Medical Informatics

Clinical Decision Support Systems

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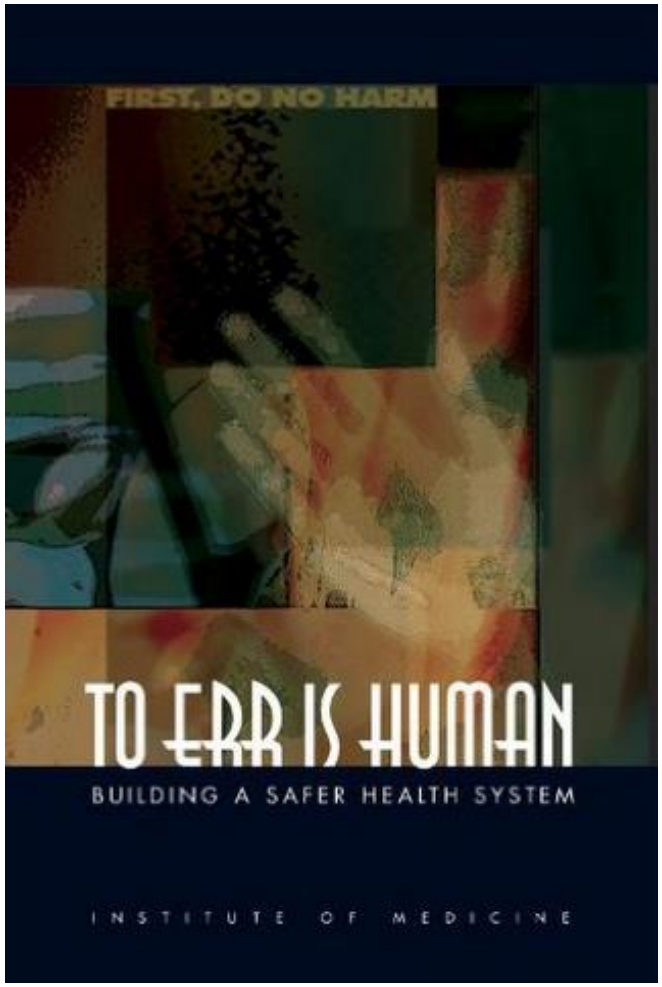
Learning objectives

- Give examples of situations in which computerized clinical decision support systems are useful in dentistry
- Know what are the basic components of computerized decision support systems
- Describe key decision support models
- Use examples of computer-based decision support services
- Explain the general idea behind machine learning
- Know basic methods to evaluate quality of decision support in classification tasks
- Discuss where are the strengths and weaknesses of clinical decision support in medicine and health care

Patient Safety



To err is human: building a safer health system

MS Donaldson, JM Corrigan, LT Kohn - 2000 - books.google.com

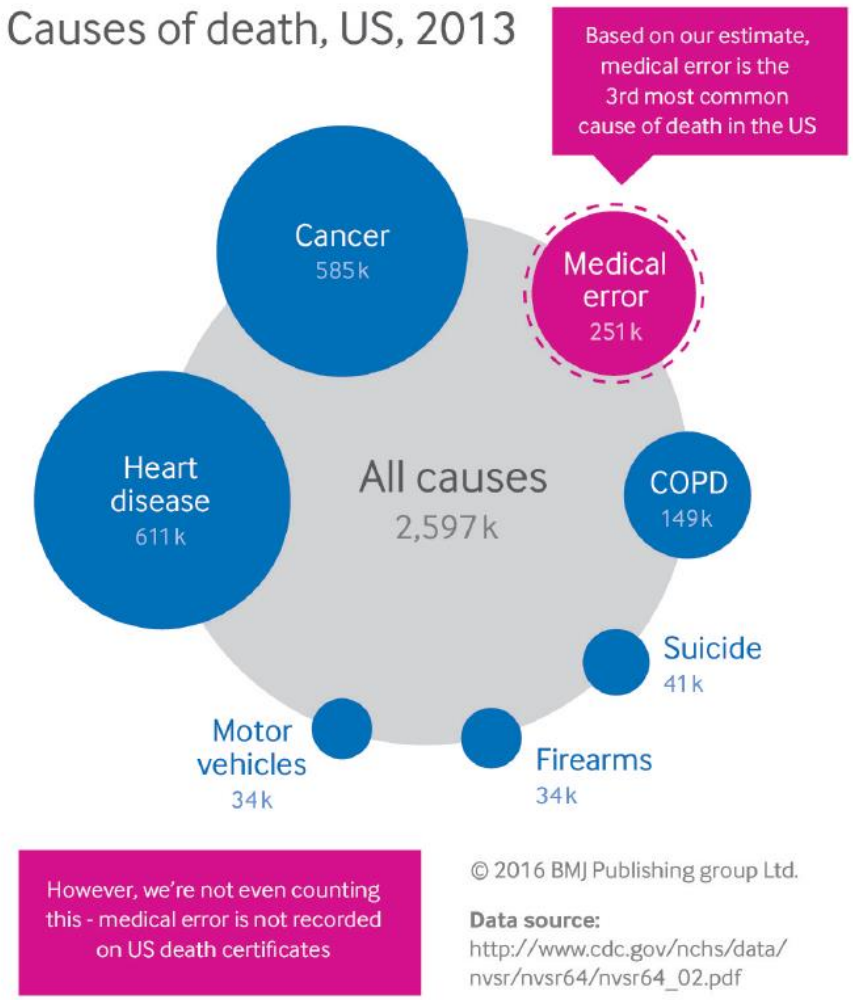
Experts estimate that as many as 98,000 people die in any given year from medical errors that occur in hospitals. That's more than die from motor vehicle accidents, breast cancer, or AIDSâ€" three causes that receive far more public attention. Indeed, more people die …

☆ ❞ Cited by 23942 Related articles All 43 versions

Makary MA, Daniel M

BMJ 2016;353:i2139 doi: 10.1136/bmj.i2139 (Published 3 May 2016)

Medical error—the third leading cause of death in the US



Progress in artificial intelligence

Autonomous vehicles

IBM Watson Jeopardy Champion

Artificial Intelligence Assistants

AlphaGo

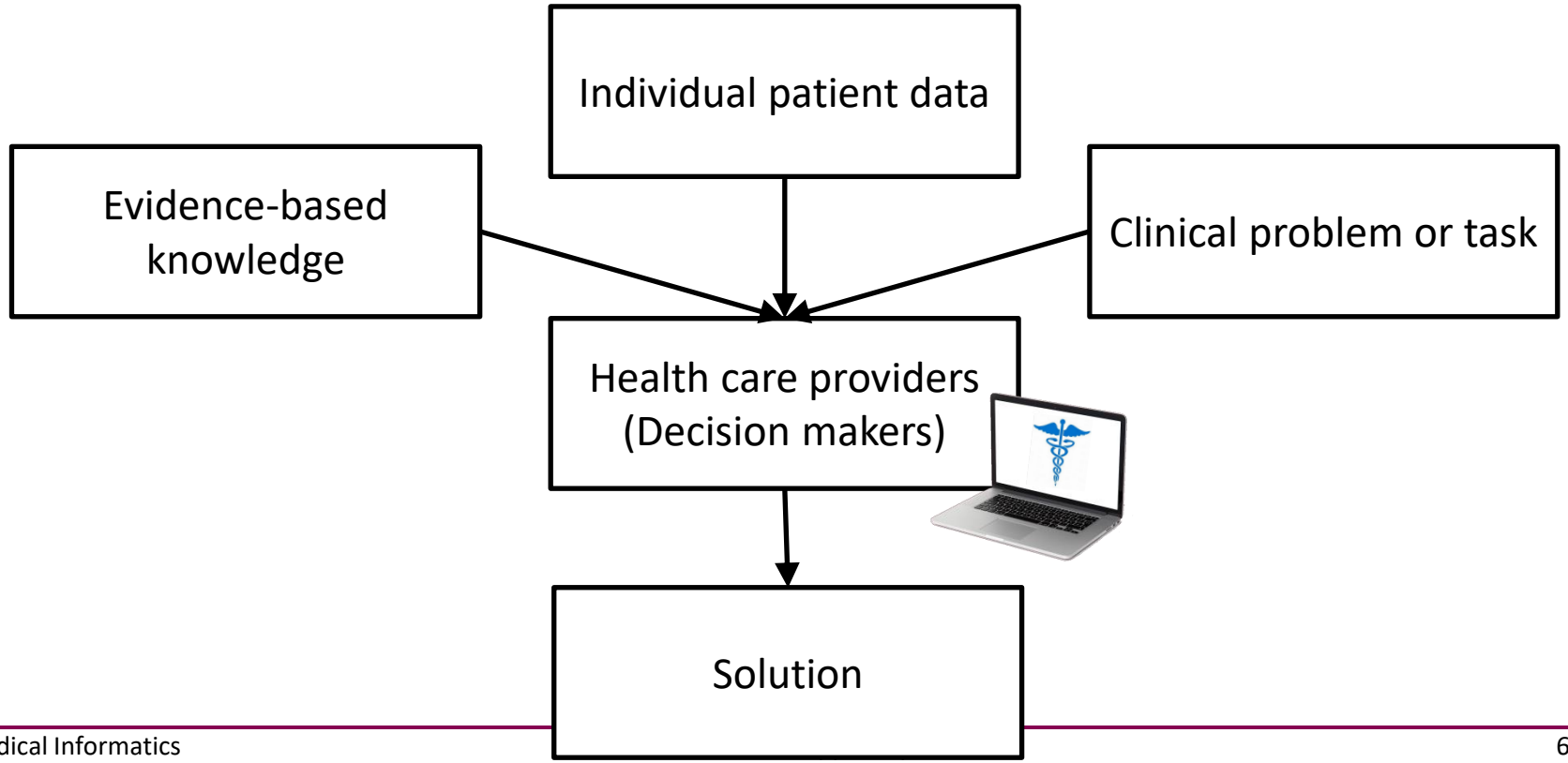
Google AlphaGo

The Man vs Machine argument

- Consider the recent breakthroughs in artificial intelligence
  - *IBM Watson beats human champs in Jeopardy;*
  - *Self-driving cars (Google, Tesla);*
  - *AI assistants* (Siri, Cortana, Alexa)
- Argue against or for whether computers can replace health professionals in decision-making?
- What are the unique strengths of computers and humans?

What are clinical decision support systems?

- Clinical decision support systems (CDSS)
  - assist health professionals in making good decisions regarding patient care
- Artificial Intelligence (AI)
  - ability of machines to mimic human cognition and behaviour



Exercise 1: CDSS in dentistry

- **You are divided in groups A,B and C**
- **Browse through the research articles assigned to your group. Prepare for the other groups a short summary using plain language what were the goals of the decision support system described in the papers assigned to your group.**

Clinical Decision Support Systems

Types of decision support

- Diagnosis
- Test selection
- Choice of treatment
- Prognosis
- Monitoring actions
- Focusing attention
- Optimizing workflows
- Improving patient communication
- Better quality of documentation

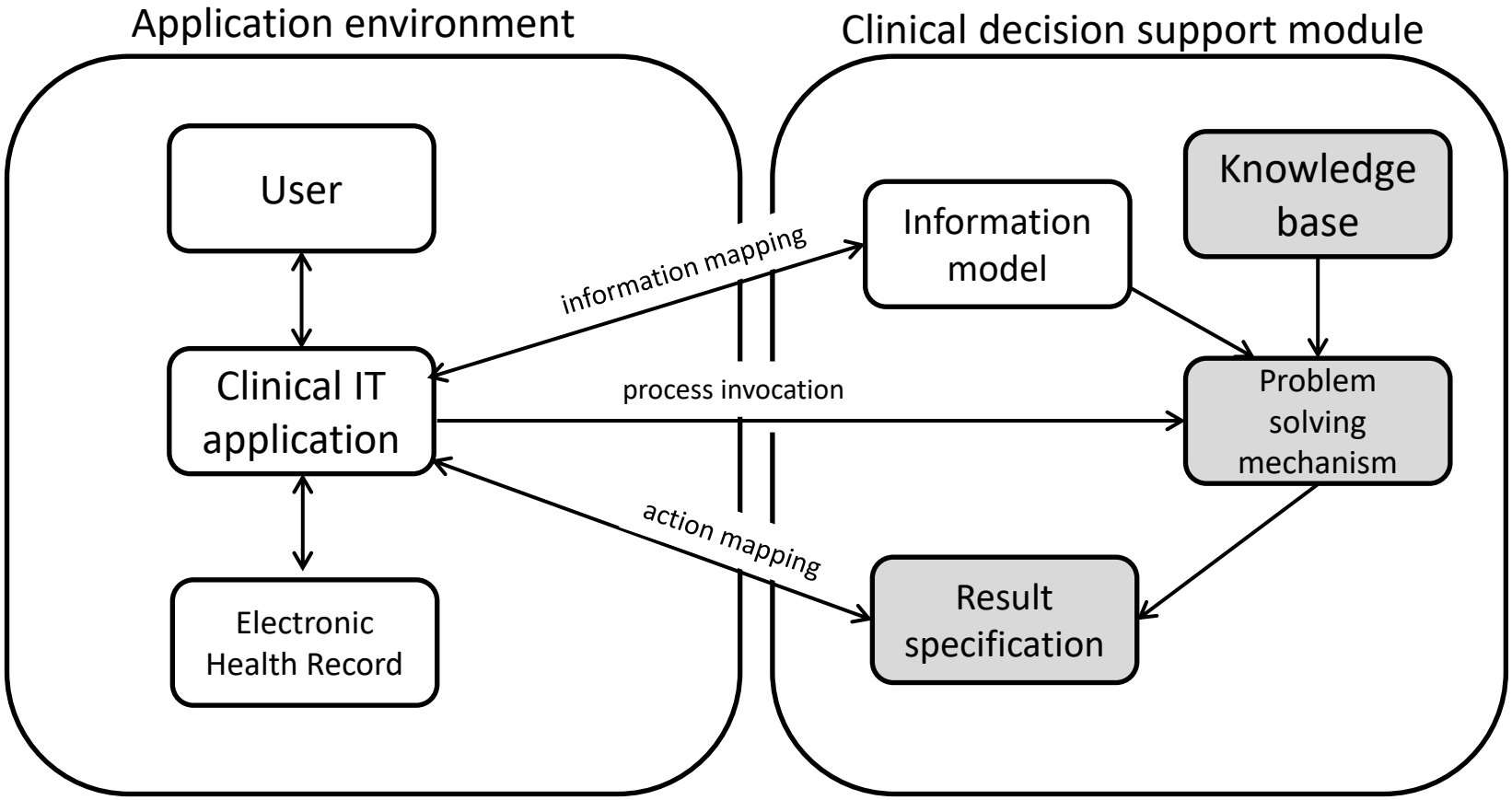
Motivation behind CDSS

- Growth in complexity
- Time pressure
- Variability in quality
- Economic reasons
- Better technology
- New health care legislations

Basic components of CDSS

- **Knowledge base**
  - e.g. facts and rules, parameters in computational models (statistical, machine learning), narrative descriptions (text of guidelines, research synthesis)
- **Problem solving mechanism**
  - provides new relevant information, predict future states of the system, describes past states, generalizes, explains the findings
- **User interface**
  - interacts with the user
  - enables update of the knowledge base

A conceptual model of CDSS design components



adapted from Greenes, R. A. "Clinical decision support: the road to broad adoption." (2014)

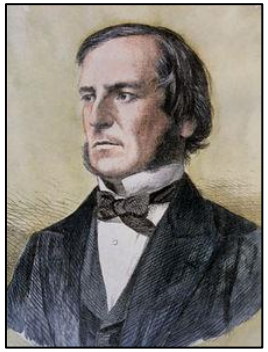
Models of decision support

1. Rule-based systems
2. Bayesian reasoning
3. Information retrieval

Rule-based systems

Production rules – statements of the form

IF (condition) **THEN** (action)



George Boole

Example 1:

IF Systolic blood pressure > 130 mmHg **THEN** Increase dose of ACEI/ARB

Logical condition may include several expressions combined by Boolean operators (AND, OR, NOT)

Action performed when the logical condition evaluates to true.

Example 2:

Diagnosis: **Systolic heart failure**
IF (Patient has either heart failure signs **OR** heart failure symptoms)
AND ECG abnormal (left bundle branch block AND anterior Q waves)
AND patient has (ischemic heart disease)
AND Chest X-ray abnormal (cardiothoracic ratio > 0.5)
AND natriuretic peptides abnormal (BNP > 100 pg/ml))

Dosing alerts

LMR OC4A2 MEDICATIONS - Windows Internet Explorer

http://lmrintra.partners.org/scripts/phsweb.mwl?PKG=0&ZXSOPT=

Favorites | LMR OC4A2 MEDICATIONS | Page | Safety | Tools

Bwhlmrmapltest,Fifteen | AW860 1/1 BIMA

24252884 (BWH) | 12/25/1933 (79 yrs.) M

Home | Select | Desktop | Pt Chart: Medications | Oncology | Custom | Reports | Admin | Sign | Results | ? | Resource | Popup

Allergies:

Unknown | No Insurance Found | Patient Info | As of | Refresh

OTC-Gen

Restrictions: None

IBUPROFEN 200 MG TABLET Alternatives

Sig: 1 TABLET (200 MG) PO Q8H

Geriatric Dosing - appropriate doses and frequencies for geriatric population: doses - 200 MG, 400 MG, 400-600 MG, 400-800 MG, 600 MG, 600-800 MG, 800 MG; frequencies - Q8H. Ibuprofen increases the risk of CV and GI events (black box warning), as well as renal failure. If used, especially long-term, monitor CV, GI and renal function.

Basic | Variable | Alternate

Dose	Strength & Form, Take	Frequency
	take	Q8H
As directed		
200 MG	200 MG TABLET take 1	Q8H
Special Instructions		
400 MG	400 MG TABLET take 1	Q8H

PRN: | Patient Educated | No Substitution

Duration: day(s) | Cannot Expire w/o Duration

Dispense: Tablet(s)

Refills:

Start Date: 01/21/2013

End Date:

Retail Pharmacy | Mail Order | Add 2nd Rx

Comments (This will not print on prescription)

Add to My Practice Favorites as: | Rx | no Rx

Ok | Ok Add New | Ok & Sign | Cancel | Back To Search

Done | Local intranet | Protected Mode: Off | 100%

Alerts, reminders

- Production rules are often used to implement alerts and reminders

- **Alerts** – triggered on data entry
  - draw attention to a potentially risky action
  - e.g. wrong medication dosage, drug-drug-interactions
- **Reminders** – time-triggered
  - recommended actions are "due" for a patient
  - e.g. vaccination, follow-up visits

- Challenges
  - Alert fatigue - a large number of frequent alerts desensitize to them or cause user frustration
  - How to manage large collection of rules to keep them up-to-date
  - Strict rules may cause problems when individualised care needs to be provided

X	Avoid combination	C	Monitor therapy	A	No known interaction
D	Consider therapy modification	B	No action needed	*More about Risk Ratings*	▼

1 Result

Filter Results by Item ▾ Print

D

Aspirin (Salicylates)
Ibuprofen (Nonsteroidal Anti-Inflammatory Agents (Nonselective))

Lexicomp® Drug Interactions

< Back

Interaction Details

Title Salicylates / Nonsteroidal Anti-Inflammatory Agents (Nonselective)

Risk Rating D: Consider therapy modification

Summary Nonsteroidal Anti-Inflammatory Agents (Nonselective) may enhance the adverse/toxic effect of Salicylates. An increased risk of bleeding may be associated with use of this combination. Nonsteroidal Anti-Inflammatory Agents (Nonselective) may diminish the cardioprotective effect of Salicylates. Salicylates may decrease the serum concentration of Nonsteroidal Anti-Inflammatory Agents (Nonselective). **Severity** Moderate **Reliability Rating** Good

Patient Management Monitor for increased risk of bleeding during concomitant use of nonselective nonsteroidal anti-inflammatory drugs (NSAIDs) and salicylates. Ibuprofen, and possibly other nonselective NSAIDs, may reduce the cardioprotective effects of aspirin. It seems prudent to avoid regular, frequent use of ibuprofen in patients receiving aspirin for its cardioprotective effects. Alternative analgesics (eg, acetaminophen) may be a safer choice. Patients may require counseling about the appropriate timing of ibuprofen and aspirin dosing. Ibuprofen should be administered 30-120 minutes after immediate release aspirin, 2 to 4 hours after extended release aspirin, or at least 8 hours before aspirin.

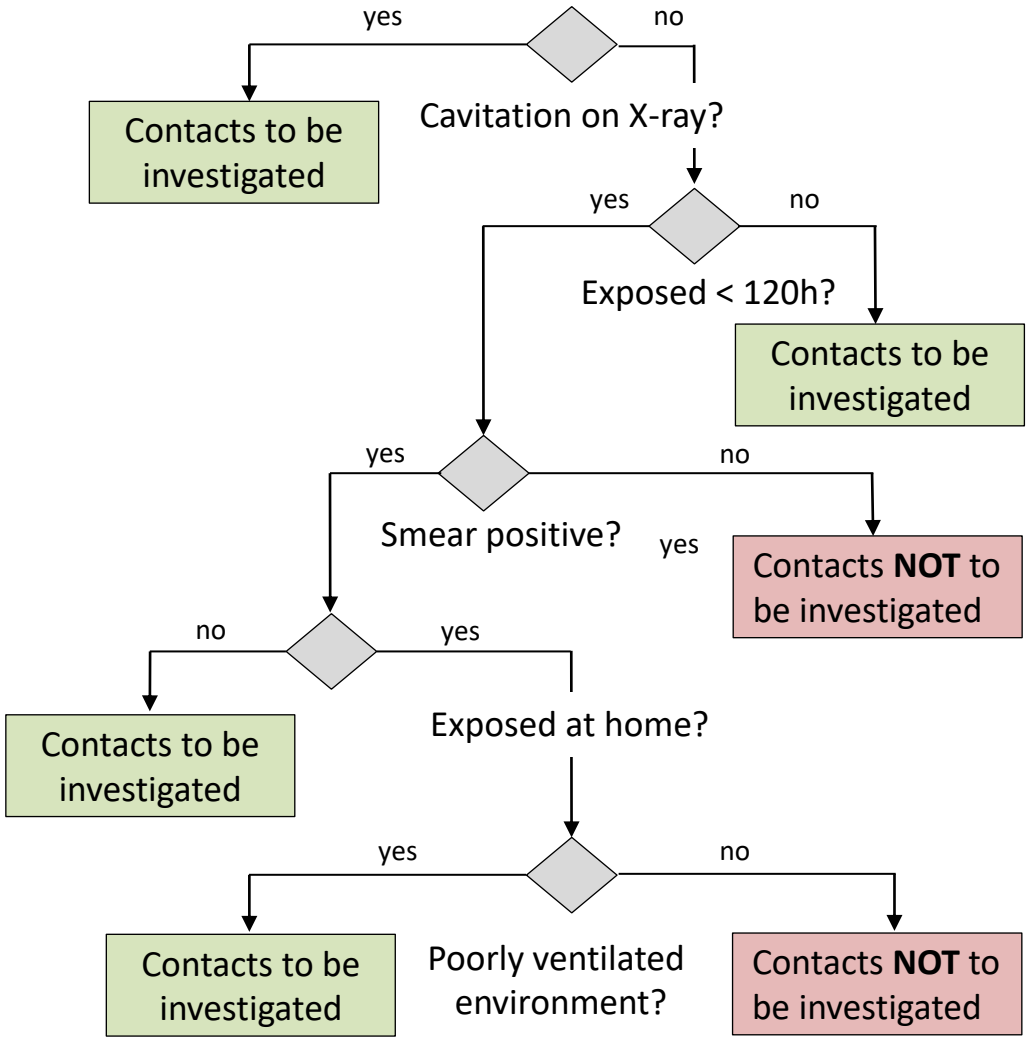
Nonsteroidal Anti-Inflammatory Agents (Nonselective) Interacting Members Aceclofenac, Acemetacin, Dexibuprofen, Dexketoprofen, Diclofenac (Systemic), Diflunisal, Dipyrone, Etodolac, Fenoprofen*, Floctafenine, Flurbiprofen (Systemic), Ibuprofen*, Indomethacin*, Ketoprofen, Ketorolac (Nasal), Ketorolac (Systemic), Lornoxicam, Loxoprofen, Meclofenamate*, Mefenamic Acid, Meloxicam, Nabumetone, Naproxen*, Oxaprozin, Pelubiprofen, Phenylbutazone, Piroxicam (Systemic)*, Propyphenazone, Sulindac*, Tenoxicam, Tiaprofenic Acid, Tolfenamic Acid, Tolmetin*, Zaltoprofen

Salicylates Interacting Members Aminosalicylic Acid, Aspirin*, Bismuth Subsalicylate, Choline Salicylate, Magnesium Salicylate, Salsalate, Sodium Salicylate, Triflusal
Exception Choline Magnesium Trisalicylate

** Denotes agent(s) specifically implicated in clinical data. Unmarked agents are listed because they have properties similar to marked agents, and may respond so within the context of the stated interaction.*

Discussion The combination of a salicylate and a nonsteroidal anti-inflammatory drugs (NSAIDs) may increase the risk of gastrointestinal bleeding.

Decision trees



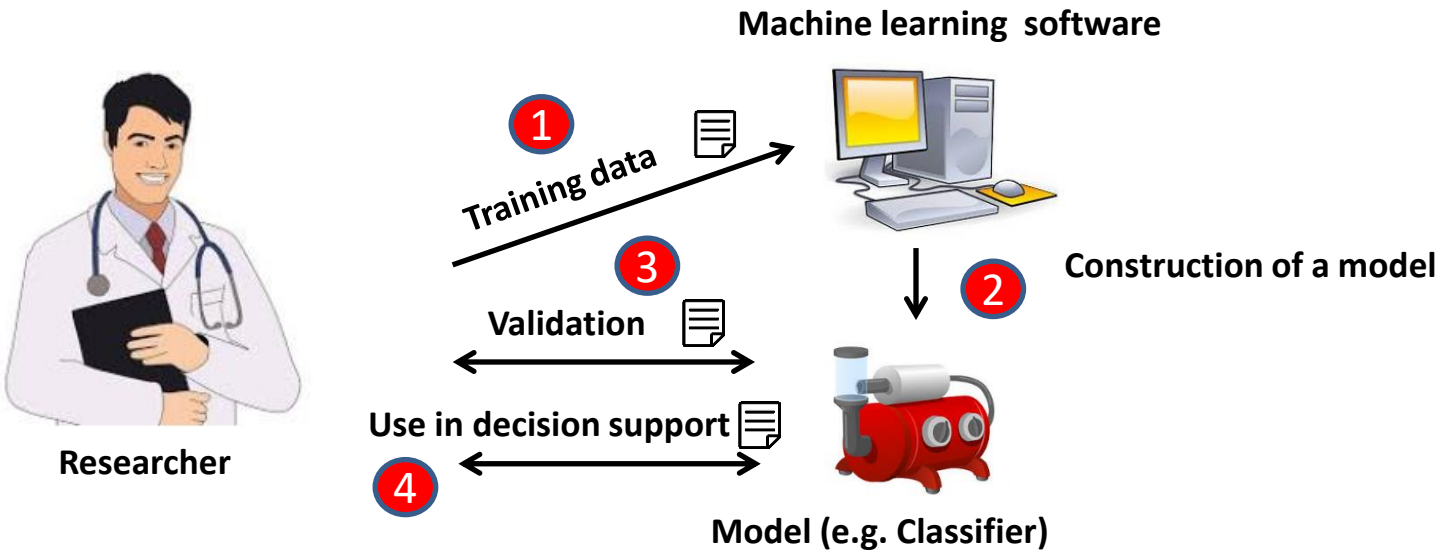
Gerald, Lynn B., et al. "A decision tree for tuberculosis contact investigation." . Am J Respir Crit Care Med 166.8 (2002): 1122-1127.

Source of knowledge in CDSS

- Human → Experts
  - Cognitive task analysis
    - Interviews with experts, think aloud protocols, observational studies
- Literature → Meta-analysis
  - Evidence-based medicine
    - Generalization of results from high quality clinical trials
    - Cochrane initiative
- Computer → Machine learning
  - Automatic pattern recognition in large datasets

What is machine learning?

- **Machine Learning**
  - computer "learns by itself" how to solve a problem based on existing data
  - methods how to (semi-automatically) construct models out of data



  - a model – a mathematical simplification of reality where all negligible details have been removed

- **Data mining**
  - Application of machine learning to large databases (-> Big Data)

Basic concepts in machine learning

- **Attributes**
  - Variables we know
- **Labels**
  - Variables we would like to predict based on attributes
- **Training set**
  - A set of records (**instances**) we use to create a machine learning model. Both attributes and labels are known
- **Validation set**
  - A set of instances we use to test our machine learning model. We know the „true" labels but let the computer predict them based on attributes and test accuracy of the predication

Radiology dataset

This data set can be used to predict the severity (benign or malignant) of a mammographic mass lesion from BI-RADS attributes and the patient's age. It contains the patient's age and three attributes (mass shape, margin, density) together with the ground truth (the severity field) for 516 benign and 445 malignant masses that have been identified on full field digital mammograms collected at the Institute of Radiology of the University Erlangen-Nuremberg between 2003 and 2006. http://tiny.cc/ifvpdz

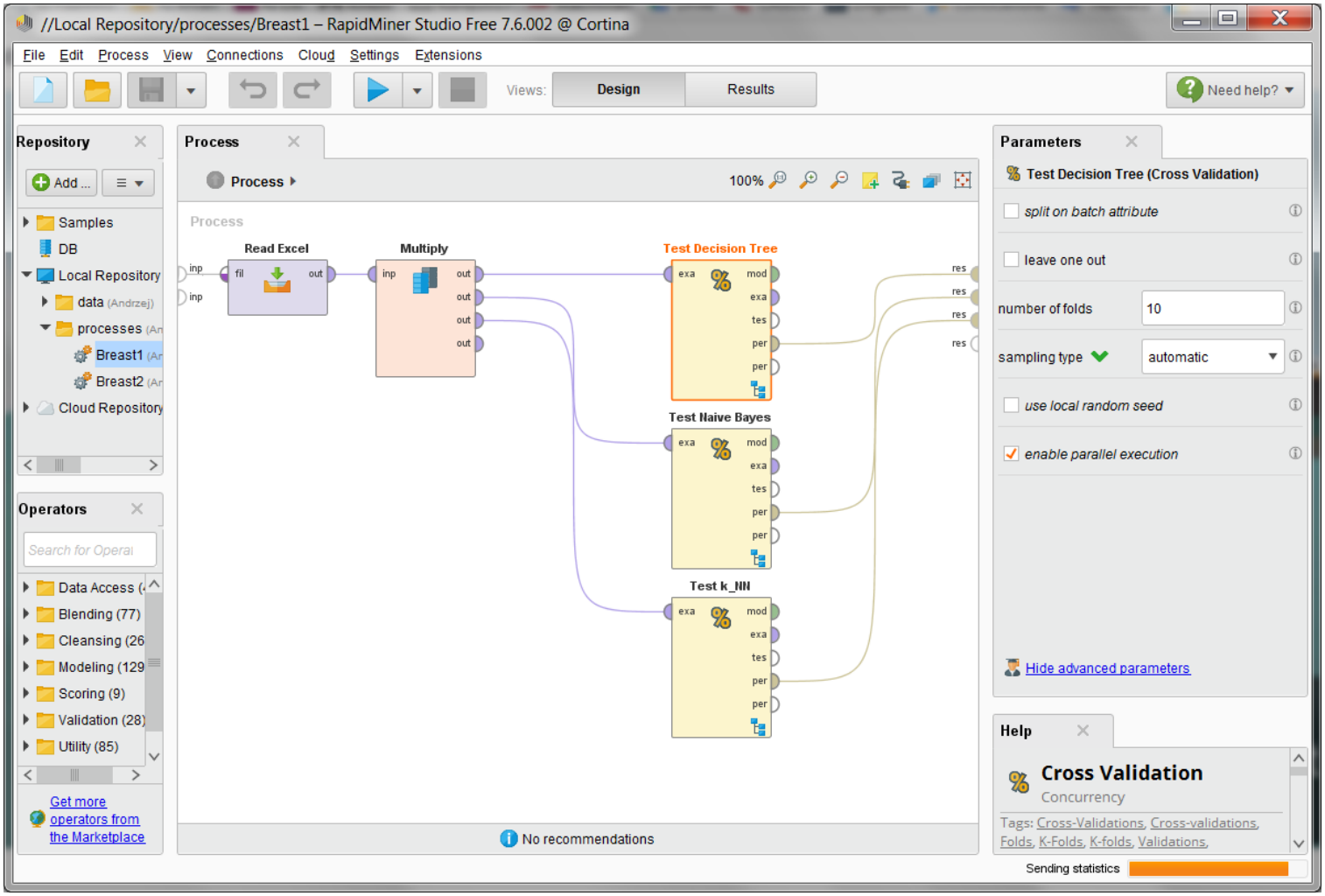
Step-by-step manual

- Import a data set from a spreadsheet.
- Split the data into a training set and validation set. Divide it in the ratio 2:1.
- Create a data model based on the training set
- Apply the model to classify instances in the validation set.
- Evaluate performance of your model.

Rapid Miner

https://rapidminer.com

RapidMiner - free for non-commercial use data science platform.
Machine learning algorithms with a simple visual interface.



Sensitivity/specificity

A 2 × 2 contingency table for HIV antibody enzyme-linked immunoassay (EIA)

Truth/Gold standard

Test results

EIA test result	Disease present	Disease absent	Total
Positive EIA	99 **TP**	3 **FP**	102
Negative EIA	1 **FN**	297 **TN**	298
	100	300	

- Sensitivity – True-positive rate (TPR)
  - ratio of diseased patients with a positive test to all diseased patients
  - p[positive test | disease] = 99/100=0.99
- Specificity – True-negative rate (TNR)
  - likelihood that a non diseased patient has a negative test result
  - p[negative test | no disease] = 297/300=0.99

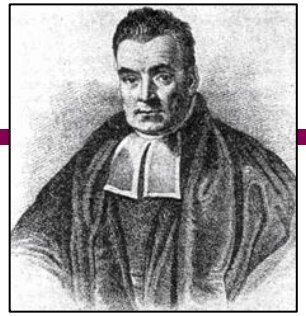
Exercise 2

- The table below presents performance of a hypothetical decision support system in use in lung cancer screening

		Actual class	
		Benign (-)	Malignant (+)
Predicted class	Benign (-)	164	16
	Malignant (+)	34	136

- What is the sensitivity and specificity of the clinical decision support system?

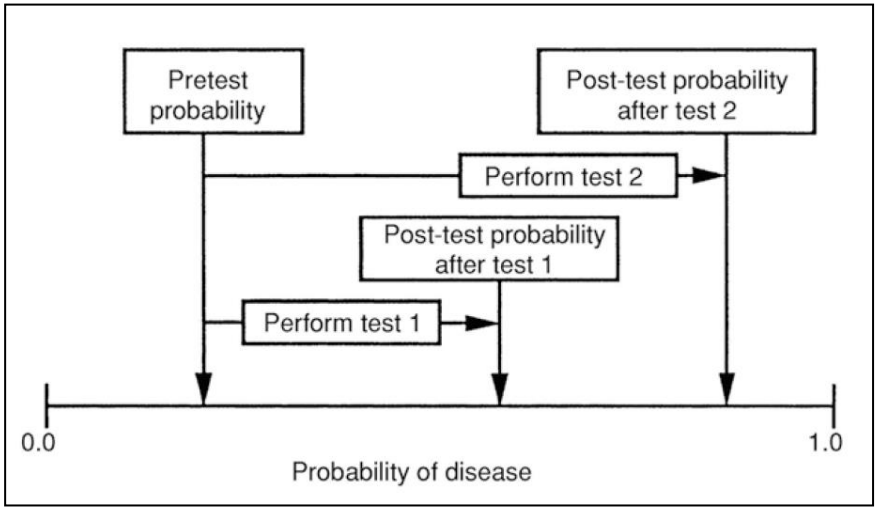
Bayesian reasoning



Thomas Bayes

The **Bayes' theorem** quantifies how will change our initial (a priori) belief in the hypothesis (e.g diagnosis, D) when given evidence (e.g. test results R or symptom)

$$P(\boldsymbol{D}|\boldsymbol{R}) = \frac{P(\boldsymbol{R}|\boldsymbol{D})P(\boldsymbol{D})}{P(\boldsymbol{R})}$$



(Shortliffe, 2014)

Another form:

$$P(\boldsymbol{D}|+) = \frac{\text{sensitivity} \cdot P(\boldsymbol{D})}{\text{sensitivity} \cdot P(\boldsymbol{D}) + (1 - P(\boldsymbol{D})) \cdot (1 - \text{specificity})}$$

Positive Predictive Value

Example

Consider the case of a 22-year-old student who had routine HIV test. The test result was positive. The young man assumed this meant he was infected with the virus. But what is the probability that he really has the virus given a positive test?

Suppose that

- in case you have HIV the testing gives a positive result with 99% probability (**test sensitivity**)
- in case you don't have HIV the testing methods gives a negative result that with 99% probability (**test specificity**).
- the adult prevalence (**base-rate**) of HIV is one in 1000.

Calculator: Post Test Probability from Pre Test Probability, Sensitivity and Specificity

Input:

Pre Test Prob	0.001	fraction
Sensitivity	99	%
Specificity	99	%

Results:

Post Test Prob Pos Result	9.016	%
Post Test Prob Neg Result	0.001	%

Decimal Precision: 3

Exercise 3 (Bayesian reasoning)

Assume that several research studies have investigated a **microbiological assay** for a **periodontal pathogen** that affects women of Mediterranean descent in whom periodontal disease is resistant to therapy. The condition is known to affect an average of one in 10 women of Mediterranean descent in whom periodontal disease is resistant to therapy. Based on a recent evaluation study it is known that the assay positively identifies 70 percent of the existing cases of the condition in the target population. Several studies also report a true-negative rate of exactly 80 percent.

You observe a woman in your practice who is of Mediterranean ancestry and in whom periodontal disease is highly resistant to several courses of therapy, and the assay is positive. What is your estimate of the **probability that this patient has the pathogen**?

Adapted from: Chambers et al, 2010

Information retrieval

- Information retrieval
  - ability to find information relevant to a problem
- Information science
  - field of study concerned with collection, classification, storage, dissemination of information
- Evidence-based medicine
  - „explicit and conscientious attempts to find best available research evidence to assist health professionals to make the best decisions for their patients”

Sources of scientific information

- Bibliographic databases
  - Medline (PubMed, Ovid, EIFL), Embase, Scopus, CINAHL, PsycInfo, Cochrane CENTRAL
- Full-text repositories
  - Scientific Journals
  - PubMed Central, BioMed Central, ScienceDirect, CDRS
- Services with summaries, synopses, syntheses
  - UpToDate, WebMD, ClinicalKey, VisualDX, Cochrane Clinical Answers

Evidence-based Knowledge Bases

- Example: UpToDate
  - Founder Burton Rose, neurology professor at Harvard University, 1992
  - Synthesis of the most recent medical information into evidence-based recommendations
  - Literature is reviewed and synthesized by more than 6000 clinicians
  - 90% US hospitals has access to UpToDate;
  - Access via Jagiellonian University Network
  - Includes clinical calculators and a drug-drug interaction module (Lexicomp)
  - Positive effects of use of UpToDate on patient outcomes
    - reduced length of stay
    - lower risk-adjusted mortality rates
    - better quality performance (Hospital Quality Alliance indicators)

Isaac T et al. "Use of UpToDate and outcomes in US hospitals" J Hosp Med. 2012 Feb;7(2):85-90

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Topic Outline

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Polysomnography

Sleep-related bruxism (tooth grinding)

Author: Geoffrey E Gerstner, DDS, MS, PhD

Section Editor: Alon Y Avidan, MD, MPH

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Contributor Disclosures

All topics are updated as new evidence becomes available and our peer review process is complete.

Literature review current through: **Aug 2020.** | This topic last updated: **Sep 18, 2020.**

Topic Feedback

INTRODUCTION

Sleep-related bruxism involves activation of the masticatory muscles, resulting in tooth clenching and grinding during sleep. The prevalence of bruxism during sleep peaks in childhood and progressively declines with age. Although often asymptomatic, frequent bruxism may become

Symptom checkers/DDx

- Symptom checkers
  - applications for patients to collect information symptoms, suggest possible alternative diagnoses and recommended course of action (e.g. self-care, GP appointment, emergency department).
- Differential diagnosis generators (DDx)
  - related to symptom checkers but address the needs of medical doctors relevant diagnosis has been left out in considering a patient case.
- Examples
  - Ada, Babylon, Mediktor, Isabel, QMR, DXplain, DocResponse, Symcat, Doctorlink, CAIDR, Your.MD, Iliad

Isabel

- Founder: Jason Maude
- In a 2016 study ISABEL was associated with the highest accurate diagnosis retrieval rates compared to all other DDX generators

  Riches N, Panagioti M, Alam R, Cheraghi- Sohi S, Campbell S, Esmail A, et al. (2016) The Effectiveness of Electronic Differential Diagnoses (DDX) Generators: A Systematic Review and Meta- Analysis. PLoS ONE 11(3): e0148991.

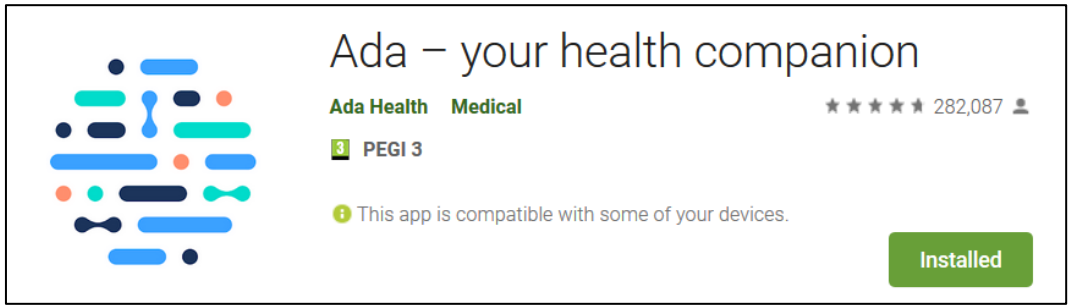
- Isabel Symptom Checker (free): Link

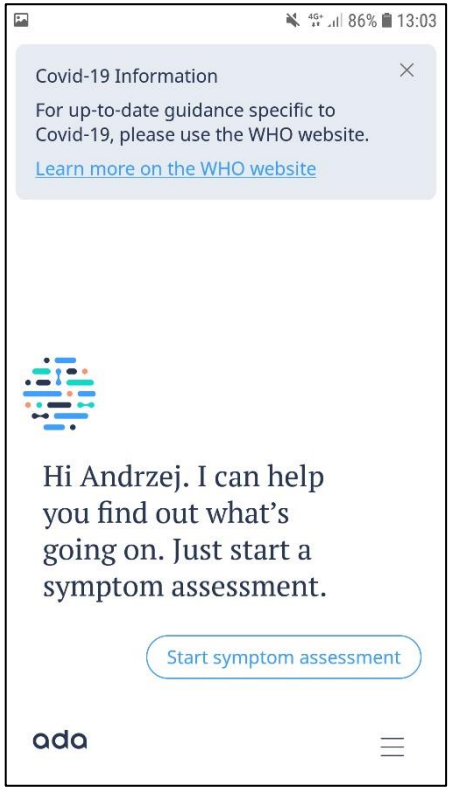
„The name of the child, and the software is Isabel"

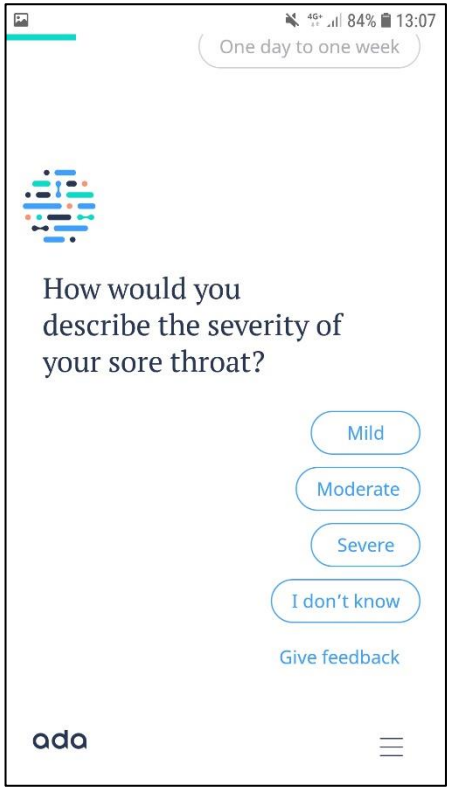
Story behind the system: link

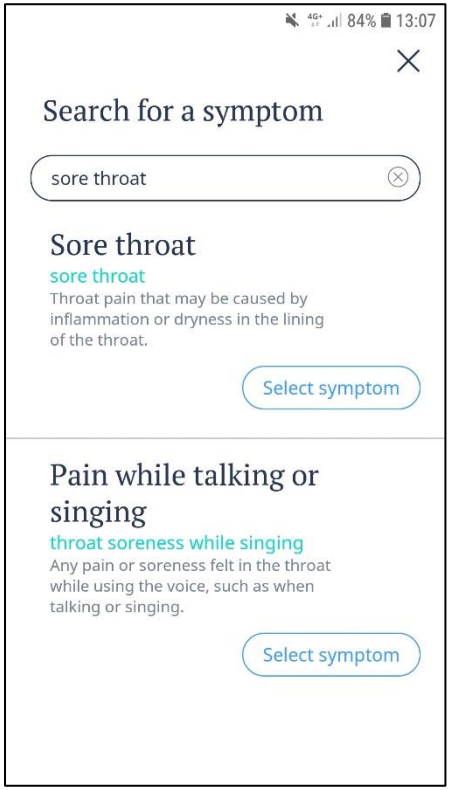
Ada

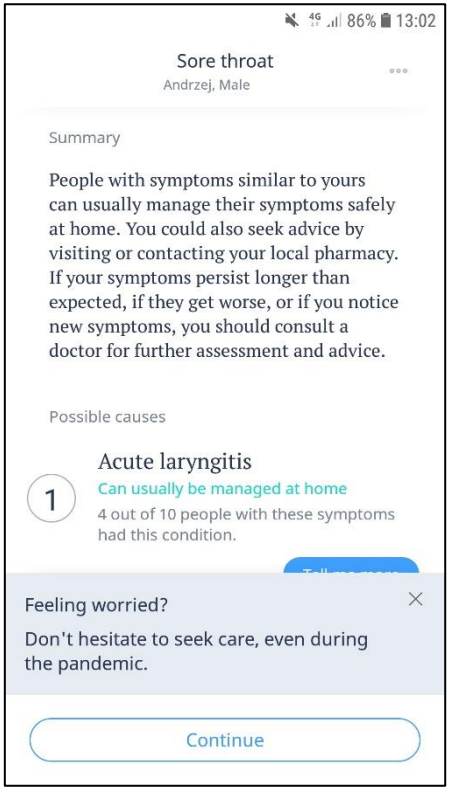
- A free symptom-checker available on smartphones https://ada.com
- Some early research results suggest Ada has at the moment of writing (2020) the highest diagnostic accuracy among all symptom checkers.











Demonstration: DDX generators

What is in the most likely diagnosis for a 30-year's old female patient from Poland, not pregnant, fever, headache, poor appetite, swollen lymph nodes and itching crusted bump on skin? What are the top 3 suggested diagnoses.

Summary

- Clinical decision support systems consist of
  - knowledge base, inference mechanism, user interface
- The knowledge-base can be expressed as
  - Synthesis of evidence-based literature (Up-to-date)
  - Set of production rules or a decision tree (Machine Learning)
  - Probabilities (Bayesian logic; HIV example)
- Source of knowledge in knowledge-bases
  - Expert, literature synthesis and machine learning
- The quality of CDSS is often measured by
  - Sensitivity, Specificity
- Computerised decision support
  - Supports but not replaces human decision making (augmented intelligence)
  - Should take into account patients' perspective (shared-decision making)
  - „Cold technology, warm hands-on medicine"