Personalized digital interventions for patient behavior change

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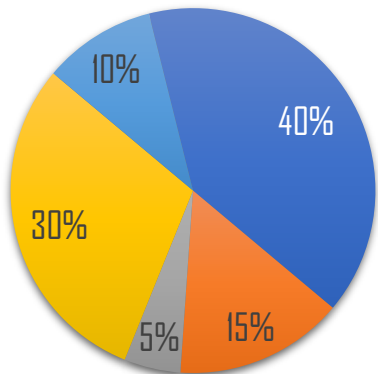Senior data scientist
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The role of patient in managing their health

Schroeder's "**40/30/20/10** rule" (NEJM, 2007)
Contributors to Premature Death

- Chronic diseases stay with a patient, even when they are at home.

- Lifestyle and health behavior are significantly more important predictors of health outcomes than the medical care

- About 20% - 50% of patients do not take medications as prescribed

Pie chart data:
- 40% Behavioral Patterns
- 15% Social Circumstances
- 5% Environmental Exposure
- 30% Genetic Predisposition
- 10% Health Care

Legend:
- Behavioral Patterns
- Social Circumstances
- Environmental Exposure
- Genetic Predisposition
- Health Care

S. A. Schroeder, N Engl J Med 2007; 357:1221-1228. September 20, 2007
Also, **Actual causes of death in the United States** JM McGinnis, WH Foege - Jama, 1993

The problem statement

- Rapidly rising burden of chronic diseases in aging societies

- How do we empower the patients? How do we affect a sustained change their health behavior?

Ageing in Singapore	2009 %	2017 %
Three or more chronic health conditions:	20	37
High blood pressure	74	72
Diabetes	22	25
Cataract	19	31
Joint pain, arthritis, rheumatism or nerve pain	31	29
Obesity	8	9
Difficulty with three or more activities of daily living	3.5	5
Feeling somewhat or mostly lonely	51	34
Depressive symptoms	15	12

Source: DUKE-NUS MEDICAL SCHOOL'S CENTRE FOR AGEING RESEARCH AND EDUCATION
ST PHOTO: KELVIN CHNG   STRAITS TIMES GRAPHICS

Risk communication

- Do patient understand a risk-score?

> Your risk for cardiovascular disease is 17%

_vs_

> Your heart is like that of a 65-year-old person

- Multiple borderline risk factors _vs_ one very poorly controlled one?

- Risk factors for onset of a disease are sometimes different from prevention of that disease
  - Lowering BMI has stronger than expected effect on reducing risk of onset of diabetes

The next best action
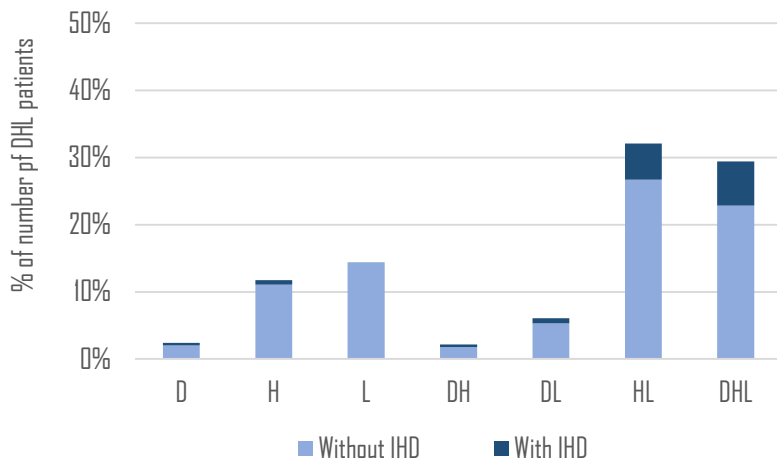
Most patients have multiple chronic diseases

- Most chronic disease patients have multiple diseases, and multiple risk factors.

- Majority of the early-stage chronic disease patients know what needs to be done!

- Can a personalized advice about the most impactful intervention useful?
  - Focus on weight loss first, and once you have it in control, we will focus on medication adherence.

A patient education tool

Visual aid during a clinic visit

A tool like this can facilitate shared decision making, based on clear understanding of personalized risk factors

Learning from data

Age
Gender
Ethnicity
HbA1c (only for diabetic patients)
LDL (only for dyslipidemia patients)
Creatinine (for 40% patients)
Diagnosis history (diabetes)
-   -   -   (hypertension)
-   -   -   (dyslipidemia)
-   -   -   (CKD)
-   -   -   (IHD)
-   -   -   (CHF)
-   -   -   (Cerebrovascular disease)
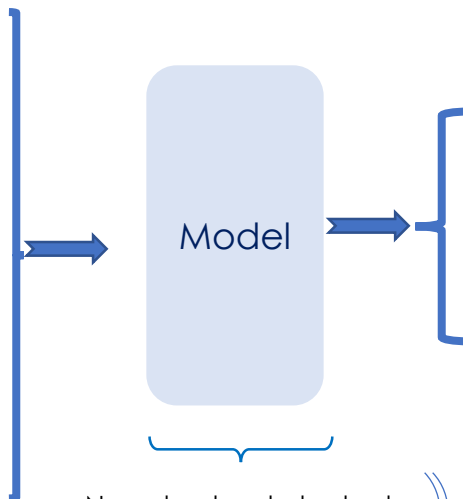
Model

Neural network stacked over gradient boosting trees

Shapley values used to get personalized risk factors

★ Predicting multiple disease trajectories from the same model

Risk over time (CKD)
-   -   -   (IHD)
-   -   -   (CHF)
-   -   -   (Cerebrovascular disease)

Description of the population

- Data from Singapore public healthcare system

- All the patients whose first diagnosis of (diabetes | hypertension | dyslipidemia) was between 30th June 2012 and 31st December 2012

Inputs

Outcomes

Disease at time = 0	Number (%)
Diabetes	4193 (21%)
Hypertension	12715 (63%)
Dyslipidemia	14814 (74%)

Ethnicity	Number (%)
Chinese	15878 (79%)
Malay	1692 (8.4%)
Indian	1420 (7.1%)

Gender	Number (%)
Female	10706 (53.4%)
Male	9347 (46.6%)

Disease at time = 5 years	Number (%)
CKD	912 (4.5%)
IHD	3205 (16%)
CHF	634 (3.2%)
Cerebrovascular disease	1817 (9.1%)

Demo of a Patient Education Tool
HbA1c=7.2, LDL = 3.5 mmol/L
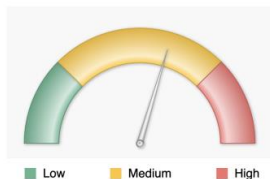
The risk of IHD is high, and lowering LDL is the best way to manage that. It is usually very easy to lower LDL by medications, unlike HbA1c.

The patient is told the importance of compliance to statins and expected improvement in risk profile

@Thel
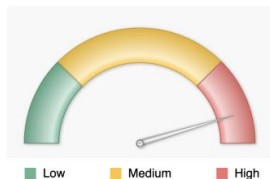
Demo of a Patient Education Tool
HbA1c=7.2, LDL = 2.8 mmol/L
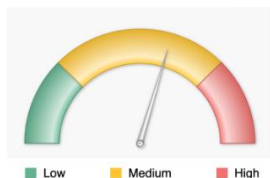
3 months later: LDL management improved the risk a bit. But IHD risk is still high.

The next goal is to reduce HbA1c. The patient is now encouraged to change lifestyle after some improvement in risk profile

@Thel

Demo of a Patient Education Tool
HbA1c=6.5, LDL = 2.8 mmol/L
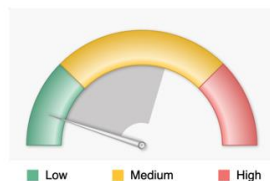
6 months later: Improved lifestyle has reduced HbA1c to 6.5 and there is a major improvement in the risk profile of the patient.

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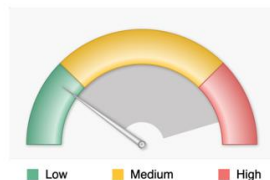
Education vs behavior change
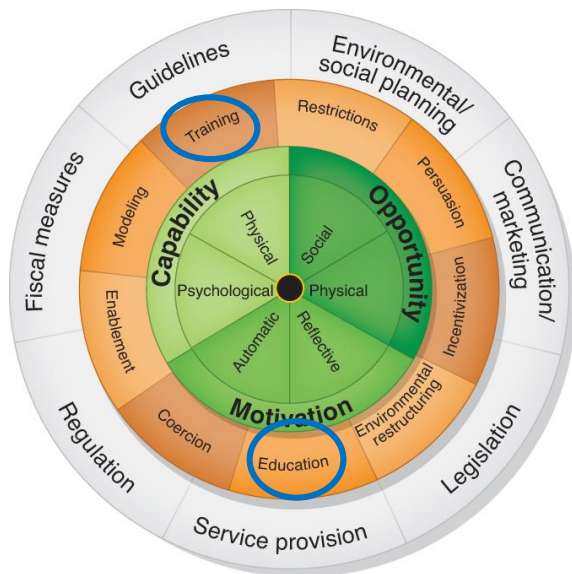
Knowledge ≠ Behavior change

Michie, S., West, R. *Nat Med* **27,** 749–752 (2021)

Digital health programs at MOHT
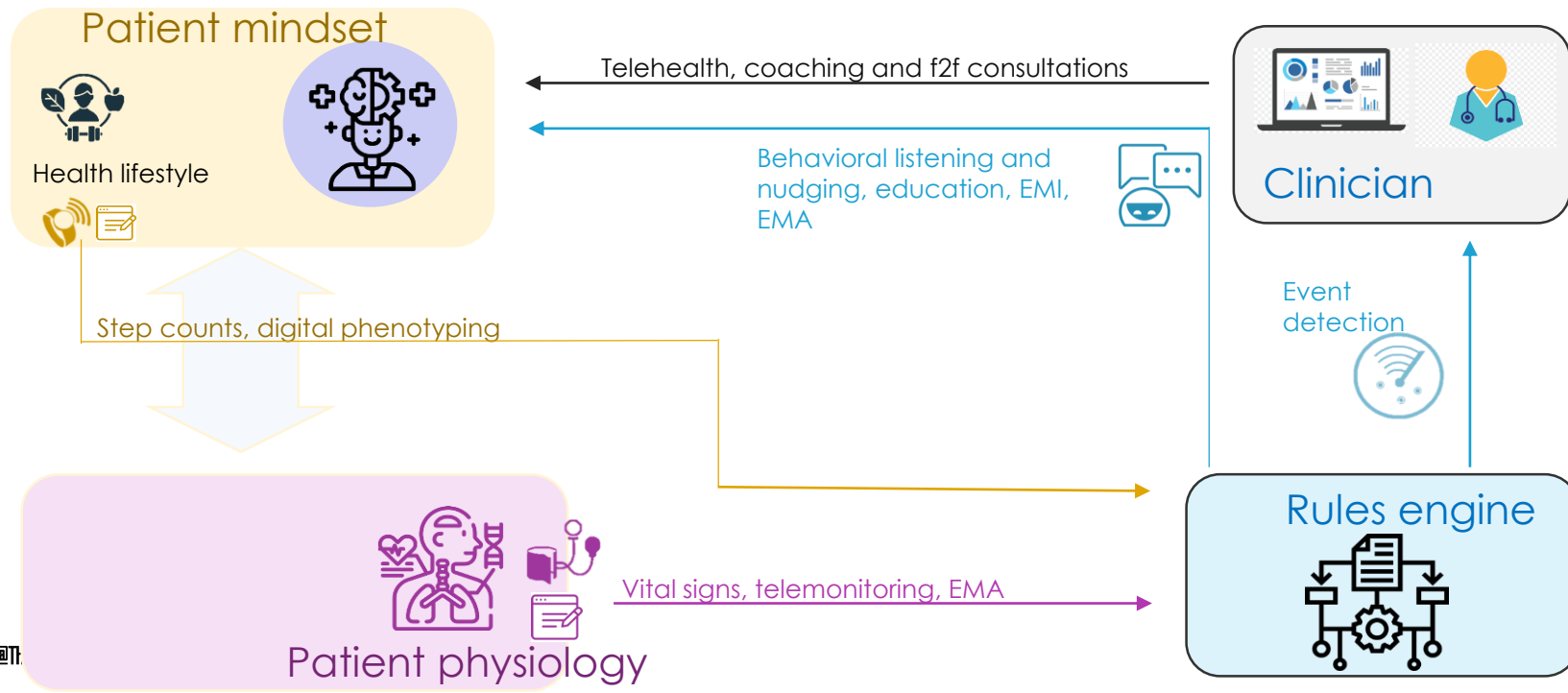
Digital health programs at MOHT

1. Remote blood pressure monitoring and management for **hypertensive patients**, with or without diabetes

2. Remote management of blood pressure and early medication titration for **post-discharge AMI patients**

3. Predicting and **preventing schizophrenia relapse** using signals from cell phone and wearables

Mechanism of personalized coaching

How to achieve this?

The Four Levels of Patient Activation

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
	Predisposed to be passive	Building knowledge and confidence	Taking action	Maintaining behaviors, pushing further
	Patients lack the confidence to play an active role in their health.	Patients have some knowledge but large gaps remain. They can set simple goals.	Patients have the key facts and are building skills. They are goal-oriented.	Patients have adopted new behaviors but may struggle in times of stress or change. Healthy lifestyle is a key focus.
	'My doctor is in charge of my health.'	'I could be doing more.'	'I'm part of my health-care team.'	'I'm my own advocate.'
GENERAL POPULATION:	10-15%	20-25%	25-30%	20-25%

① **Clinical risk profile**   **②** **PAM level**

Uncertain/reluctant patient
: Reminders, assurance, basic education, encouragement

Careless patient
: Education, motivation

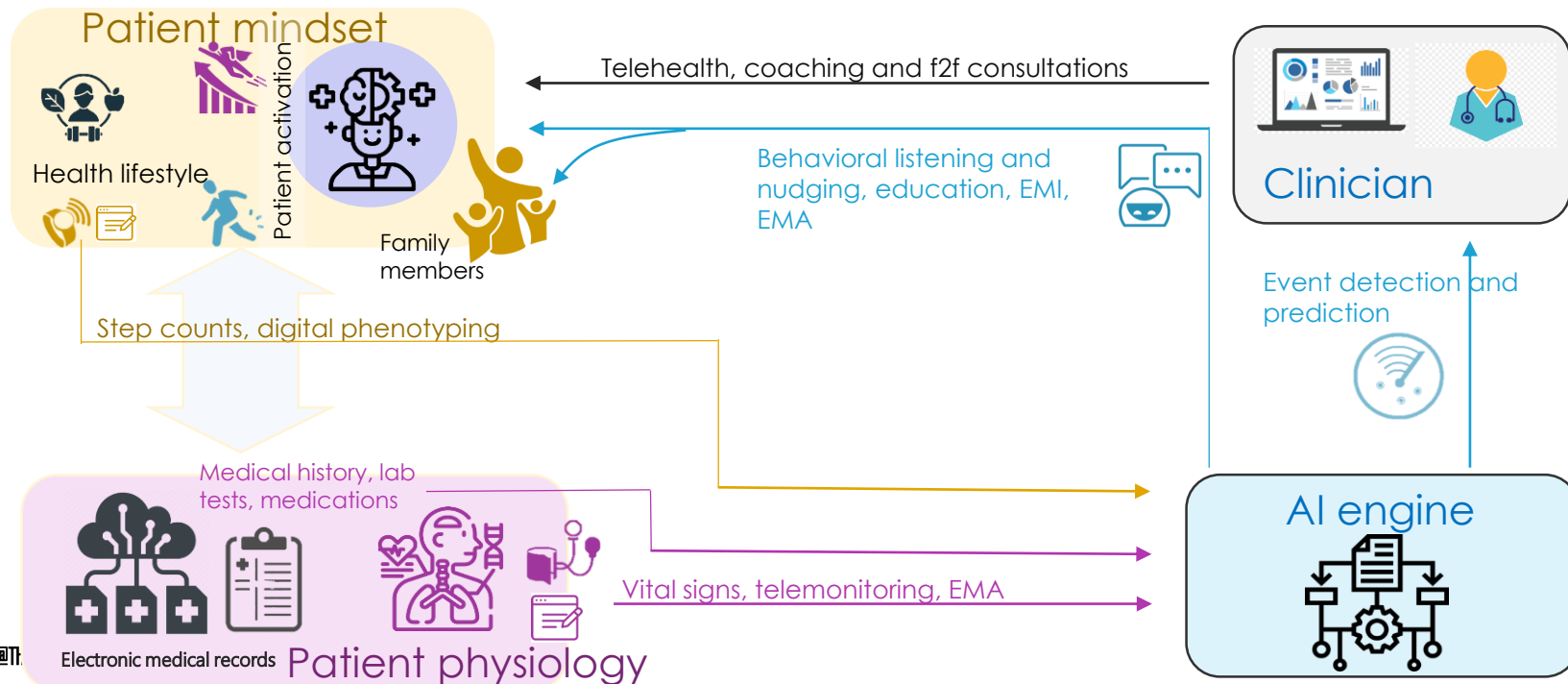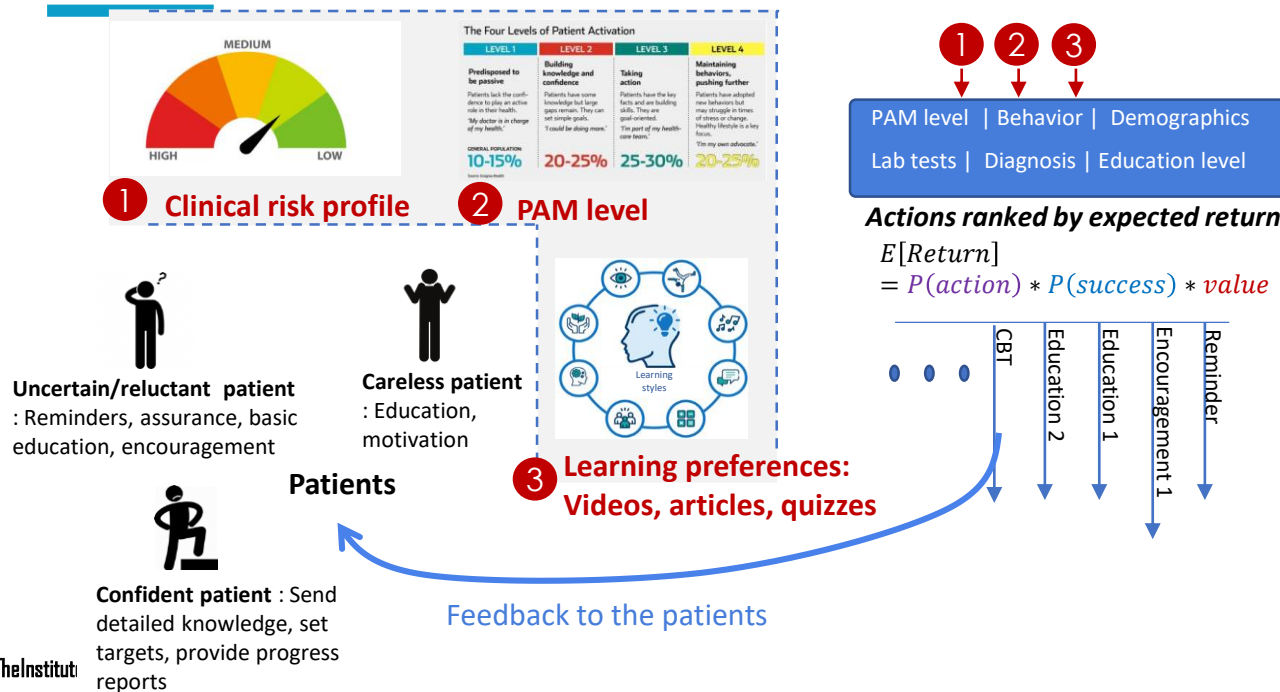Learning styles

Patients

③ **Learning preferences:**
Videos, articles, quizzes

Confident patient : Send detailed knowledge, set targets, provide progress reports

Feedback to the patients

① **②** **③**

PAM level | Behavior | Demographics

Lab tests | Diagnosis | Education level

Actions ranked by expected return

$E[Return]$
$= P(action) * P(success) * value$

CBT | Education 2 | Education 1 | Encouragement 1 | Reminder

value
- historical EHR data
- Literature
- Personalized to patient's clinical profile
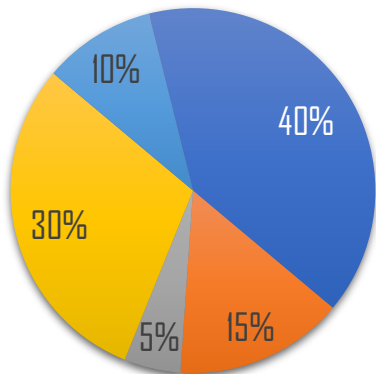- Notification frequency

P(success), P(action)
- Cold start / PAM level
- Learn from telemonitoring data
- Patient surveys and workshops
- Personalized to patient behavior and activation
- Notification frequency

The role of patient in managing their health

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Contributors to Premature Death

Patients are a resource if they participate in their health management

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