accurately and objectively measures colors
- quantify bilirubin levels in blood cells

[de Greef et al. '14]

5. continuous health management

leverage passive sensing to continuously measure

- physiological signals
- behaviors
- contextual variables

infer person's health state from them

suitable use-cases

- cough detection and classification
- stress/mental health management
- smoking events
- just-in-time adaptive interventions

5. continuous health management

example: schizophrenics

- experience dynamic changes and frequent episodes
- cannot be constantly monitored by clinicians

opportunity: behavior observations

- smartphones can measure behavioral, environmental, and contextual indicators
- mental health can be inferred from them (e.g., activity level, sleep duration, location, …)

[Wang et al. '16]

momentary vs. continuous assessment

momentary (actively elicited)

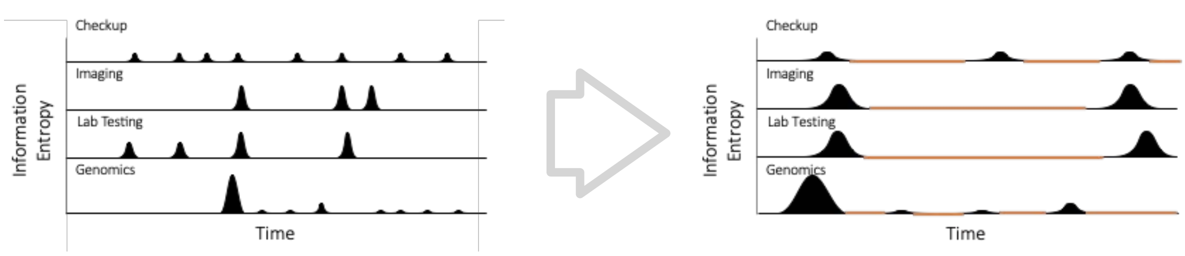
+ more control over where, when, and how data is collected
– requires users to remember to test themselves
– may require expertise to be used properly

continuous (passively observed)

+ designed to collect data passively without need for user involvement
+ richer time resolution of data
+ enables opportunistic interventions
– limited control over where, when, and how data is collected
– more things can go wrong due to higher measurement frequency

mhealth to fill the information gap

temporal



mhealth to fill the information gap

spatial

mobile devices

“traditional” devices

smartphones

smartwatches
& fitness trackers

mobile/“feature”
phones

palm pilots/PDAs

wearable devices

smart watches

smart glasses

smart rings

smart patches

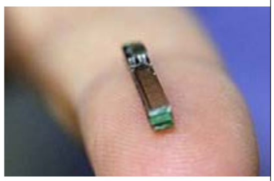
“emerging” devices

smart fabrics

smart soles

skin sensors

smart
contact lenses



implantables

other technologies for mHealth

phone
attachments

environmental
sensors

smart speakers

access points

advantages of mobile devices I

smartphone penetration is high

- 67% of the global population has a mobile phone
- 48% has a smartphone (BankMyCell '21 [1])

connectivity is high

- in sub-Saharan Africa, 86% of people have a SIM connection
- 65% of them come from a smartphone (GSMA '20 [2])

distribution seems promising

- consistently high across genders, ethnicities, socio-economic status
- potentially quicker path to major impact

[1] https://www.bankmycell.com/blog/how-many-phones-are-in-the-world
[2] https://www.gsma.com/mobileeconomy/sub-saharan-africa/

advantages of mobile devices II

mobile devices are often nearby

- people keep their smartphone within arm's reach
- 50% of the time and in the same room 90% of the time (Dey et al. '11 [1])
- people wear their smartwatches for ~9 hours per day (Jeong et al. '17 [2])

➩ more opportunities for sensing, interaction, and intervention

[1] https://doi.org/10.1145/2030112.2030135 [2] https://doi.org/10.1145/3131892

advantages of mobile devices III

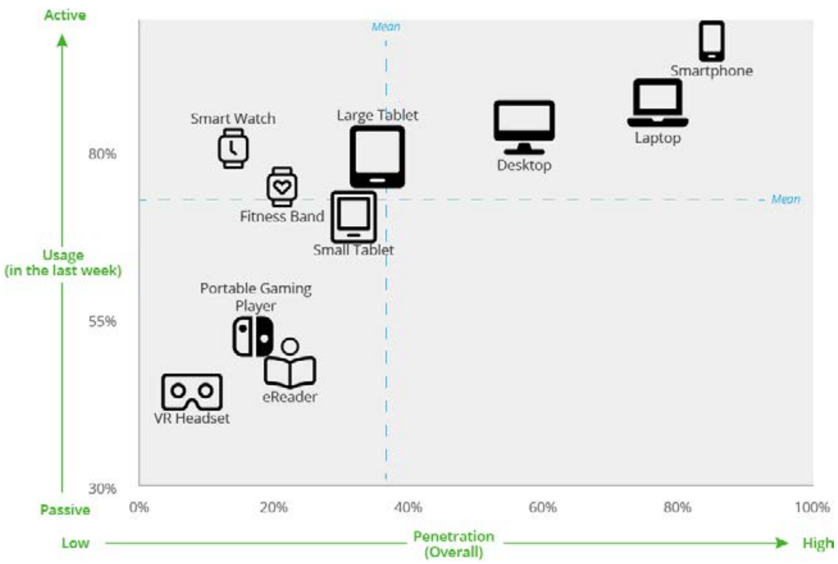
mobile devices are familiar interfaces

- people are willing to keep their phone in working condition
- people are willing to upgrade their phone on a semi-regular basis, leading to better hardware over time

usability (almost) ensured

- leverage common interaction patterns
- create familiar interfaces to make usable apps

advantages of mobile devices IV



[Deloitte Global Mobile Consumer Survey: United States 2018 Statistics]
https://www2.deloitte.com/us/en/pages/technology-media-and-telecommunications/articles/wearable-device-usage-versus-penetration.html

challenges in mobile health

challenges in mHealth I

tradeoffs in hardware sophistication

	Dedicated Hardware	High-End Smartphones	Low-End Smartphones
Deployability	Need strategy to distribute at scale	Limited to tech-savvy	Most ubiquitous
Instrumentation	Can be specifically designed to requirements	Better sensors	Limited sensors
Control	Complete control over hardware and software	At the mercy of smartphone manufacturers and developers	

challenges in mHealth II

designing for non-expert users

	Research Study	Clinical Deployment	Smartphones
Device Operator	Typically a researcher or study coordinator familiar with the data	Doctors, EMTs, and nurses with training	Ordinary people without training
Environment	Controlled lab environment	Hospital lighting, consistent noise	Anywhere

challenges in mHealth III

designing for non-expert users

accurate interpretation can be critical

- doctors are trained to interpret medical information
- not so ordinary people

data leads to interpretation

- even "simple" data may produce illogical conclusions
- example on weight scales: Kay et al. '13 [1]

[1] https://doi.org/10.1145/2493432.2493456

challenges in mHealth IV

not all smartphones are created equal

different physical layout of sensors

- relative position of microphone and speaker
- relative position of camera and flash
- relative position of
  vibration motor and accelerometer

different sensor specifications

- camera color sensitivity
- sampling rate

different levels of API access

challenges in mHealth V

need for reference or gold standard

difficult to obtain in scenarios (lab vs. in the wild)

example: depression monitoring

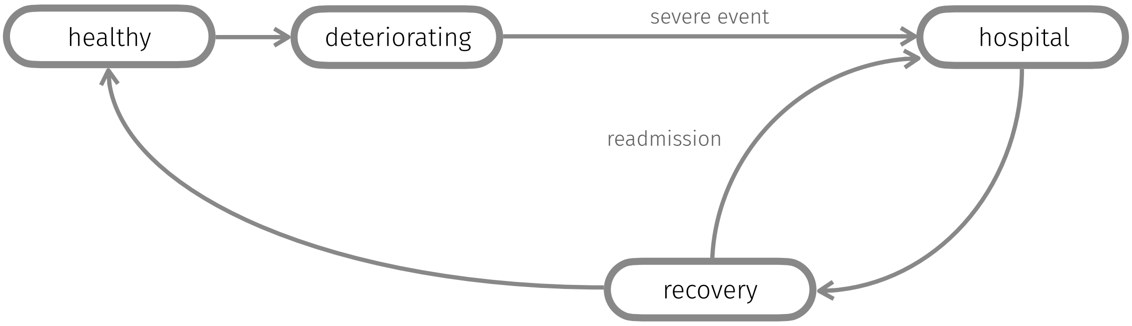
- common argument: sensors are better at detecting depression than survey instruments
- how do ML-based techniques beat the gold standard?

benefits other than accuracy prevail

- timeliness
- objectivity

challenges in mHealth VI

maintaining retention



challenges in mHealth VII

much potential for bias

examples of **demographic bias**

- optical pulse sensing: skin tone
- cough counting: voice characteristics across genders
- pupil measurements: eye color

technical bias

- step counting: device placement (e.g., pockets but not purses)
- device model
- data collection environment for targeted populations

end

prof. christian holz
mobile health & activity monitoring, spring 2023

sensing,
interaction &
perception lab