ITU KALEIDOSCOPE
ATLANTA 2019

Artificial Intelligence at Home:
Supporting Patients, Families and Caregivers

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Artificial Intelligence at Home: Supporting Patients, Families and Caregivers

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HARVARD MEDICAL SCHOOL TEACHING HOSPITAL

Division of Clinical Informatics

YEARS 1970 – 2020

DIVISION OF CLINICAL INFORMATICS™

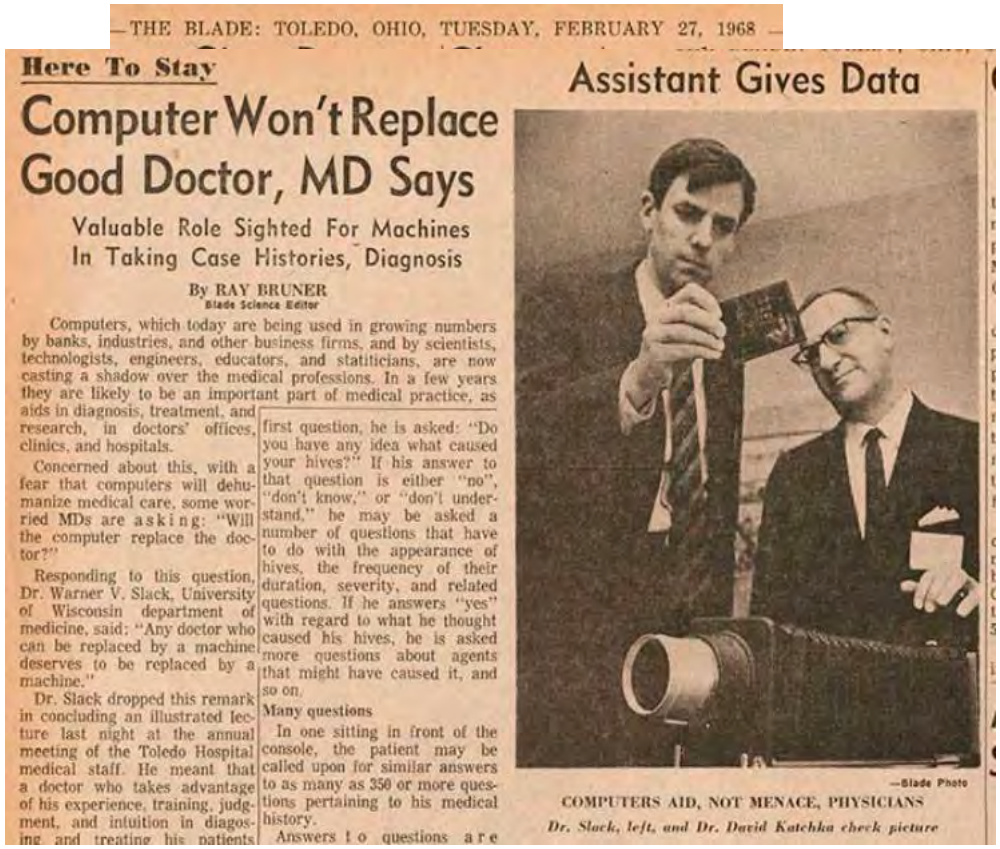
An Academic Division of the Dept of Medicine
at Harvard Medical Faculty Physicians at BIDMC, Inc.

The most under utilized resource in healthcare is the patient!

Warner Slack, MD
1970

http://www.warnerslack.org

AI for Augmenting not replacing



—THE BLADE: TOLEDO, OHIO, TUESDAY, FEBRUARY 27, 1968 —

Here To Stay

Computer Won't Replace Good Doctor, MD Says

Valuable Role Sighted For Machines In Taking Case Histories, Diagnosis

By RAY BRUNER
Blade Science Editor

Computers, which today are being used in growing numbers by banks, industries, and other business firms, and by scientists, technologists, engineers, educators, and statiticians, are now casting a shadow over the medical professions. In a few years they are likely to be an important part of medical practice, as aids in diagnosis, treatment, and research, in doctors' offices, clinics, and hospitals.

Concerned about this, with a fear that computers will dehumanize medical care, some worried MDs are asking: "Will the computer replace the doctor?"

Responding to this question, Dr. Warner V. Slack, University of Wisconsin department of medicine, said: "Any doctor who can be replaced by a machine deserves to be replaced by a machine."

Dr. Slack dropped this remark in concluding an illustrated lecture last night at the annual meeting of the Toledo Hospital medical staff. He meant that a doctor who takes advantage of his experience, training, judgment, and intuition in diagosing and treating his patients

first question, he is asked: "Do you have any idea what caused your hives?" If his answer to that question is either "no", "don't know," or "don't understand," he may be asked a number of questions that have to do with the appearance of hives, the frequency of their duration, severity, and related questions. If he answers "yes" with regard to what he thought caused his hives, he is asked more questions about agents that might have caused it, and so on.

Many questions

In one sitting in front of the console, the patient may be called upon for similar answers to as many as 350 or more questions pertaining to his medical history.

Answers to questions are

Assistant Gives Data

—Blade Photo

COMPUTERS AID, NOT MENACE, PHYSICIANS
Dr. Slack, left, and Dr. David Katchka check picture

"Any doctor who can be replaced by a machine should be replaced by a machine."

Warner Slack 1968

Source: https://www.epatientdave.com/2018/06/27/patients-are-the-most-underused-resource-warner-slack-1933-2018/

http://hmfpinformatics.org/slack/

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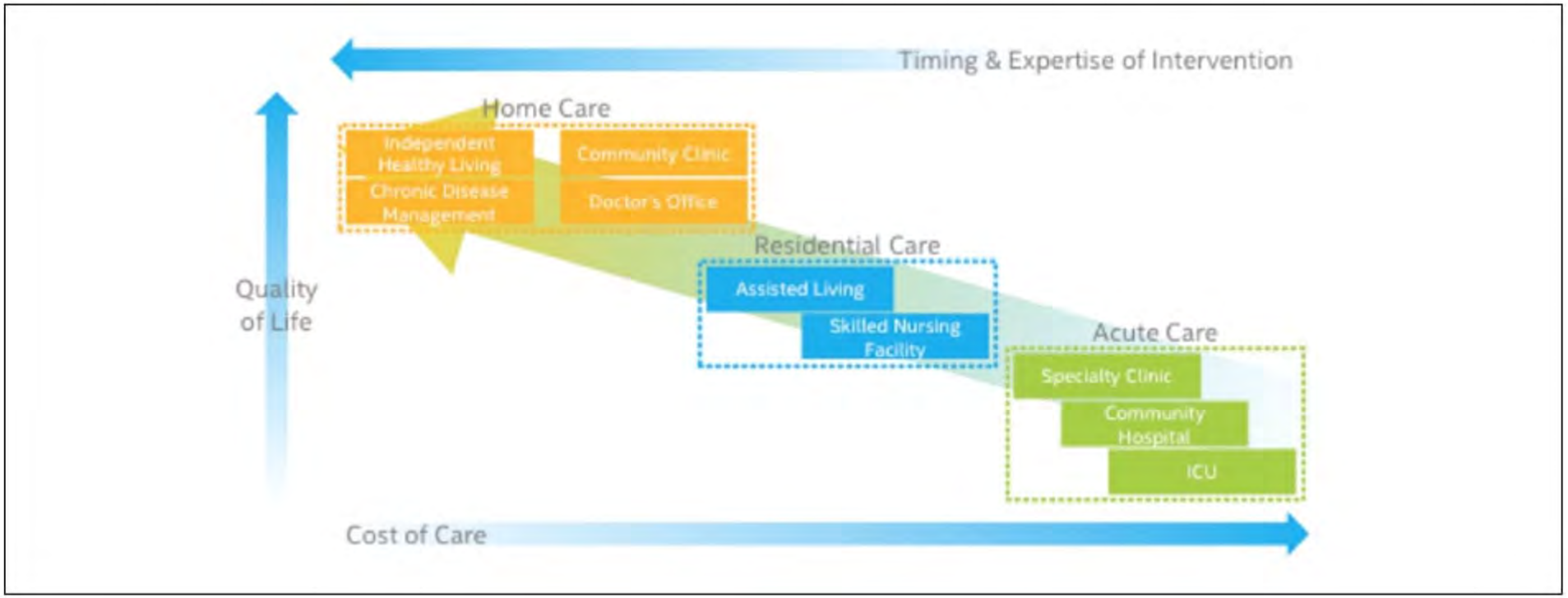
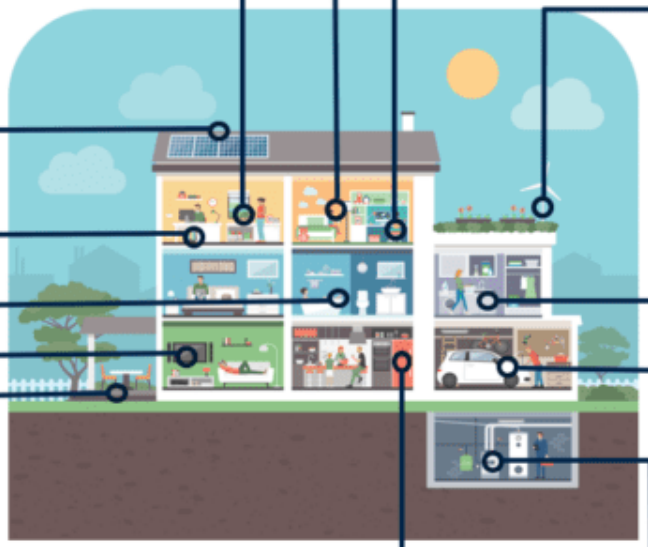


Figure 3. Strategy for innovation.
Source. Eric Dishman, Intel Corporation (presented October 1, 2014, IOM-NRC Workshop on "The Future of Home Health Care").
Note. IOM = Institute of Medicine; NRC = National Research Council; ICU = intensive care unit.

Source: Landers et. Al. The Future of Home Health Care: A Strategic Framework for Optimizing Value, Home Health Care Management & Practice 2016, Vol. 28(4) 262–278

SMART HOME MARKET MAP: 60 COMPANIES MAKING THE HOME MORE INTELLIGENT



GENERAL SMART HOME SOLUTIONS

NETATMO
BroadLink
sevenhugs
ORVIBO
IOTAS
LifeSmart
wigwag

PLATFORMS

seeed
arrayent

LIGHTING

deako
LIFX

MONITORING & SECURITY

smartfrog
canary
FENOTEK
ring

ENERGY & UTILITIES

rachio
tado°
CIELO
HEATWORKS
Radiator Labs
ecovent
ecobee
sense
flō

WI-FI & CYBER SECURITY

CUJO
eero
STARRY
luma

HEALTH & WELLNESS

Sleepace
AWAIR
evermind
EIGHT

HOME ROBOTS

jibo
Rokid
TURING ROBOTIC INDUSTRIES
unibo
OLLY

AUDIO & MEDIA

KAMARO
INDEPENDA
Electric Objects
SONOS

KITCHEN & HOME APPLIANCES

KUVÉE
innit
JUICERO
Petnet
June

MISCELLANEOUS

nucleus
UZER
pHin

ALARM SYSTEMS

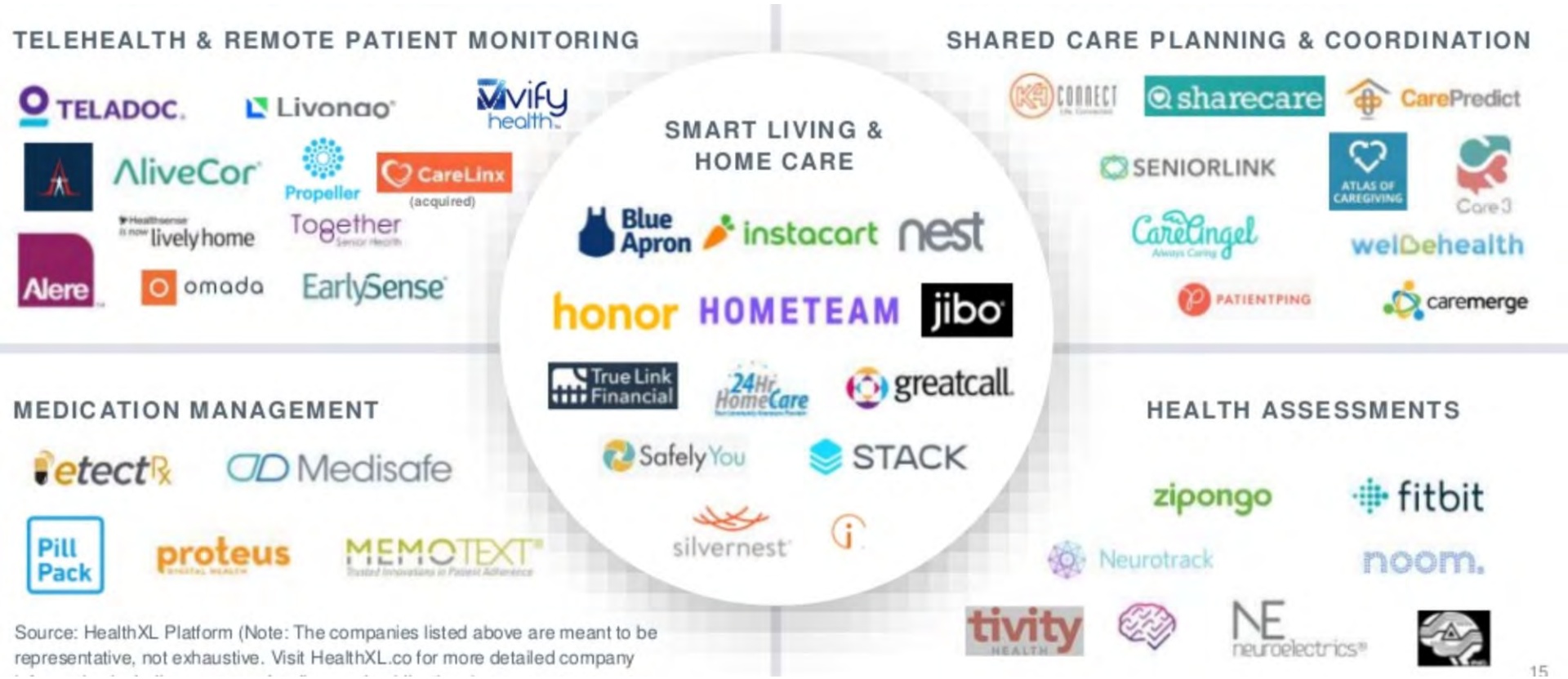
audio analytic
Cocoon
leeo

SMART LOCKS

august
NUKI
UNIKEY
Glue
LATCH

CBINSIGHTS

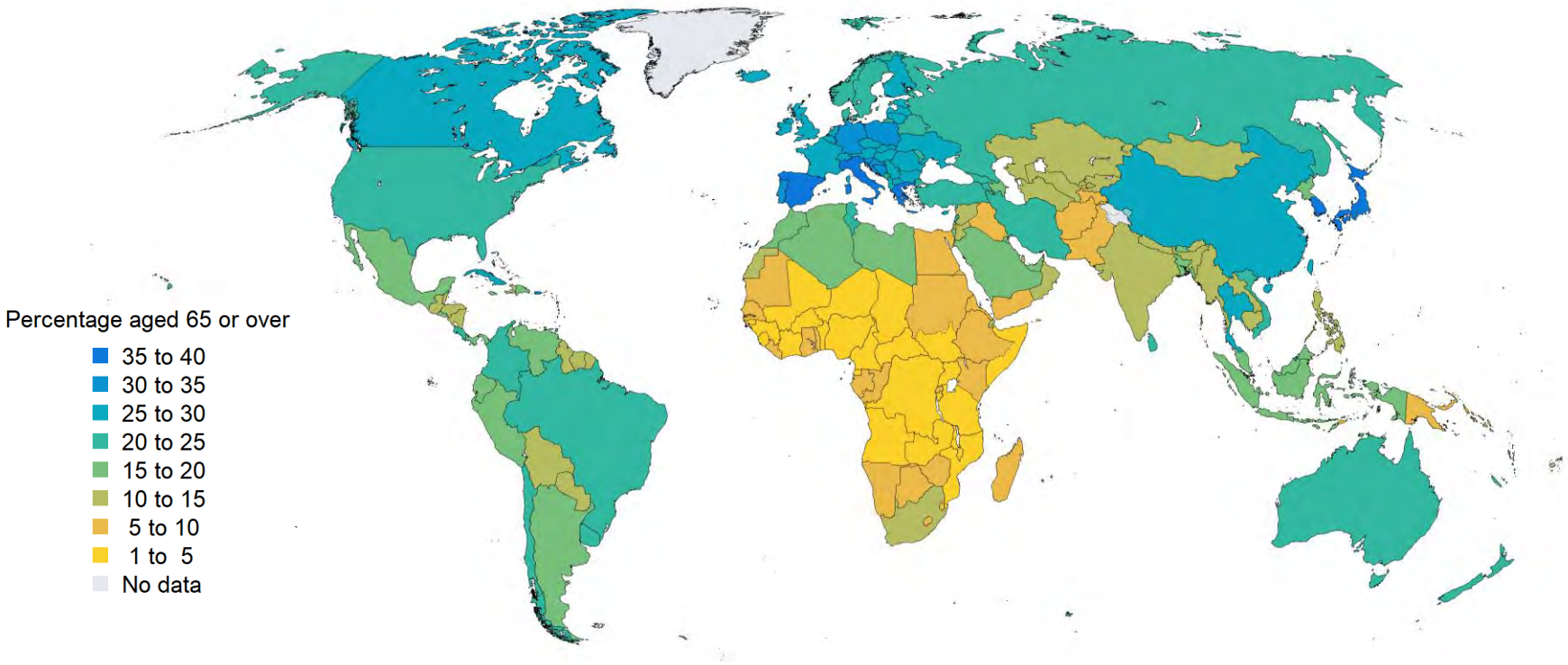
Marketplace of Solutions



Source: CrunchBase and [Digital Health Report] HealthXL & AARP: Enabling Connected & Independent Living Through New Care Models

Caring for an Aging Population

Aging Population



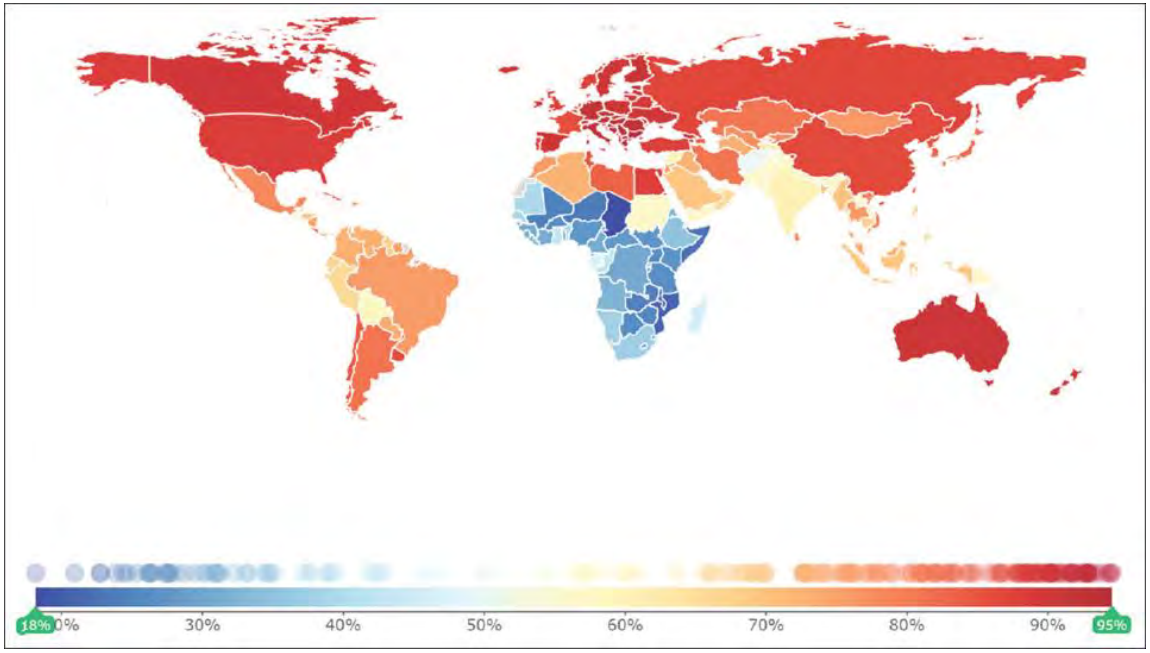
2050

23% of the planet age 60+

Source: United Nations DESA, Population Division, 2019

Rise of Chronic Diseases

- We are living longer with more health conditions
- 75-85% of healthcare spending on chronic disease management
- NCDs are the leading causes of death (63%) in all regions except Africa.
- NCDs projected to cost more than US$30 trillion (48% of global GDP in 2010)
- Respiratory diseases and allergies are a major global problem



Percentage of deaths from non-communicable diseases by country, 2013 (DOI: 10.4103/1658-600X.179820 Institute for Health Metrics and Evaluation

Medication Adherence

- Adherence to medications for chronic diseases is about 50%
- Non-Adherence can account for up to 50% of treatment failures
- About 125K people die each year because of non-adherence
- 25% of hospital admissions are associated with non-adherence
- Hospital admissions due to non-adherence totals $15.2 Billion
- Nursing home admissions due to non-adherence totals $31.3 billion

*Sources: Compliance Packaging: A Patient Education Tool, American Pharmacy, Vol. NS29, No 2 February 1989
Standberg, L.R., Drugs as a Reason for Nursing Home Admissions, American Health care Association Journal, 10,20 (1984).
Osterberg, L., and Blaschke, T. (2005). Adherence to medication. *N. Engl. J. Med., 353*, 487-497.
Medication Adherence: The Elephant in the Room
https://www.uspharmacist.com/article/medication-adherence-the-elephant-in-the-room

Global Medication Adherence Trends

Some World figures…

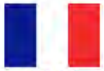
- *[WHO]* : "More health benefits worldwide would result from improving adherence to existing treatments than developing any new medical treatment."
- **50%** of patients do not take their medications as prescribed
- **$390 to $500 Billion** (€375 billion) unnecessary annual healthcare spending [*MediMedia ↦ IMS Study*][2, 3]

315 Mh

- **50%** of the 3.2 billion annual prescriptions dispensed in the US are not taken as prescribed
- Approximately **125,000 deaths per year** in the US are linked to medication non-adherence[4]
- Total cost is ranging from **$177** to **$213 billion** (€158 billion) each year[5]

504 Mh

- **50%** of patients don't take their medicine properly
- Approximately **200,000 premature deaths** in Europe
- Total cost estimated to $172 billion (**€125 billion**) each year[6]



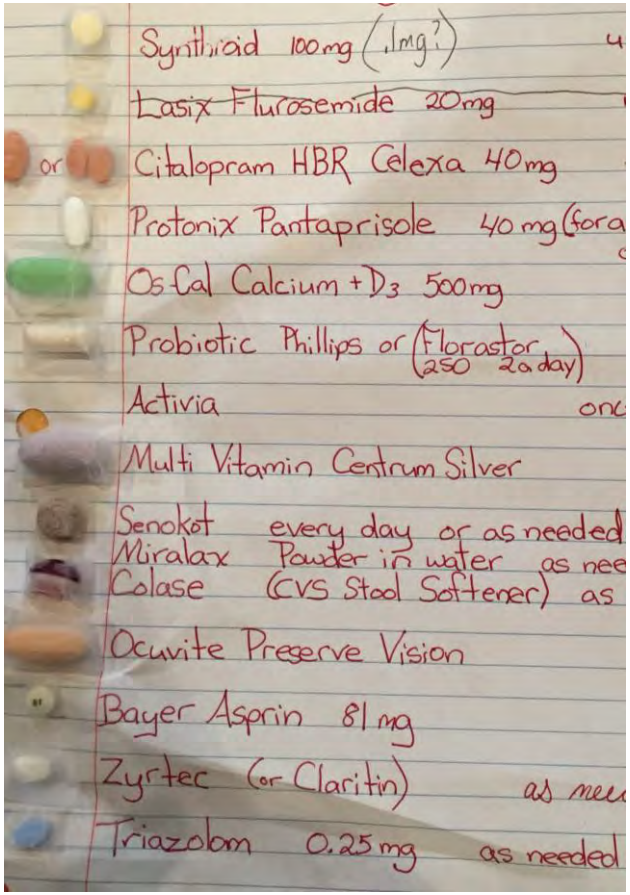
63 Mh

- **20%** of patients do not even buy prescribed medicines in France[7]
- Approximately **8,000 deaths per year** and 1.1 million hospital days[8]
- Total cost estimated to $26 billion (**€19 billion**) each year

Source: Economic aspect of medication adherence using mobile medication reminder in French Health System
http://www.medetel.lu/download/2014/parallel_sessions/presentation/day2/Economic_aspect_of_medication.pdf

Medication Lists

Older adults often have high number of medications and complex schedules for taking them



Understanding Health Information

- 1 in 5 North American adults aged 75 or over has a self-reported **seeing disability**
- About 50% of North American adults have **low literacy**, meaning they lack the literacy skills needed for everyday life
- About 60% also have **low health literacy** and struggle to "obtain process, and understand basic health information and services needed to make appropriate health decisions

Preventing Falls in Older Adults

- More than 1/3rd aged 65+ years fall each year
- Older adults hospitalized for fall-related injuries 5X more often than for other injuries
- Fall injury costs $19,440 (hosp, nursing home, ER, home health care, but not physician services)
- Total cost of all fall injuries for people age 65+ in 1994 was $27.3 billion in U.S.
- 2020, cost of falls to be $43.8 billion in U.S.

*Sources: http://www.cdc.gov/ncipc/factsheets/fallcost.htm; CDCReport: A Toolkit to Precent Senior Falls

Parkinson's

- 1 million Americans suffer from Parkinson's disease today
- 40,000 new cases diagnosed each year in U.S.
- 15% with Parkinson's are diagnosed before age 50
- Total cost to the USA is estimated to exceed $5.6 billion annually
- Parkinson's drugs costs patients $2500+ each year
- Therapeutic surgery costs up to $100k per patient

Source: http://www.pdf.org/AboutPD/index.cfm

Alzheimer's

- Of those at least 65 years of age, there is an estimated 5.0 million adults with dementia in 2014 and projected to be nearly 14 million by 2060. (CDC)
- Alzheimer's disease is ultimately a fatal form of dementia. It is the sixth leading cause of death in the United States, accounting for almost 4% of all deaths in 2014.
- 1 in 3 older adults dies with Alzheimer's or other dementias. Deaths related to Alzheimer's are more than breast cancer and prostate cancer combined.
- More than 16 million Americans provide unpaid care for people with Alzheimer's or other dementias
- These caregivers provided an estimated 18.5 billion hours of care valued at nearly $234 billion
- In 2019, Alzheimer's or other dementias will cost the nation $290 Billion. By 2050 costs could reach $1.1 Trillion

Source: CDC https://www.cdc.gov/aging/dementia/ and Alzheimer's Association https://www.alz.org/alzheimers-dementia/facts-figures

Age-Related Diseases and Clinical and Public Health Implications for the 85 Years Old and Over Population

- 62% of Americans over 65 have more than one chronic condition (34) and the prevalence of multiple chronic conditions is increasing (35)
- Prevalence of diabetes among American older adults may increase more than 400% by 2050 (31).
- Cardiovascular disease remains the most common cause of death, Cancer is the second leading cause of death
- Rates of dementia increase with age. Death rates from Alzheimer's disease have been rising while death rates for cardiovascular disease have been falling.
- Frailty is defined as special vulnerability to stressors and is suggested by weakness, slowness, exhaustion, and weight loss (46). In one study, 38% of people aged 85–89 were frail (47)
- 20% of people meet criteria for sarcopenia (meaningful loss of muscle mass and strength) (11)
- Major depression is common throughout adulthood but incidence rates drop after age 60 and then rise again after age 80. Depression prevalence for adults over age 85 is double the rate seen at age 70–74 (23).
- Social isolation predicts mortality and other adverse outcomes in older adults (58). Five percent of older adults are home bound, rarely leaving the home except for important medical appointments (59). Most of these older adults are >80.
- Approximately 13% of women and 8% of men over age 85 live in nursing facilities or other institutional settings (62).
- By 2035, the number of American households with someone over age 80 will double (61) .

Source: Front Public Health. 2017; 5: 335. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5732407/

Healthcare Provider Shortage

Shortage of Geriatricians

"There are about 7,000 **geriatricians** in practice today in the United States.

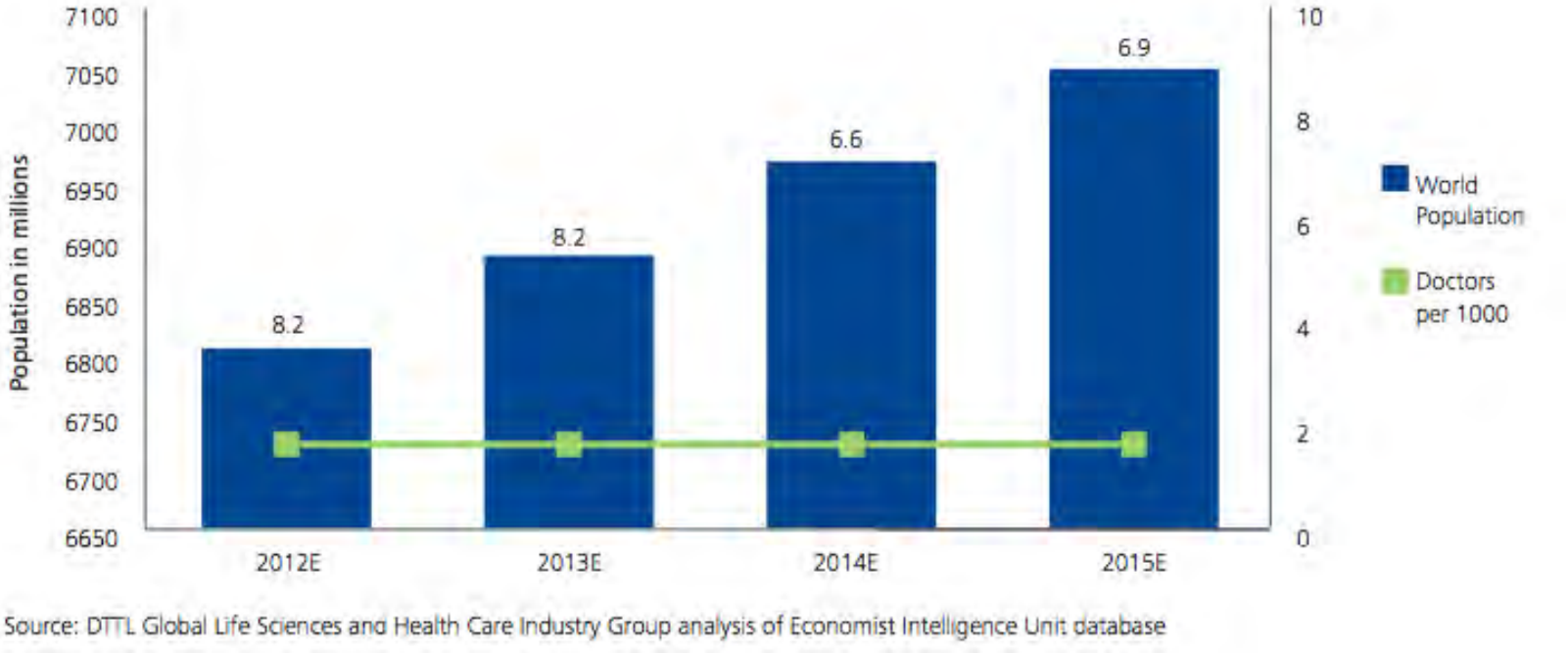
The American **Geriatrics** Society estimates that to meet the demand, medical schools would need to train at least 6,250 additional **geriatricians** between now and 2030, or about 450 more a year than the current rate."

NY Times Jan 26, 2016

https://www.nytimes.com/2016/01/26/health/where-are-the-geriatricians.html

Healthcare Provider Shortage

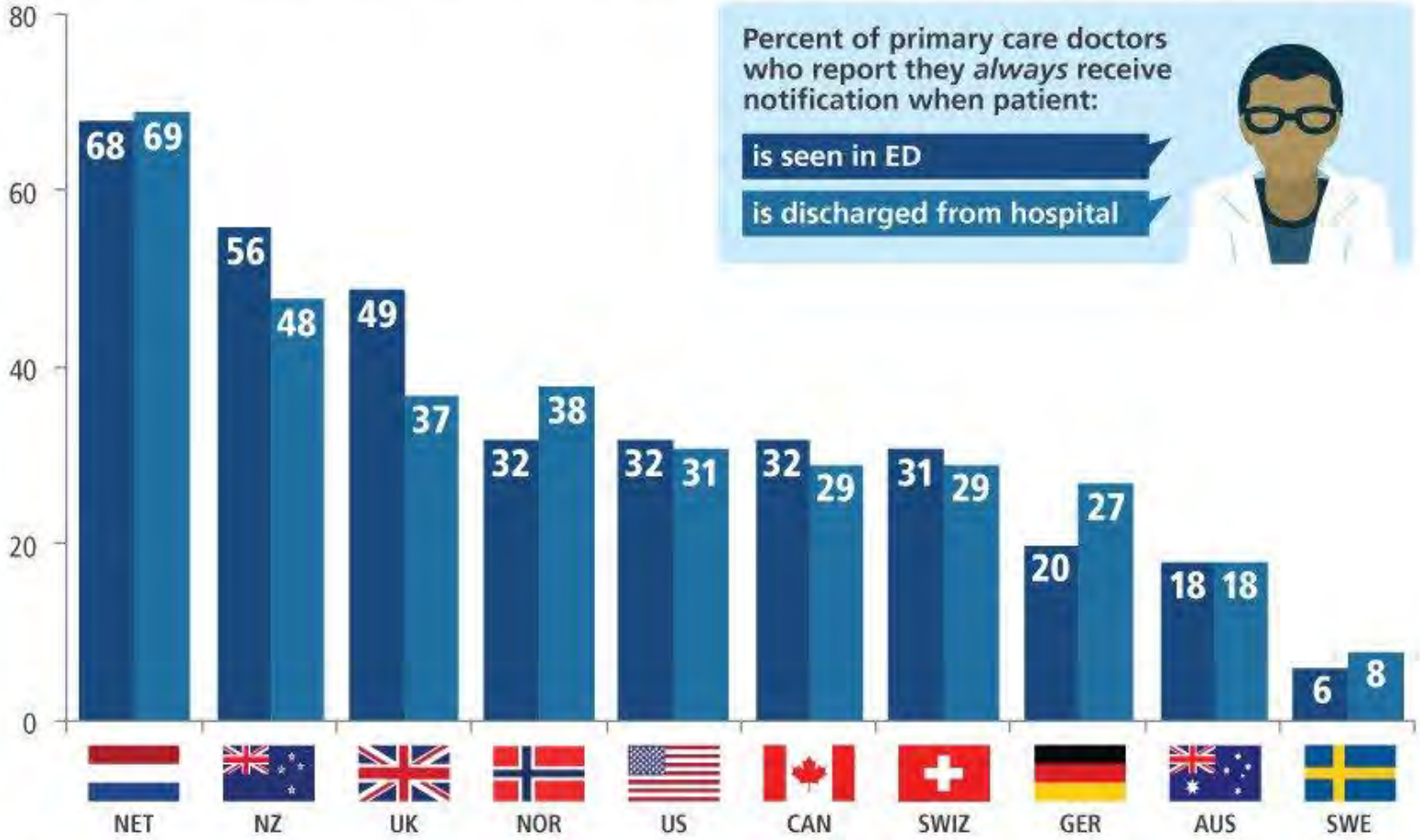
- There will be a shortage of 230,000 physicians in Europe
- The number of caregivers in 36 countries in Africa is inadequate to deliver even the most basic immunization and maternal health services.



Source: Deloitte 2014 Global health care outlook
https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/dttl-lshc-2014-global-health-care-sector-report.pdf

All Nations Face Challenges Coordinating Care

Doctors in every country in a 10-nation survey reported that their practices struggled to coordinate care and communicate with other health providers, which is key to managing patients with complex care needs.



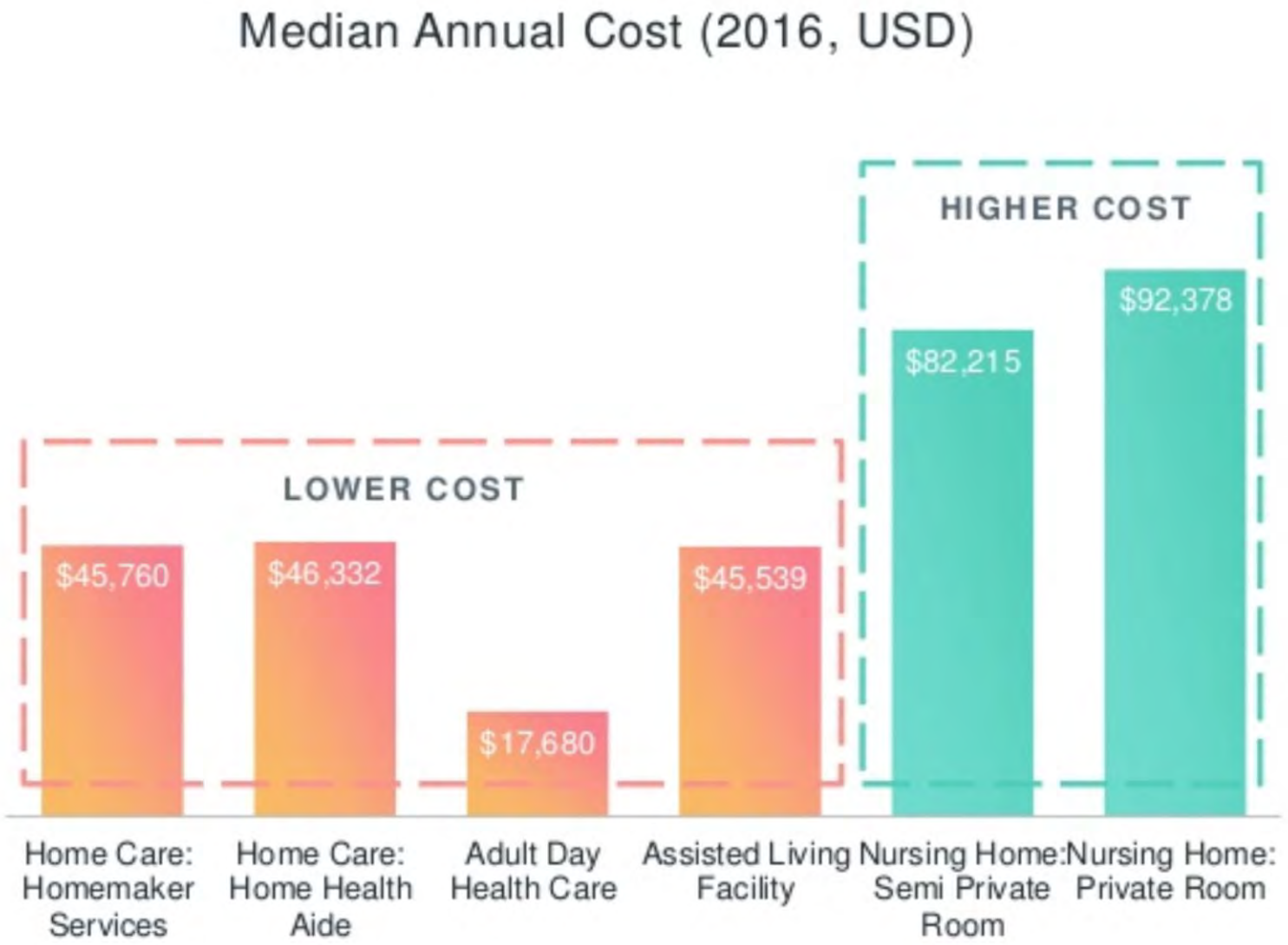
Source: 2015 Commonwealth Fund International Health Policy Survey of Primary Care Physicians.

Caring for patients with complex health needs is a challenge for providers around the world
Source: Commenwealth Fund http://buff.ly/21UFQVl

Financials of Elder Care

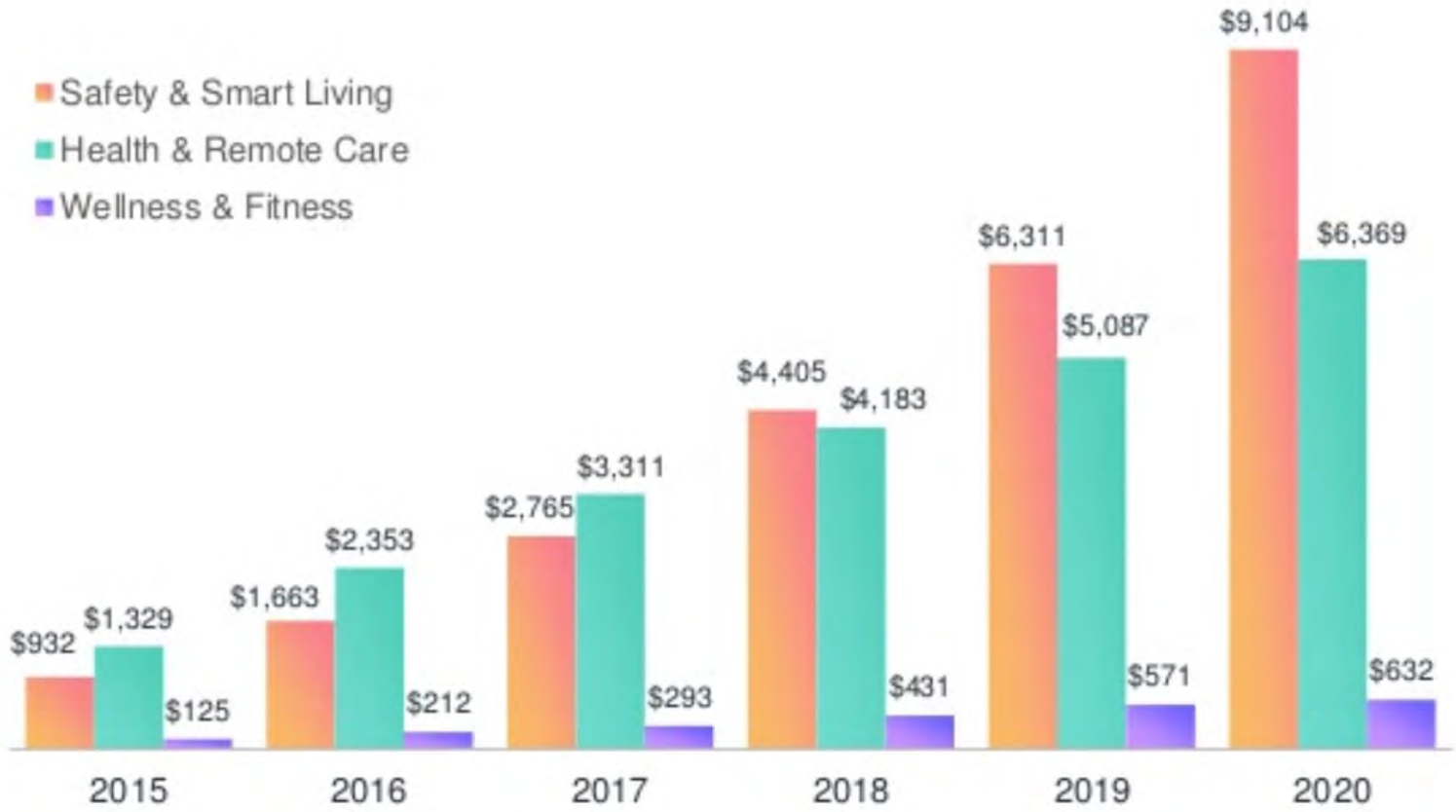
Rising Health Costs

Source: Deloitte 2014 Global health care sector outlook www.deloitte.com/2014healthcareoutlook



Source: Genworth Financial Website, CDC (2016) and
[Digital Health Report] HealthXL & AARP: Enabling Connected & Independent Living Through New Care Models

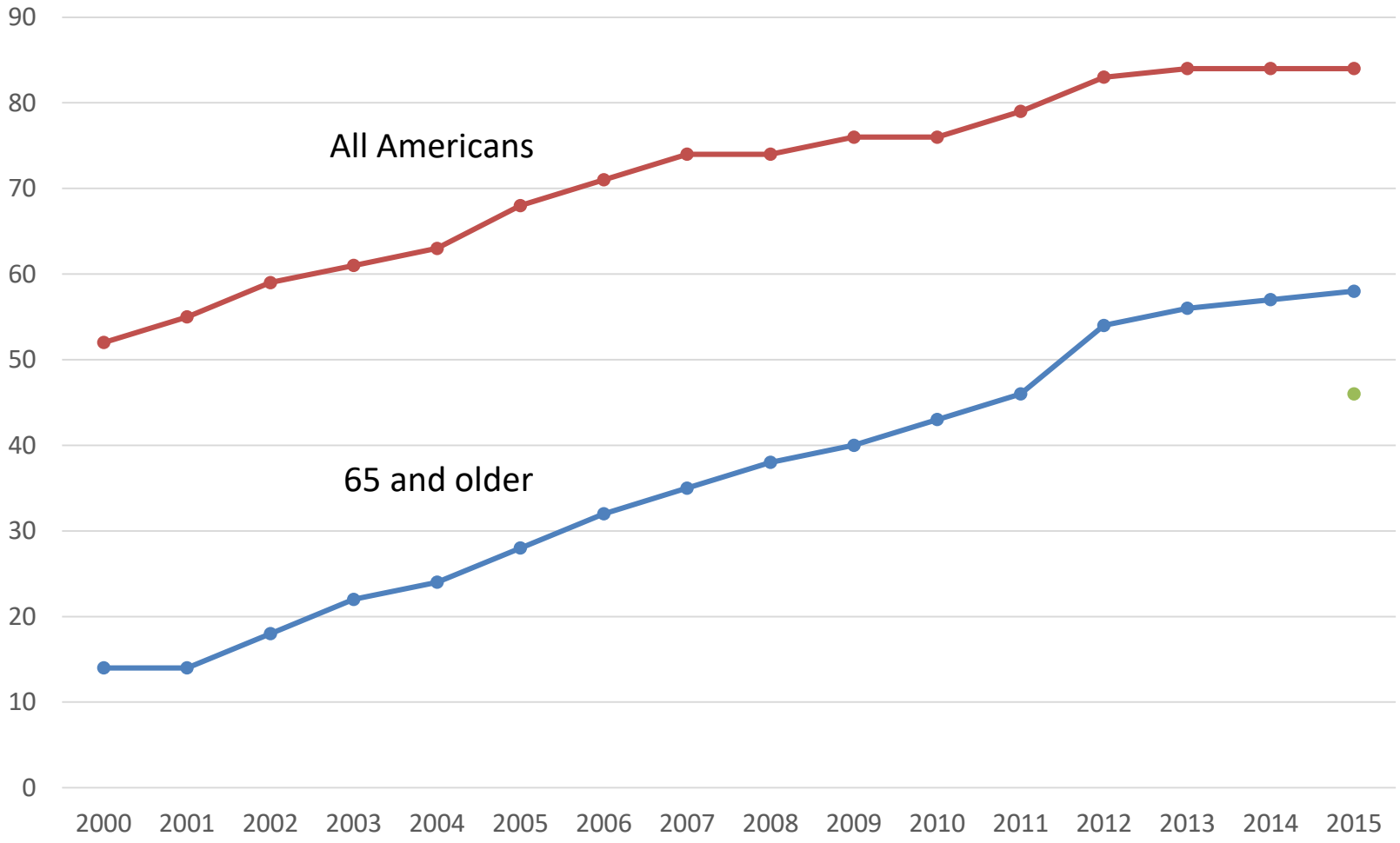
U.S. Active Aging Market Forecasts – Connected Solutions (USD, Millions)



Source: Genworth Financial Website, CDC (2016) and
[Digital Health Report] HealthXL & AARP: Enabling Connected & Independent Living Through New Care Models

Technology and Elders

Internet Access



http://www.pewinternet.org/2015/06/26/americans-internet-access-2000-2015/

Older adult's use of technology

Usage drops off by age. Form factor is an issue.

	Internet Use	Broadband	Smart Phone	Social Media
65-69 (n=531)	74%	65%	29%	54%
70-74 (n=401)	68%	55%	21%	42%
75-79 (n=244)	47%	34%	10%	46%
80+ (n=360)	37%	2%	5%	27%

Pew Research Center April 2014

Burden on Families

Sharing the Care Burden

"Women provide nearly two-thirds of all elder care, with wives more likely to care for husbands than vice versa and daughters 28% more likely to care for a parent than sons"

Source: https://jamanetwork.com/journals/jamaneurology/fullarticle/2624330

"The responsibilities of caring for someone with dementia often fall to women. Approximately two-thirds of caregivers are women. More specifically, over one-third of dementia caregivers are daughters"

Source: Alzheimer's Association. 2016 Alzheimer's disease facts and figures. *Alzheimers Dement*. 2016;12(4):459-509. https://www.ncbi.nlm.nih.gov/pubmed/27570871

Family-Centric Networks

Eldercare Communities

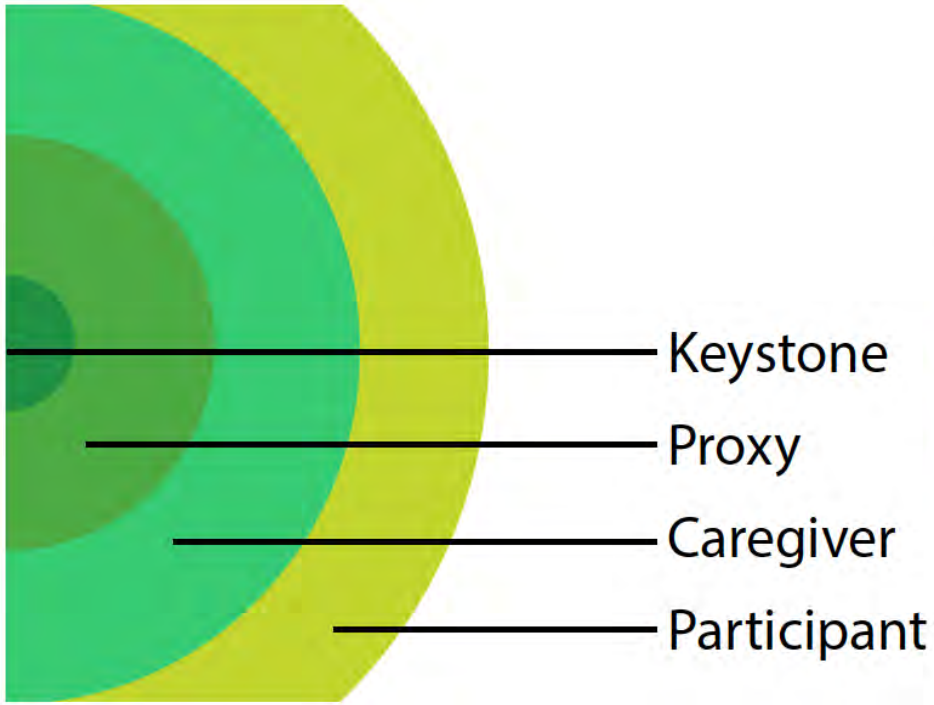
- Aging creates challenges for **elders and their families** for healthcare decision-making, information management, and communication
- **Care Coordination** is exceptionally challenging
- Respecting the **elder's preferences** and priorities is often lost in transition

http://ww.InfoSAGEHealth.org

- InfoSAGE is a family-based **private social network** for coordinating care that is centered on the elder
- InfoSAGE provides educational resources, communication tools, task management, medication management, interaction alerts, and more …
- While designed to support the care of fail elderly, system also works for other serious illnesses and conditions where families are involved in care support.

Quintana Y, Crotty B, Fahy D, Orfanos A, Jain R, Kaldany E, Lipsitz L, Engorn D, Rodriguez J, Pandolfe F, Bajracharya A, Slack WV, Safran C. InfoSAGE: Use of Online Technologies for Communication and Elder Care. Stud Health Technol Inform. 2017;234:280-285. PMID: 28186055

Design of InfoSAGE™



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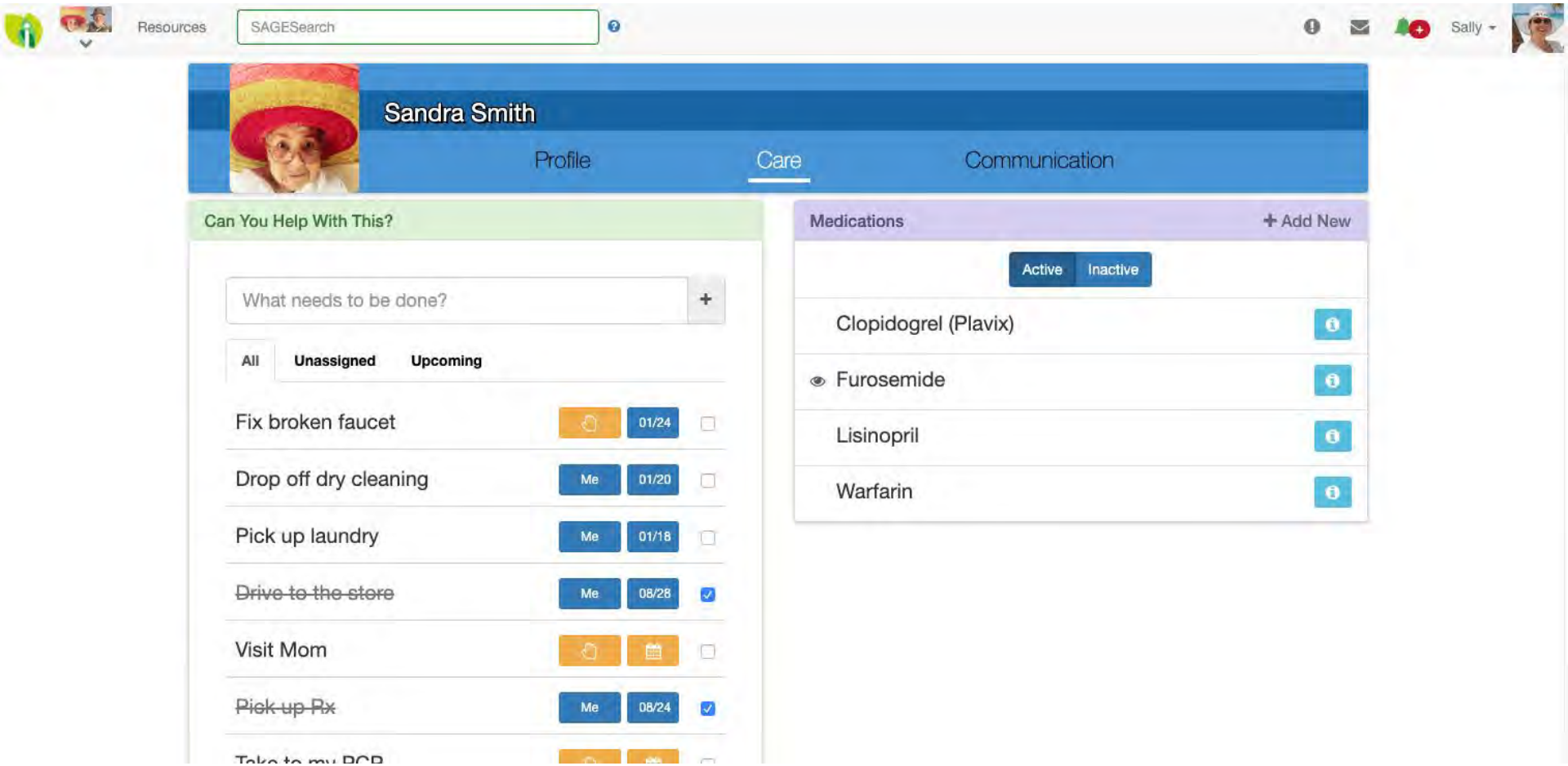
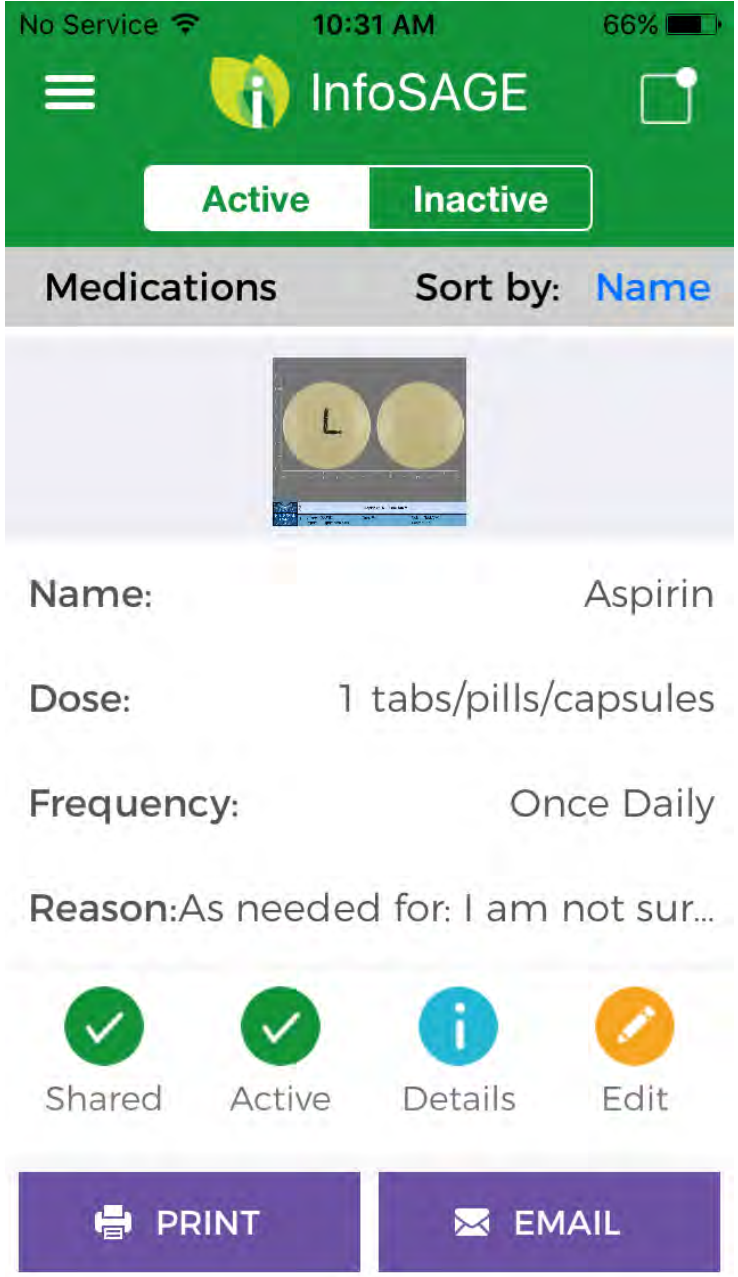
InfoSAGEHealth.org





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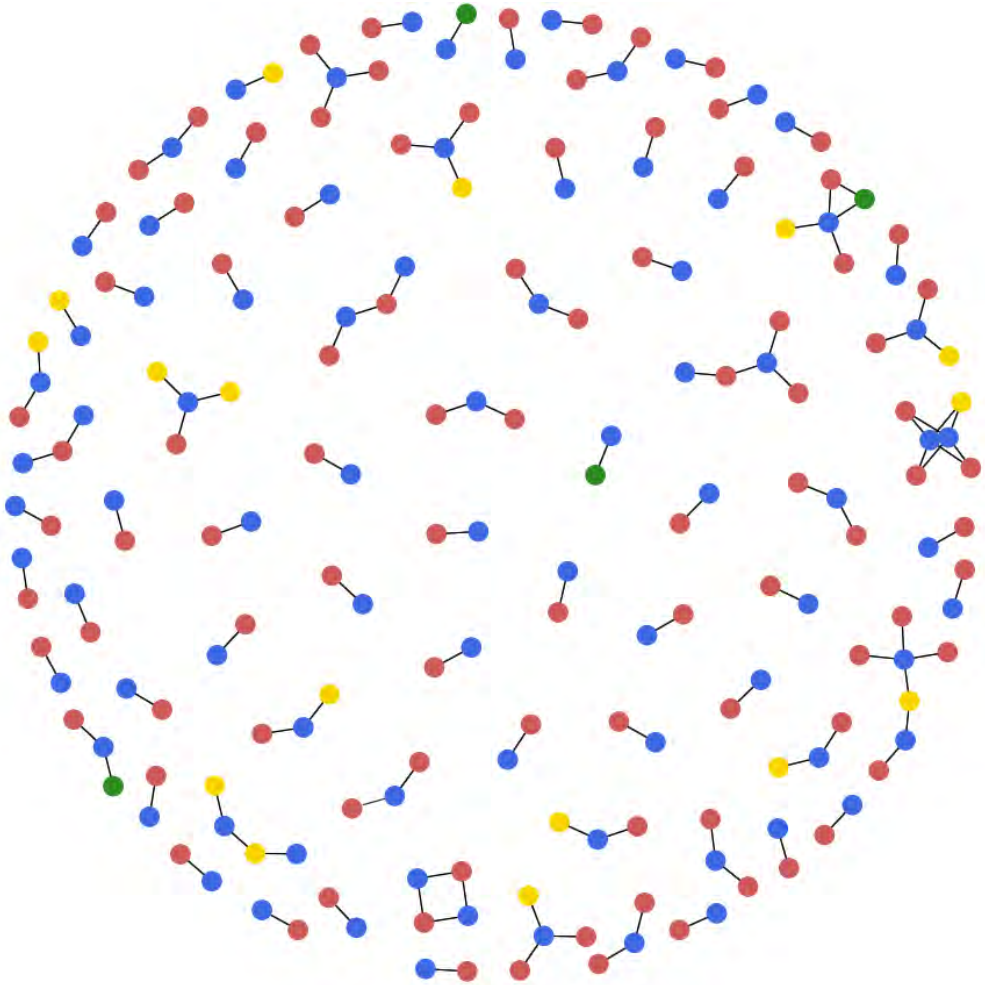
InfoSAGE™
Information Sharing Across Generations

Family Centric Networks



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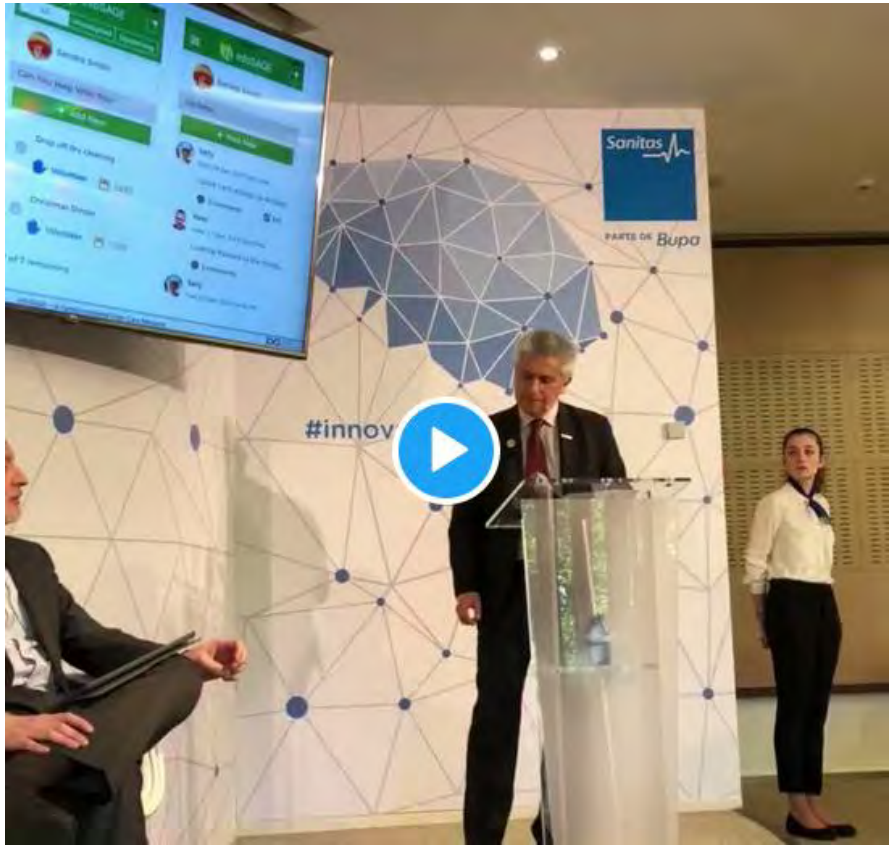
InfoSAGE™
Information Sharing Across Generations

Network 3
21 month timespan

PMID: 28186055

InfoSAGE Voice Interface

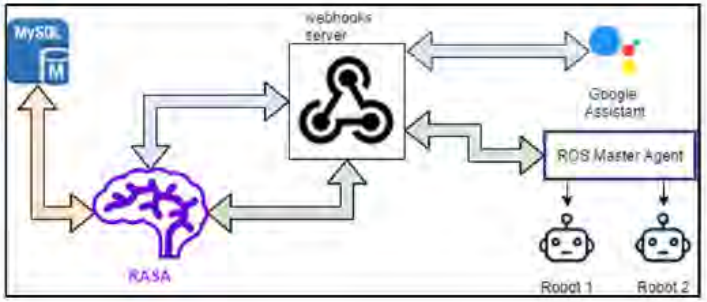


https://twitter.com/Yerburu/status/1004644954784849920

Speech Enabled Social Robots Platform for Elderly Care Support

Mahmoud Nasr and Fakhri Karray
Electrical and Computer Engineering, University of Waterloo, Canada
Yuri Quintana
Division of Clinical Informatics, Harvard University, USA

- Innovative assistive technologies are needed for care of older adults
- A system was created for natural interactions between elderly and robotic systems through speech
- Integrated capability of utilizing robots with other smart devices with a central brain
- Provided experimental results and future directions for elderly care by expanding current system



Proposed system architecture and communication

Speech Enabled Social Robots Platform for Elderly Care Support

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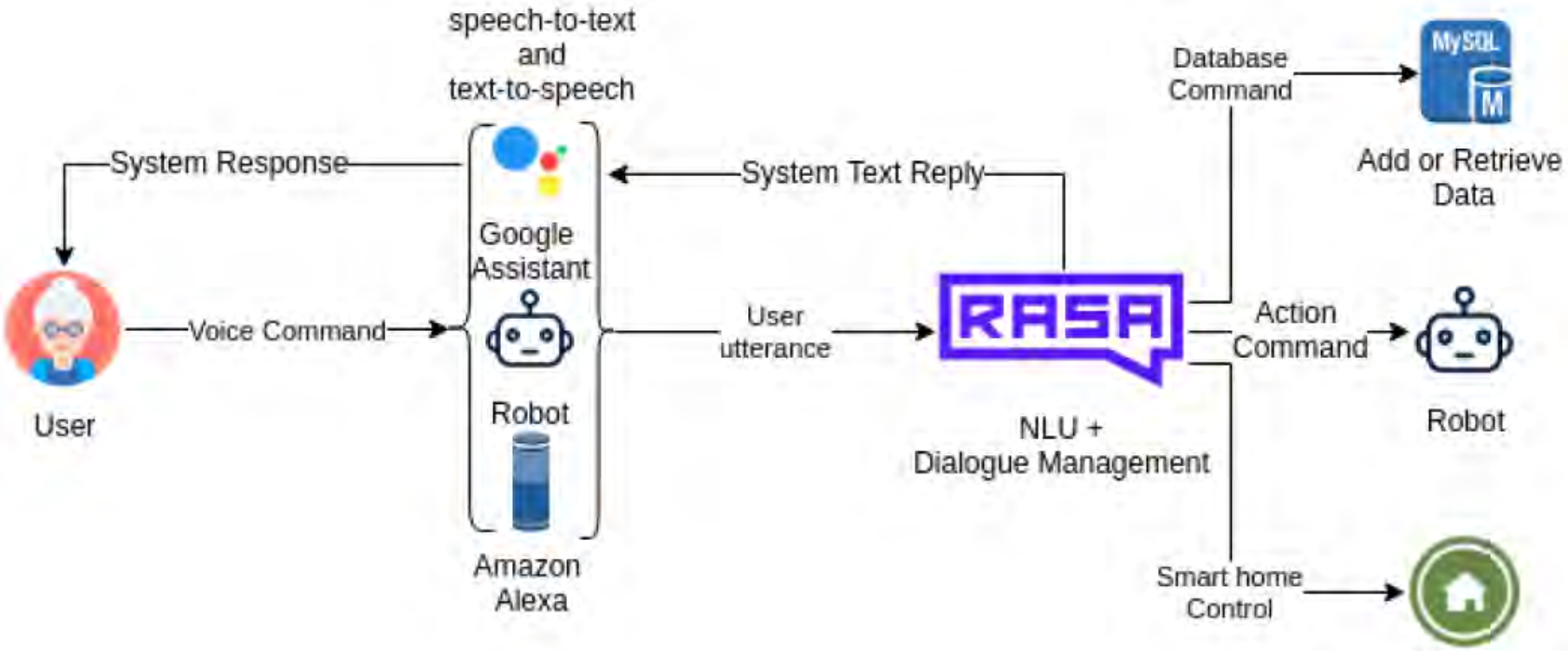
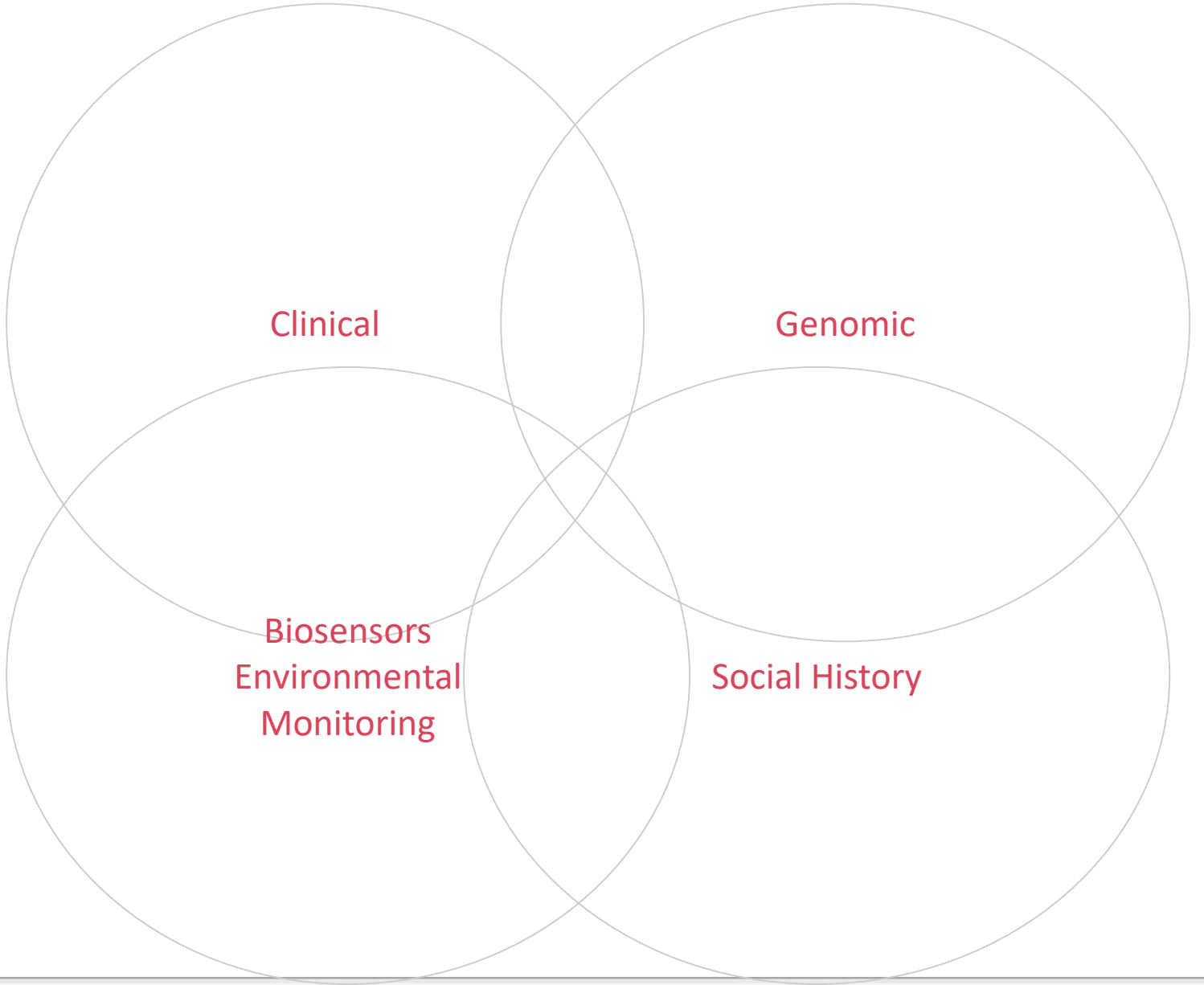


Fig. 2. System Architecture

Integration of AI with Home Monitoring Services

Healthcare is multi-dimensional



Clinical Grade Devices

[FDA Clears Biobeat's Wearable Watch and Patch for Non-invasive Cuffless Monitoring **of Blood Pressure**](26 Aug, 2019)

[Omron's smartwatch blood pressure monitor cleared by FDA](December 20, 2018)

[Garmin Health Partners with ActiGraph to Create Wearables for Clinical Trials](December 17, 2018)

medical-grade EKG
https://www.alivecor.com

Social Robots

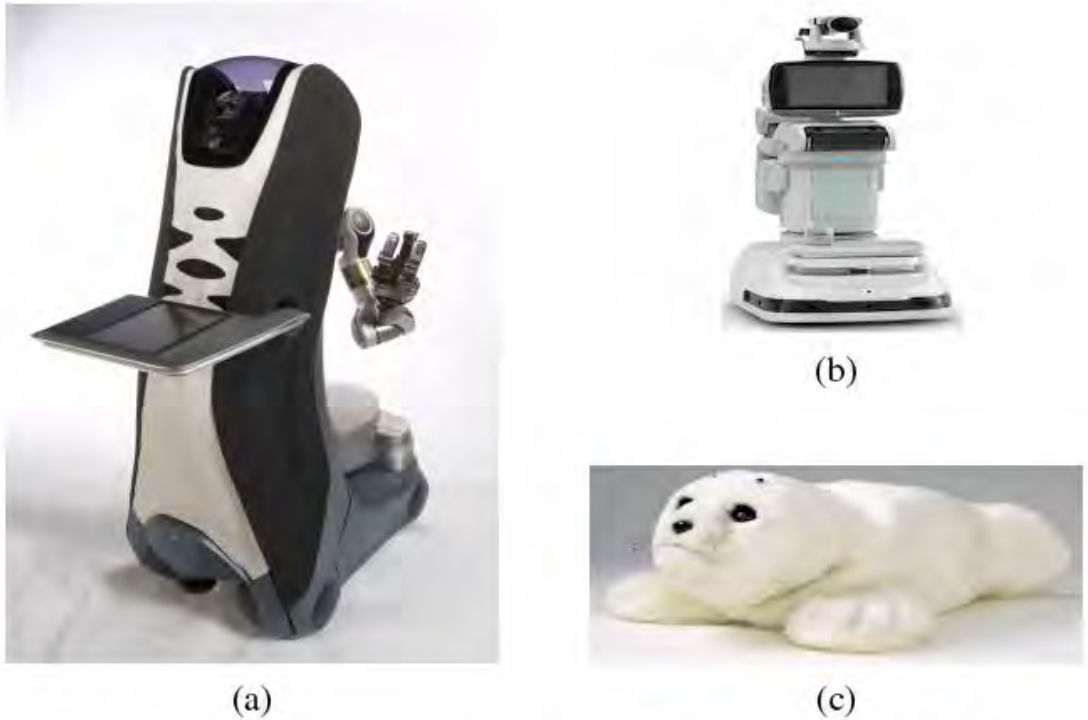


Fig. 1. Social Robots Propose for Elderly Care (a) Care-o-Bot 3 used in [8] (b) HomeMate [9] (c) Paro [7]

Next Generation Home Care Systems

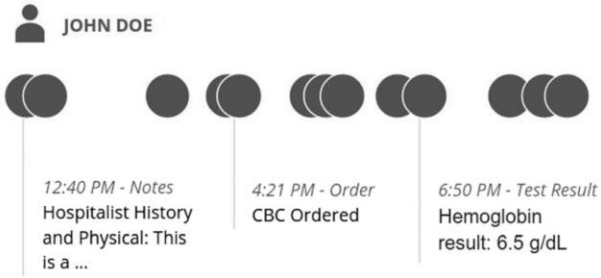
- **Patient-Centric** Models need to be co-designed with patients and families
- **Communication** between healthcare providers and their patients and families
- **Personalization** of education and care directives to patient and family
- **Accessibility** appropriate technology and form factor for older adults
- **Interoperability** - agreement on data standards and terminology
- **Outcomes** – Clinical, Education, Communication, Quality of Life, Cost

Current Challenges of Artificial Intelligence in Medicine

Deep learning with electronic health records

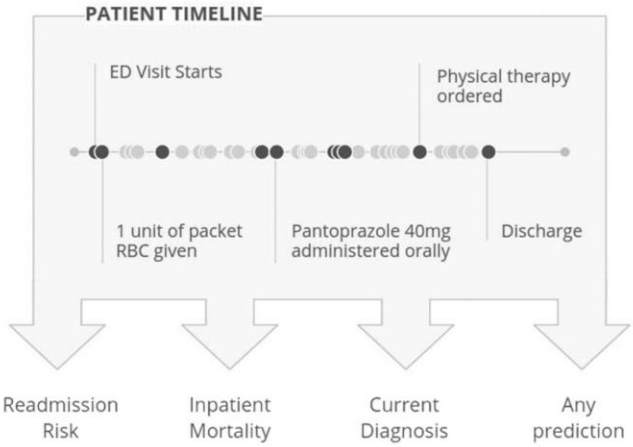
1

Health systems collect and store electronic health records in various formats in databases.



2

All available data for each patient is converted to events recorded in containers based on the Fast Healthcare Interoperability Resource (FHIR) specification.



3

The FHIR resources are placed in temporal order, depicting all events recorded in the EHR (i.e. timeline). The deep learning model uses this full history to make each prediction.

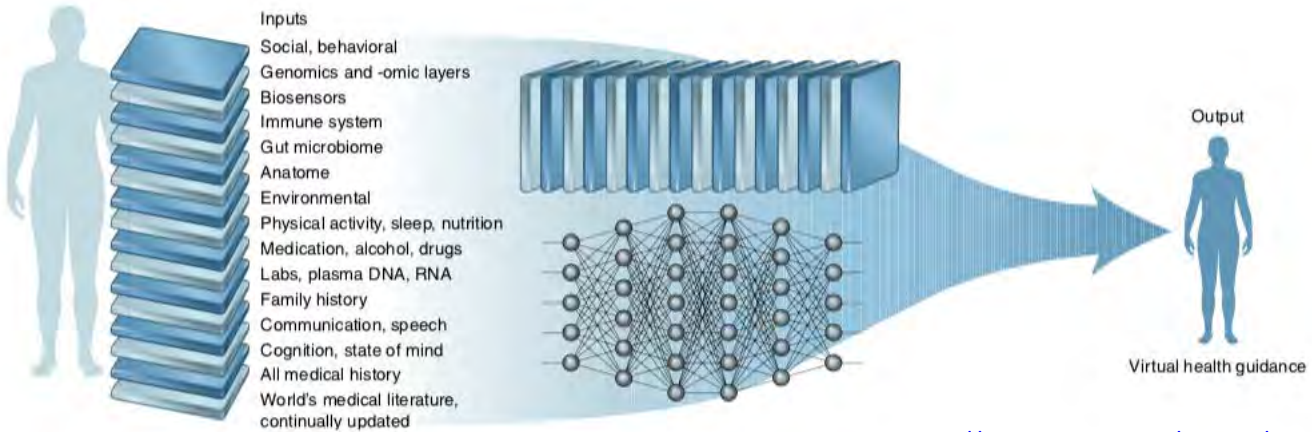
Source: Rajkomar 2018 https://www.nature.com/articles/s41746-018-0029-1.pdf

The Mystery of the Black Box

Machine learning is becoming ubiquitous in basic research as well as in industry. But for scientists to trust it, they first need to understand what the machines are doing.

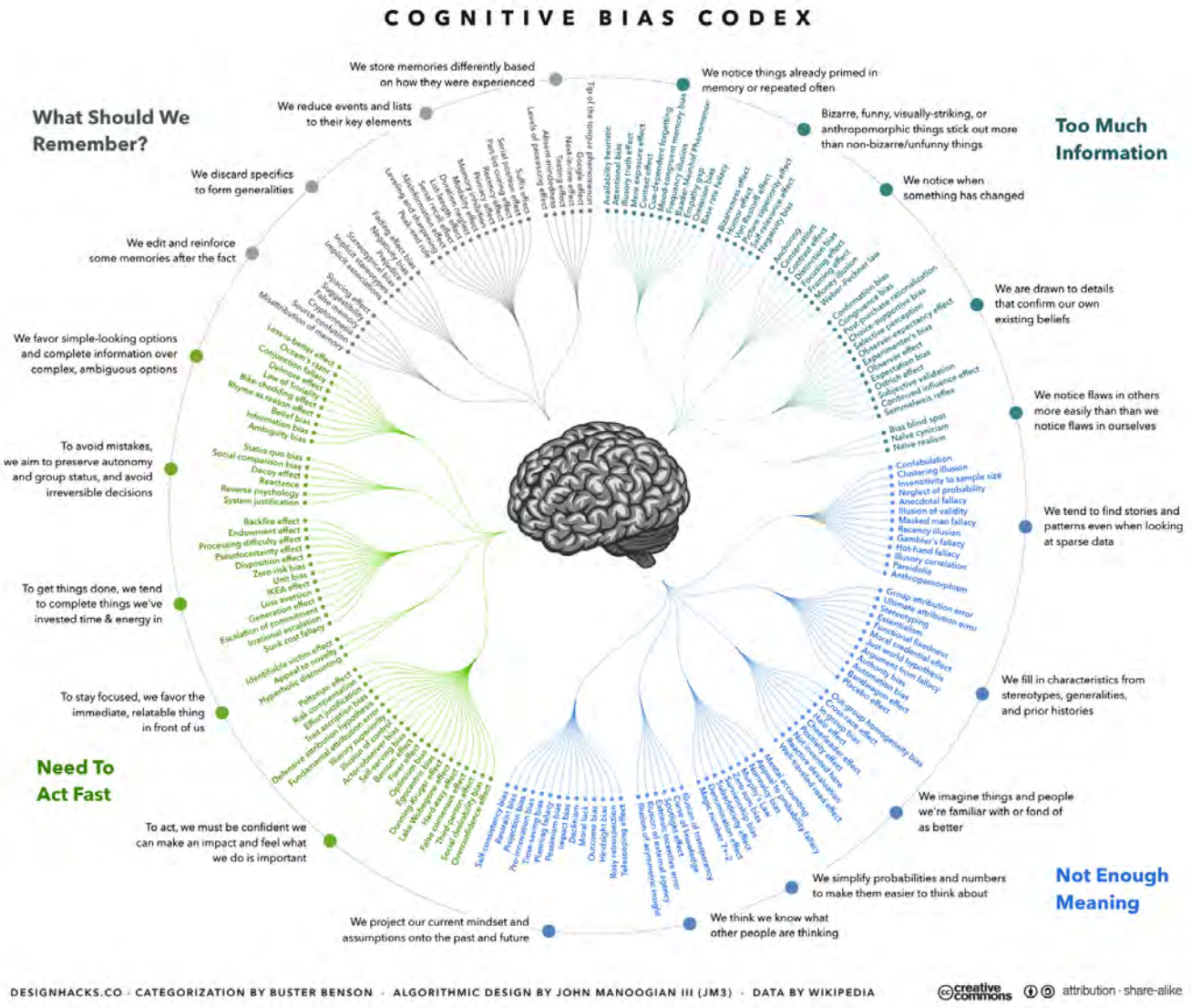
BY DAVIDE CASTELVECCHI

Source: https://www.nature.com/news/can-we-open-the-black-box-of-ai-1.20731



Source: Topol 2019 https://www.nature.com/articles/s41591-018-0300-7

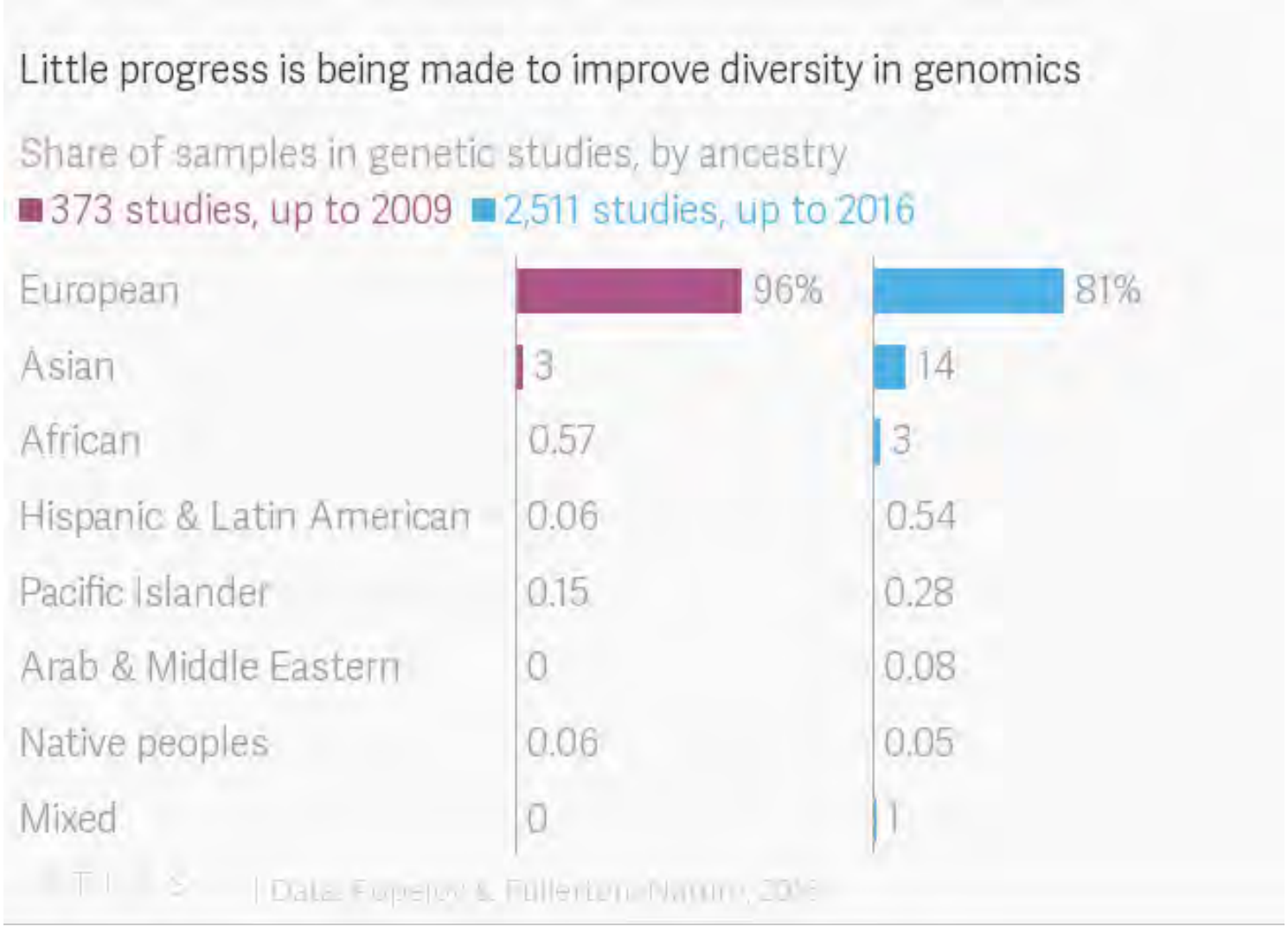
Challenge of Cognitive Bias in Algorithms



The Cognitive Bias Codex - 180+ biases, designed by John Manoogian III, Categories and descriptions originally by Buster Benson.Image from Wikimedia

See Also - Kliegr 2018 - A review of possible effects of cognitive biases on interpretation of rule-based machine learning models https://arxiv.org/abs/1804.02969

Challenge of a Lack of Diversity in Data sets



Source: https://www.theatlas.com/charts/r1U59AYw7

Challenge of De-Identification of Data

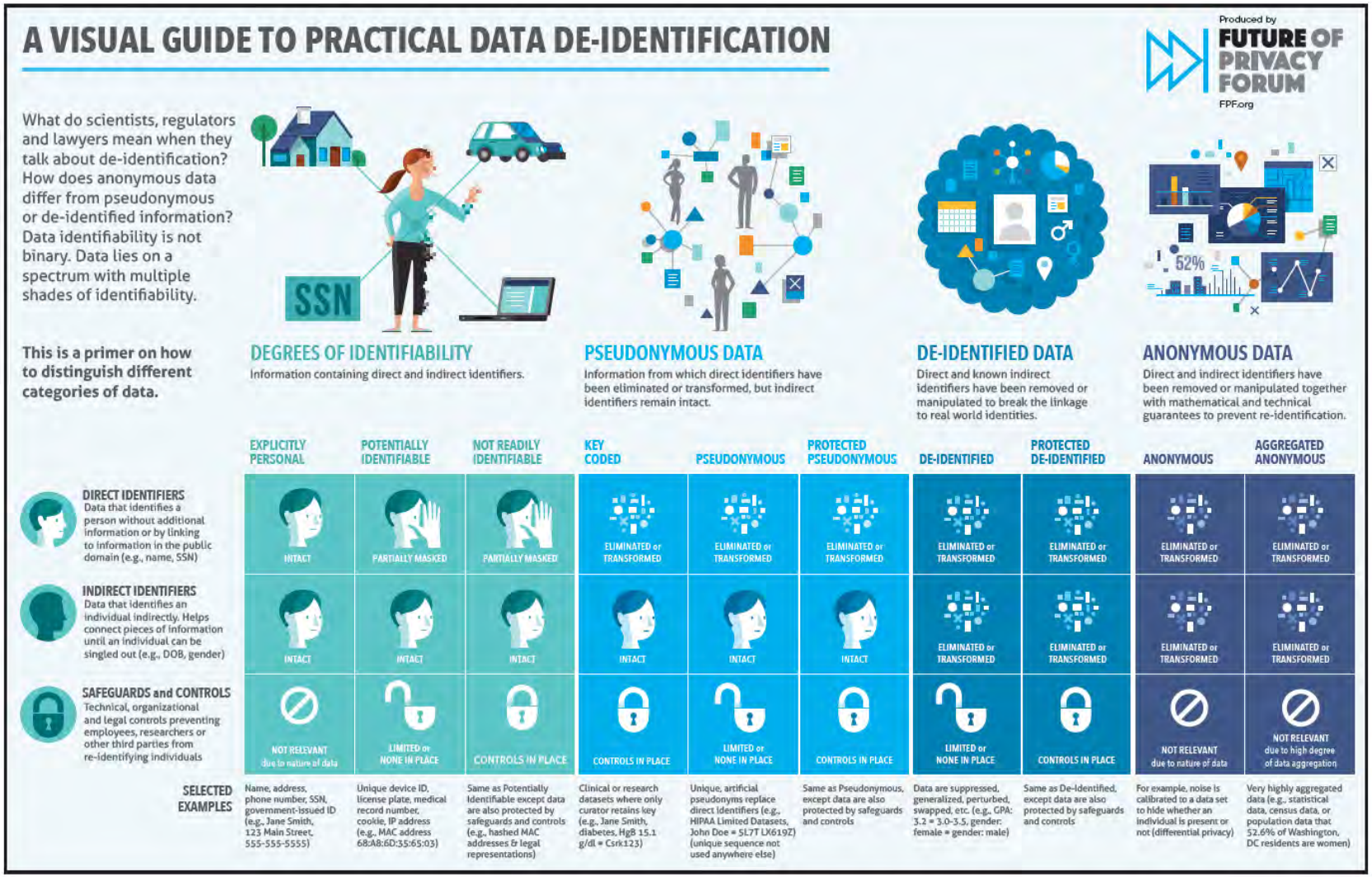


Image Source: https://fpf.org/2016/04/25/a-visual-guide-to-practical-data-de-identification/
and Shades of Gray: Seeing the Full Spectrum of Practical Data De-Identification. published in the Santa Clara Law Review.

"Are we ready for AI in Medicine?

- Systems need to communicate with patients, families and care providers in a **coordinated care network**
- Reasoning algorithms needs to take **social-demographics**
- Need **privacy** protection in large data
- Need systems to **explain** alerts and recommendations
- Need **transparency** in who is funding system and why
- Need to have human controls – **fail safe** checks
- Need to better ways to **integrate** AI Decision Support into healthcare systems, and **acceptance** by providers and patients

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Quintana Y, Henao J, Kaldany E, Gorenbeg M, Chen YP, Adra M, Lipsitz L, Safran C. InfoSAGE: Usage Pattern of a Family-Centric Care Coordination Online Platform. Stud Health Technol Inform. 2019 Aug 21;264:1972-1973. doi:10.3233/SHTI190740. PubMed PMID: 31438434.

Quintana, Y, Fahy, D, Crotty, B, Jain, R, Kaldany, E, Gorenberg, M, Lipsitz, L, Engorn, D, Rodriguez, J, Orfanos, A, Bajracharya, A, Henao, J, Adra, M, Skerry, D, Slack, WV. InfoSAGE: Supporting Elders and Families through Online Family Networks. American Medical Informatics Association Annual Symposium 2018 Dec 5;2018:932-941. eCollection 2018. PubMed PMID: 30815136.

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Quintana Y, Safran C. Global Health Informatics—An Overview. In Heimar de Fátima Marin, Eduardo Massad, Marco Antonio Gutierrez, Roberto J. Rodrigues and Daniel Sigulem, editors: Marin-Global Health Informatics, Oxford: Academic Press, 2016 , pp. 1 - 13. Chapter 1.
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Quintana Y, Patel AN, Arreola M, Antillon FG, Ribeiro RC, Howard SC. POND4Kids: A Global Web-based Database for Pediatric Hematology and Oncology Outcome Evaluation and Collaboration. Stud Health Technol Inform. 2013;183:251-6. PMID: 23388293

Projects: http://www.yuriquintana.com Papers at https://www.researchgate.net/profile/Yuri_Quintana

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