Self-monitoring technologies and health recommender systems to promote healthy behavior change
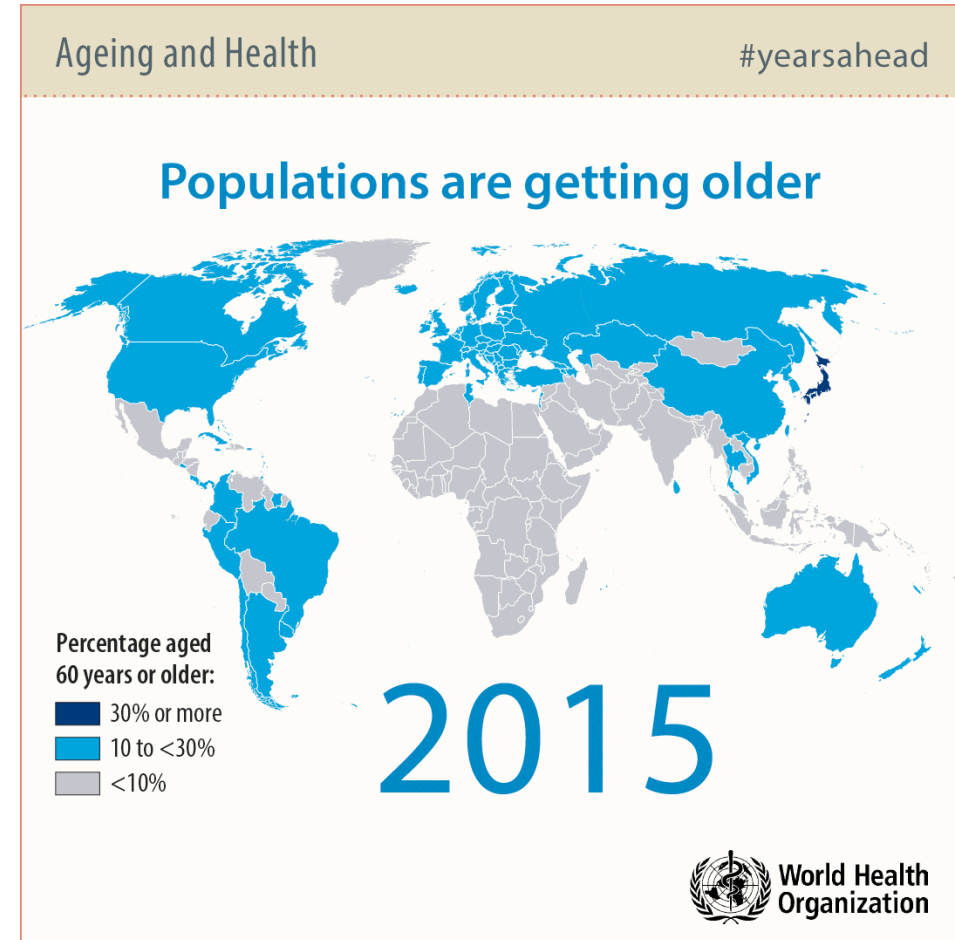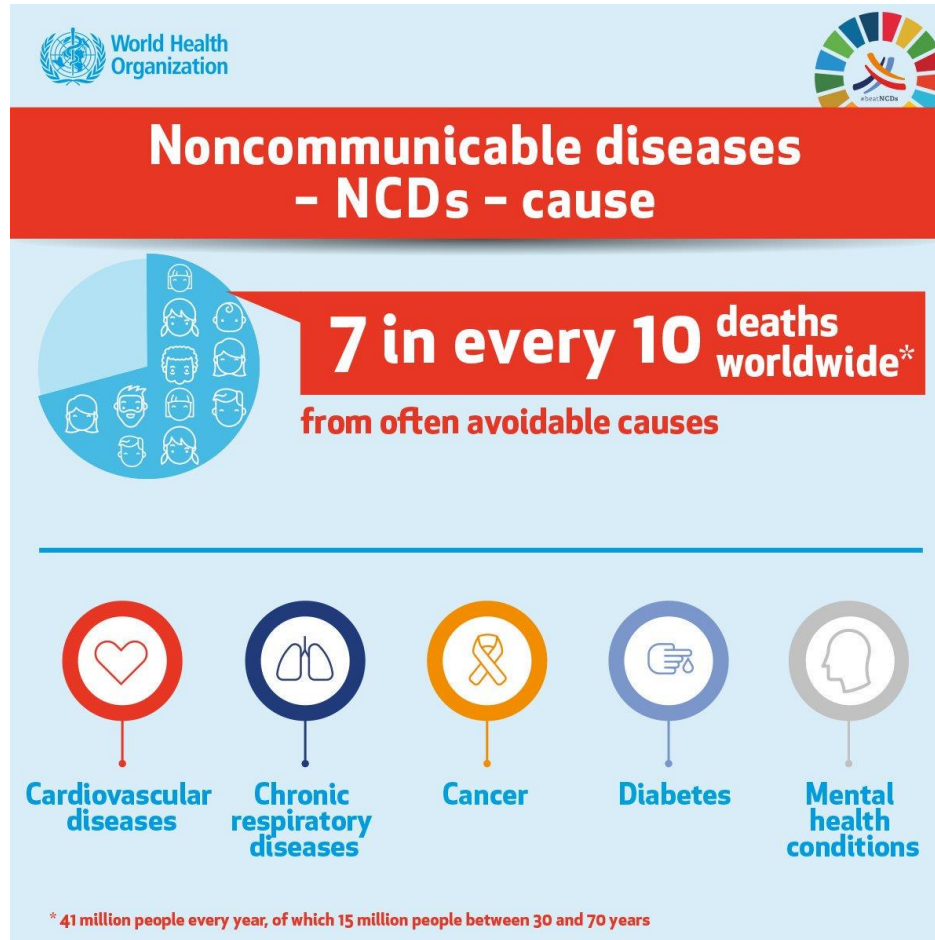
Dr. Mirana Randriambelonoro

November 3rd, 2021

Background and motivation

Main risk factors: lifestyle habits
that we can influence

Challenge

Challenge

Motivation to adopt healthy behavior and to adopt this behavior the long term

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Opportunities: self-monitoring technologies
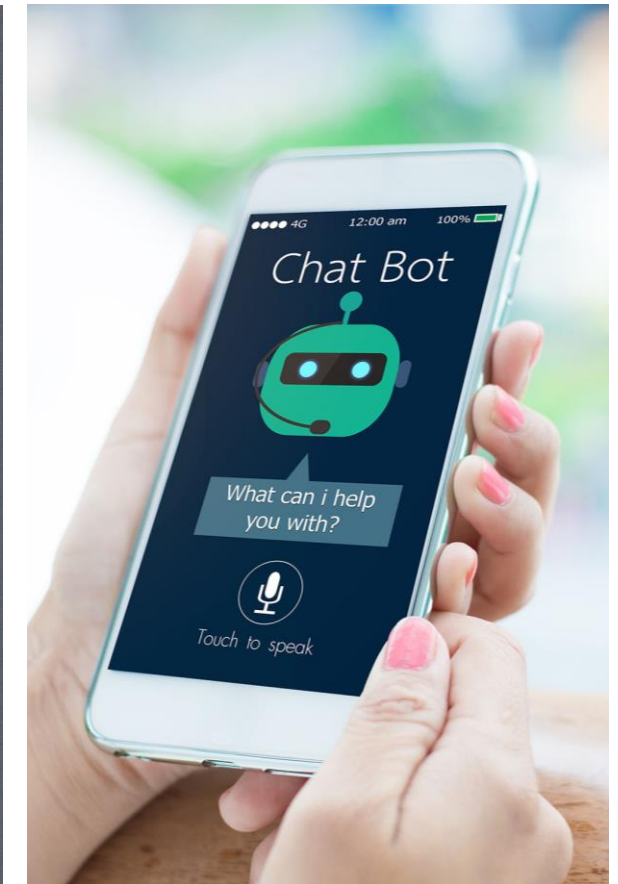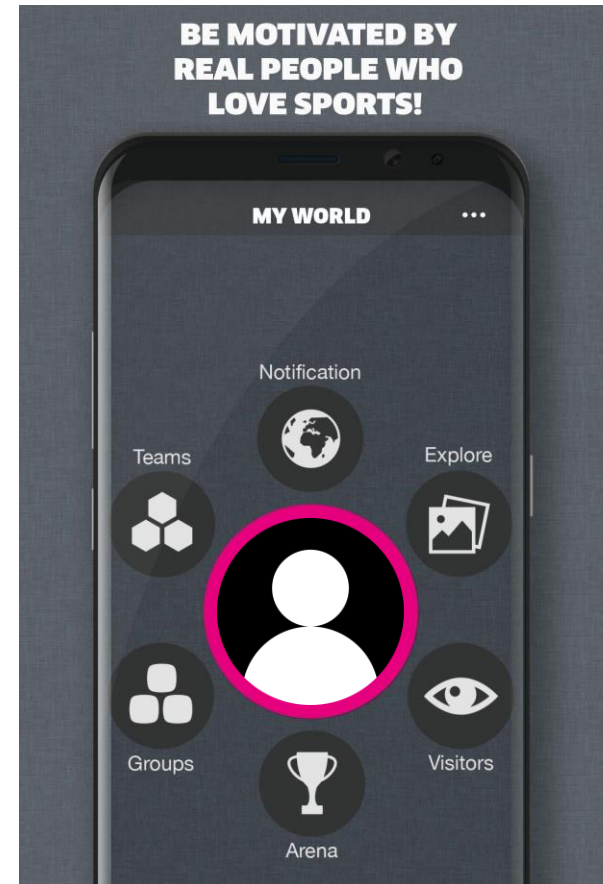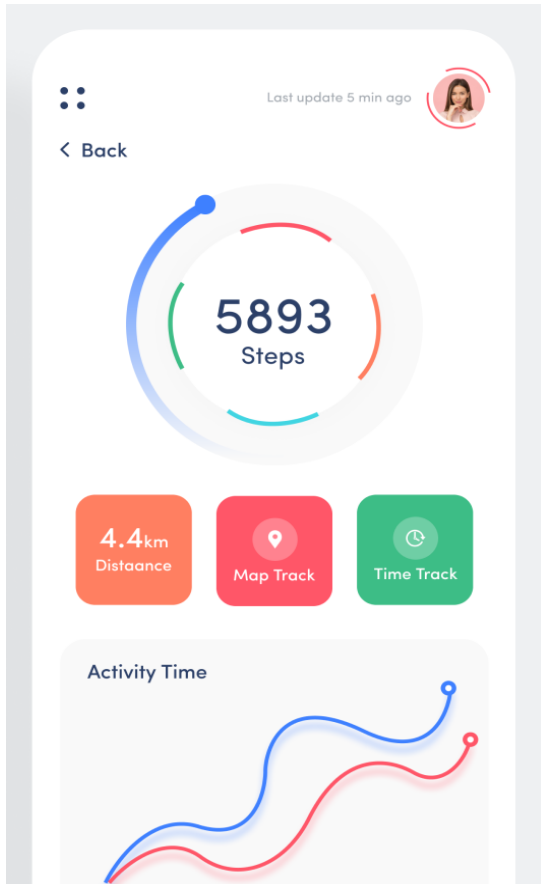
Limitations: self-monitoring technologies

Tracking health data is not enough to sustain motivation and engagement

Systems' ability to alter behavior but long-term efficacy remains unknown

Often generalized to the public. Do not answer individuals needs & pref. (pathology)
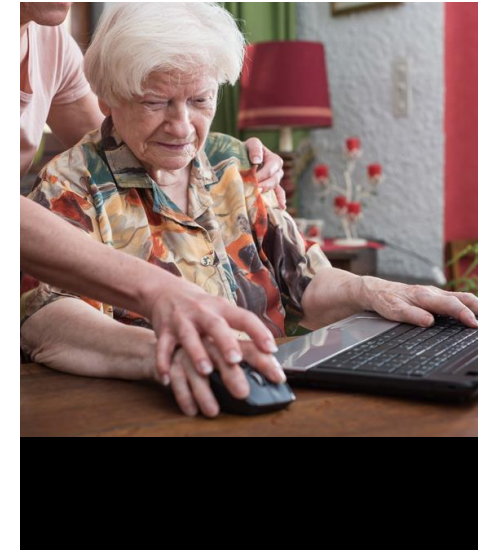
Feasibility and acceptability for specific population still understudied

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Behavior change

Behavior = "an organism or a system's external reactions to various stimuli and its environment"
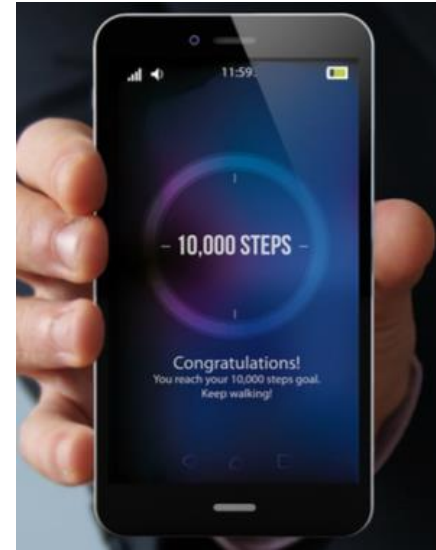

Fig 8.4.3 Pavlov's dogs—a conditioned response

smell of food

Dog produces saliva when it smells food.

smell of food and ringing of bell

Dog produces saliva when it smells food.

after many pairings of food and bell

bell rings

Dog produces saliva even if no food is offered.

Behavior change

Behavior change = "the systematic use of principles of learning to increase the frequency of desired behaviors and/or decrease the frequency of problem behaviors". APA

Behavior change

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Behavior change

Behavior change = "the systematic use of principles of learning to increase the frequency of desired behaviors and/or decrease the frequency of problem behaviors". APA

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Hedonic principles (Greek antiquity)
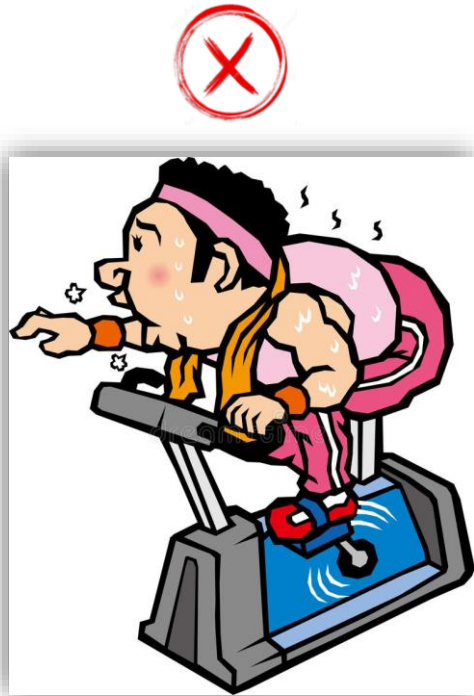
Pain

Pleasure

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Zumba

Zumba

Ping pong

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Zumba

Ping pong

Zumba

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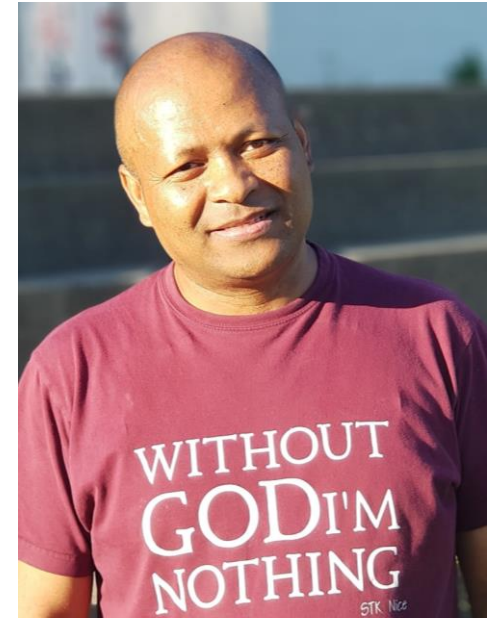
Zumba

Ping pong

Zumba

Piano

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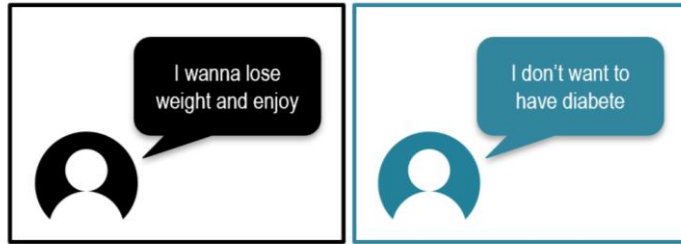
Promotion-focused

I wanna lose weight and enjoy

Prevention-focused

I don't want to have diabete

Regulatory Focus Theory
Brockner and Higgins

Zumba

?

Regulatory Focus Theory
Brockner and Higgins

Self-Determination Theory
Deci and Ryan

Zumba
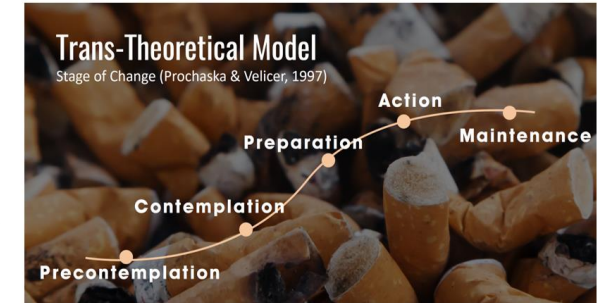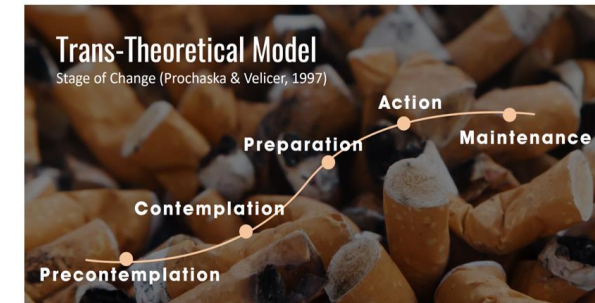
Trans-Theoretical model
Prochaska and Velice

COM-B Model
Michie

Behavior Change Framework

Behavior Change Wheel

Behavior Change Framework

State of the art

Behavior Change Wheel
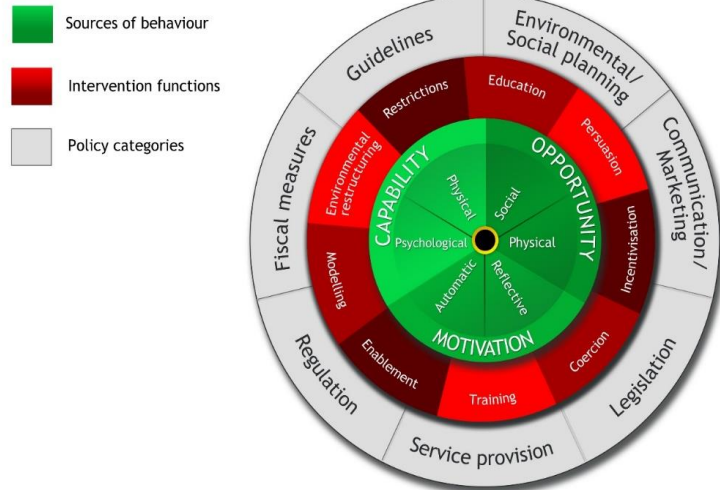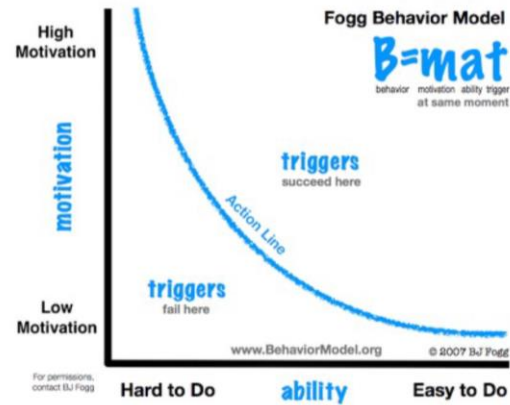
Fogg's model

(Fogg, A Behavior Model for Persuasive Design, 2009)

Behavior Change Framework

Behavior Change Wheel
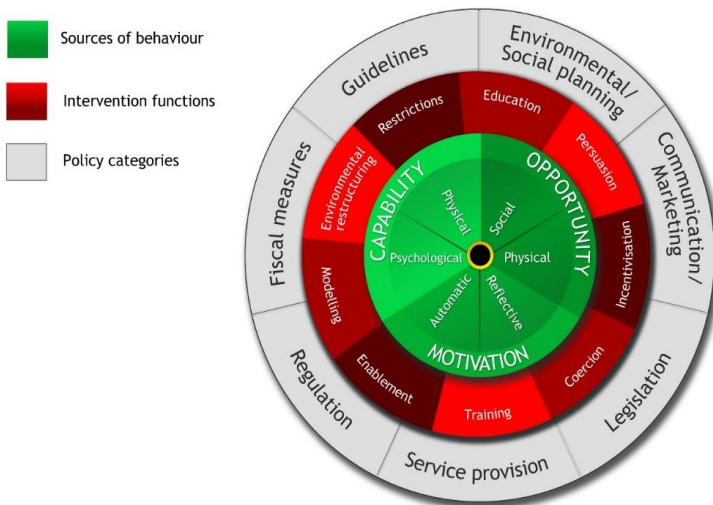
Fogg's model
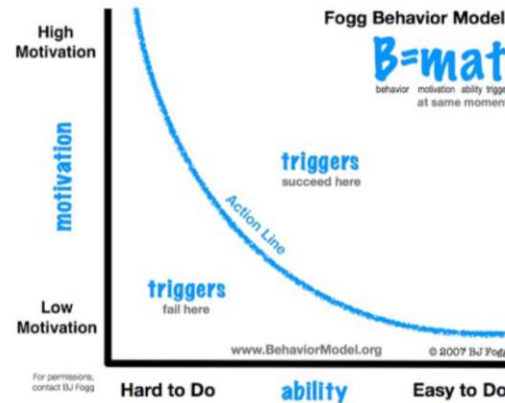
(Fogg, A Behavior Model for Persuasive Design, 2009)

Persuasive Systems Design.
(Oinas-Kukkonen & Harjumaa, 2009)

Behavior Change Framework

Self-monitoring

Gamification

Social incentives

Conversational agent
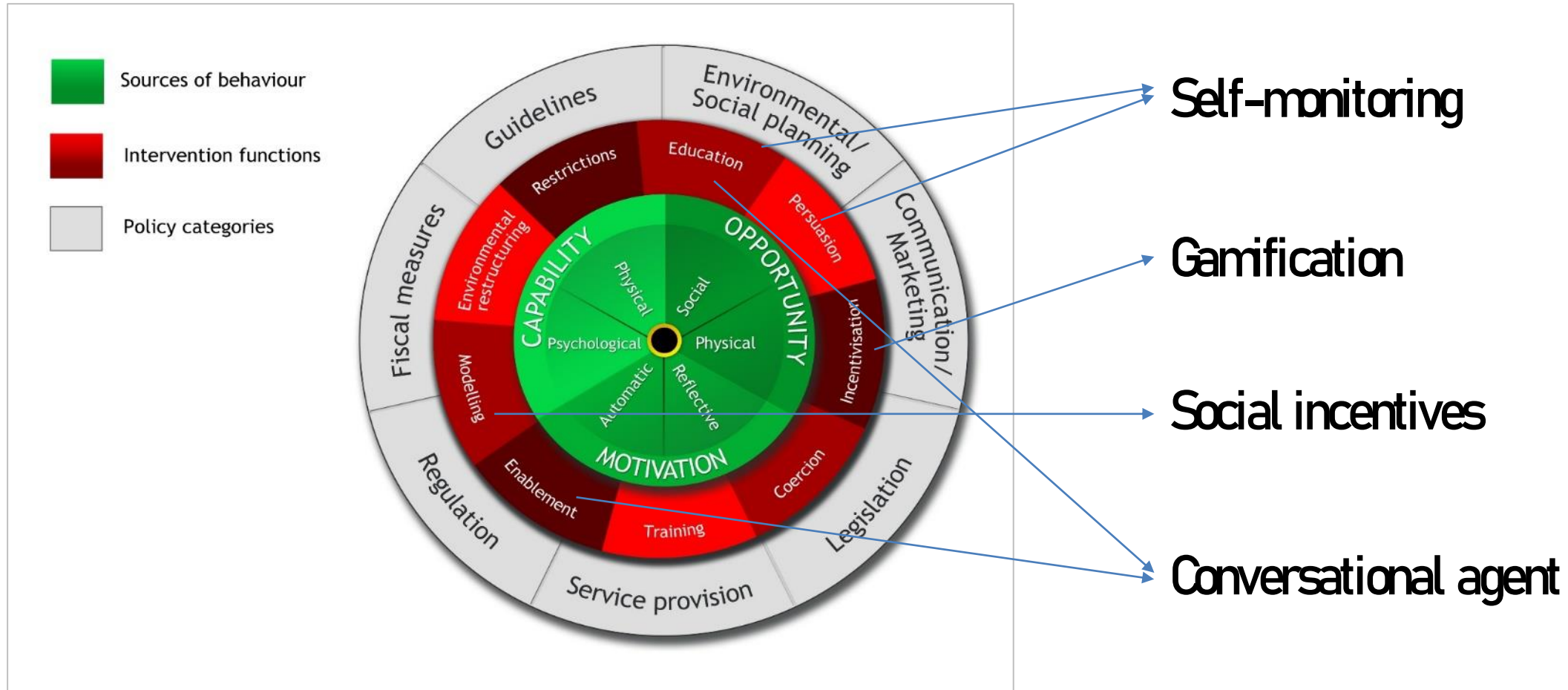
User studies and experiments

Self-monitoring

Randriambelonoro, M., Chen, Y. & Pu, P. **"Can Fitness Trackers Help Diabetic and Obese Users Make and Sustain Lifestyle Changes?"** in Computer, vol. 50, no. 3, pp. 20-29, Mar. 2017. doi: 10.1109/MC.2017.92

Type	Longitudinal qualitative study
Participants	18 obese and diabetic patients
Duration	7 months
Intervention	Wearable fitness tracker with its native application
Research question	How self-monitoring technologies are accepted and adopted by chronically-ill patients and engage them in healthy lifestyle?
Objectives	Understand acceptance and adoption in the long term
Outcomes	Guidelines to design wearable health monitors that are engaging enough to effect long-term change

Self-monitoring

TABLE 1. Average activity reported from 16 users.

Activity	After 1 month	After 2 to 6 months
No. of steps	7,852.72	9,002.30
No. of stairs	19.23	22.06

- Interviewed before, during, and after the study to identify what they expected from the tracker, how the tracker influenced their lifestyle, and what was required for the technology to change their long-term health decisions.

- After one month, changes in activity awareness, motivation to participate in activity, and a stronger sense of social connection were noted.

- After seven months, the 16 users still wearing the device reported visible health and lifestyle changes.

- Physical activity was translated to visible results such as weight loss, which reinforced activity awareness, although some users reported losing the device or forgetting to wear it.

- Social connection also remained.

Self-monitoring
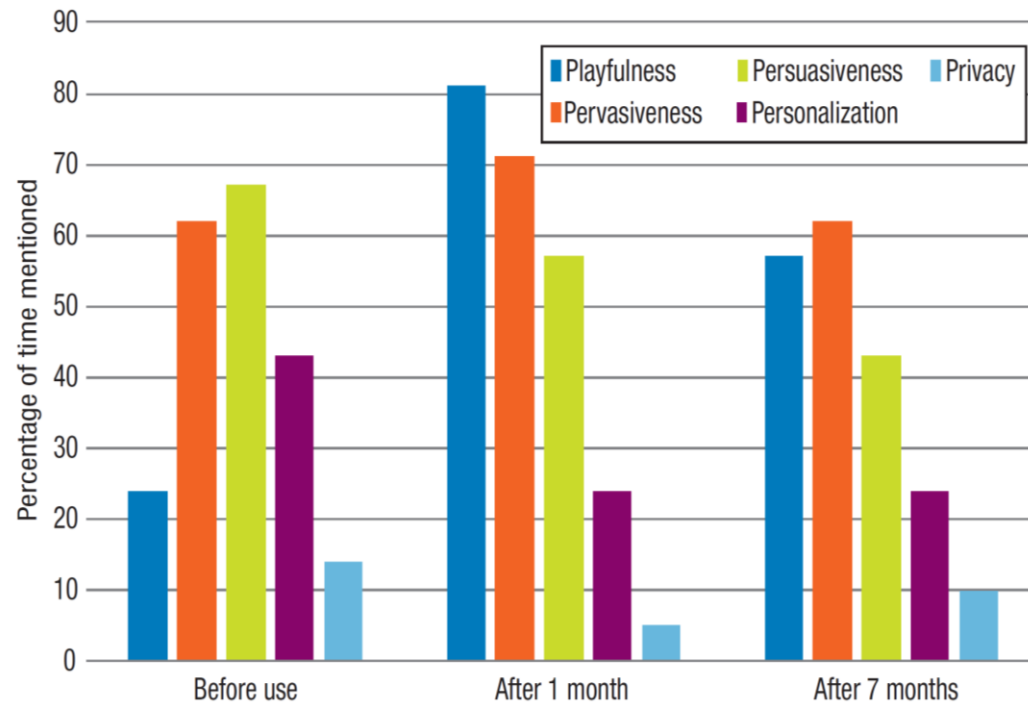
TABLE 2. Users' requirements for activity-monitoring technologies.

Requirements	Explanations	No. of users mentioning requirement		
		Before use	After 1 month	After 7 months
Playfulness	Metaphors, fun messages, motivating messages, colors	5	15	10
Pervasiveness and practicality	Ease of integration into daily life, small, lightweight, simple information	11	13	11
Persuasiveness	Notifications, rewards, warnings, comparisons, suggestions	12	10	9
Personalization	Personalized goal, information relevant to disease, recommendations	9	5	5
Privacy	Control over data sharing	3	1	2

- a set of requirements were identified, which evolved into recommendations for the design of wearable health trackers that aim to effect long-term lifestyle changes in their users' behavior.

Self-monitoring

RQ1: How self-monitoring technologies are accepted and adopted by chronically-ill patients and engage them in healthy lifestyle?

Conclusions

- Diabetic and obese users given a fitness tracker for seven months identified the device's playfulness, practicality, persuasiveness, personalization, and privacy as the top motivators for its use.

- A well-designed activity monitor can do much more than record a user's glucose level and weight; through personalization and pervasiveness, it can help users manage their lifestyle to incorporate healthier choices.

- Users' expectations of the device change with continued use. Thus, in addition to tailoring the device for the user and the user's environment and making it entertaining and easy to use, designers should consider ways that the device can adapt to changing expectations across periods of use.

Self-monitoring

Randriambelonoro, M., Chen, Y., Yürüten, O. & Pu, P. (2017). **Opportunities and challenges for self-monitoring technologies for healthy aging: An in-situ study.** Gerontechnology. 16. 173-180. Doi: 10.4017/gt.2017.16.3.006.00

Type	Qualitative study
Participants	20 senior people living at home
Duration	6 weeks
Intervention	Wearable fitness tracker with its native application
Research question	What are the opportunities and challenges for the elderly to be monitored and how would they integrate the system in their daily life?
Objectives	Understand attitudes and adoption of self-monitoring technologies
Outcomes	A set of opportunities and challenges for designing self-monitoring technologies for healthy ageing

Self-monitoring

- Before using the devices, our intent was to understand older adults' attitudes towards increasing physical activity as well as their readiness towards tracking technologies.

- The main barriers of being physically active were the absence of motivation, the incapacity due to health condition and the lack of perceived usefulness of physical exercise.

- Although half of the participants were not technology-oriented, personal interest and enthusiasm driven by family towards technology were observed.

- After 6 weeks of usage, we discovered changes in behavior and usage intention which allowed us to identify opportunities and challenges for the older adults to adopt sensors and application for health and activity management.

Self-monitoring

RQ2: What are the opportunities and challenges for the elderly to be monitored and how would they integrate the system in their daily life?

Conclusions

- This study showed the potential of acceptance and adoption of simple and manageable technology for behavior change.

- As for usage intention, some older adults start to be eager to learn new tools as long as they are able to do it, which is more and more influenced by family from younger generation.

- However, designers and engineers should consider older adults' reluctance when introducing novelty in their daily life, as well as their need for social interaction and their need to remain in control of any system given to them.

Social incentives

Chen*, Y., Randriambelonoro*, M., Geissbuhler, A. & Pu, P. **Social Incentives in Pervasive Fitness Apps for Obese and Diabetic Patients.** In Proc of the 19th ACM CSCW'16 Companion. San Francisco, USA, Feb. 2016 (*equal contribution)

Type	Qualitative study
Participants	16 obese and diabetic patients
Duration	8 weeks (4 weeks baseline – 4 weeks intervention)
Intervention	Wearable fitness tracker and HealthyTogether application
Research question	How does collaboration and competition affect the motivation of chronically-ill patients to exercise more?
Objectives	Explore the effect of social incentives for engagement
Outcomes	Insights into the role of cooperation and competition

Social incentives
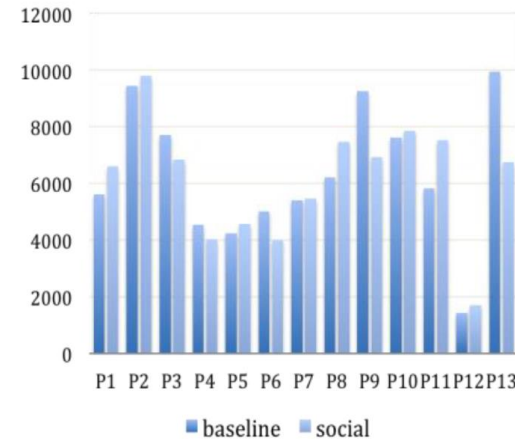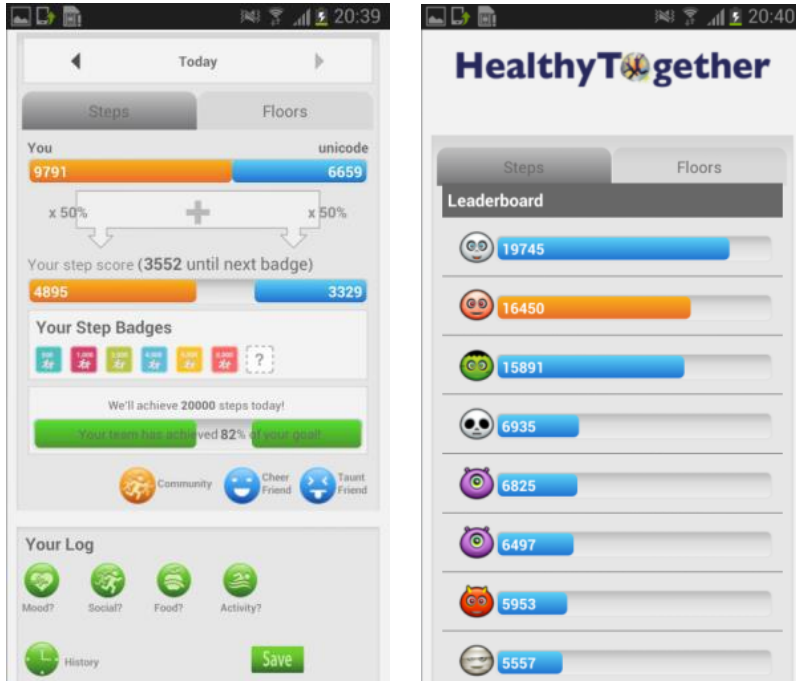
(a)
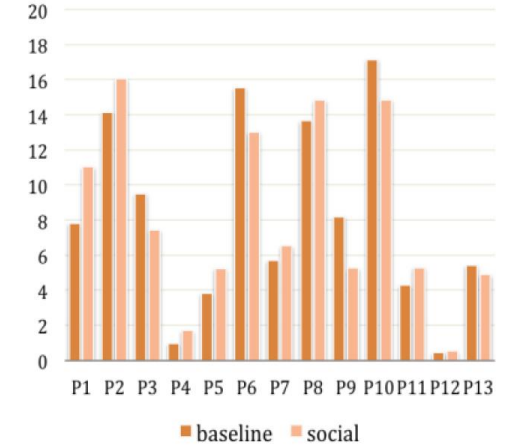
(b)

- Compared with the baseline, there was a trend of improvement in daily floors when connecting with a buddy and competing in the community: 7.72 floors/day vs. 9.17 floors/day. Participants also slightly walked more (6332 steps/day vs. 6631 steps/day).
- Three of them have an increase of more than 1,000 steps per day.

Social incentives

RQ3: How does collaboration and competition affect the motivation of chronically-ill patients to exercise more?

Conclusions

- Results show that participants exercised more with social incentives compared with their baseline.

- Collaborating with buddies to compete in a community was reported as motivating for dyads exercising with strong ties.

- Social interactions could be demotivating between dyads who did not know each other well.

- Finally, it is crucial to consider patients' technical literacy when designing behavior-changing technologies.

Gamification

Randriambelonoro, M., Perrin, C., Blocquet, A., Kozak, D, Fernandez, J.T., Marfaing, T. et al. **Hospital-to-home transition for older patients: using serious games to improve the motivation for rehabilitation.** Journal of Population Ageing

Type	Qualitative study
Participants	57 elderly patients with musculoskeletal issues
Duration	6 weeks (3 weeks hospital)
Intervention	Gamified rehabilitation equipment & wearable tracker
Research question	How does serious game-based rehabilitation impact elderly patients' motivation and activity at the hospital?
Objectives	Investigate adoption and acceptance
Outcomes	A set of opportunities and challenges / different recommendations on designing serious game-based rehabilitation intervention for healthy ageing

Gamification

Before intervention			After intervention		
Attitudes	**Both group**		**Behavior changes**	**Control group**	**Intervention group**
Attitudes towards rehabilitation	No specific habits, only following hospital routine	45 (79%)	Showed positive change in their behavior	5 (31%)	15 (60%)
	Feeling bored	32 (56%)	Still reported pain and lack of confidence	7 (44%)	3 (12%)
Attitudes towards physical activity	Sitting or light activity in the hallways as main activity	41 (72%)	Felt more active	No mention	10 (40%)
	Pain and tiredness after surgery as main barrier to be active	35 (61%)	Took part in social walking group	No mention	3 (12%)
	Consider hospital stay as a resting time	14 (24%)			
	Making slight effort to go outside	10 (17%)			
Elderly technology readiness	Positive interest	14 (24%)			
	Disinterest due to lack of ability	12 (21%)			
	Using social media	8 (14%)			
	Used/using step counter	4 (7%)			

Fun		92%
Challenging		72%
Safe		68%
Encouraging self-learning and self-efficacy		60%
Distracting		40%
Exhausting		48%
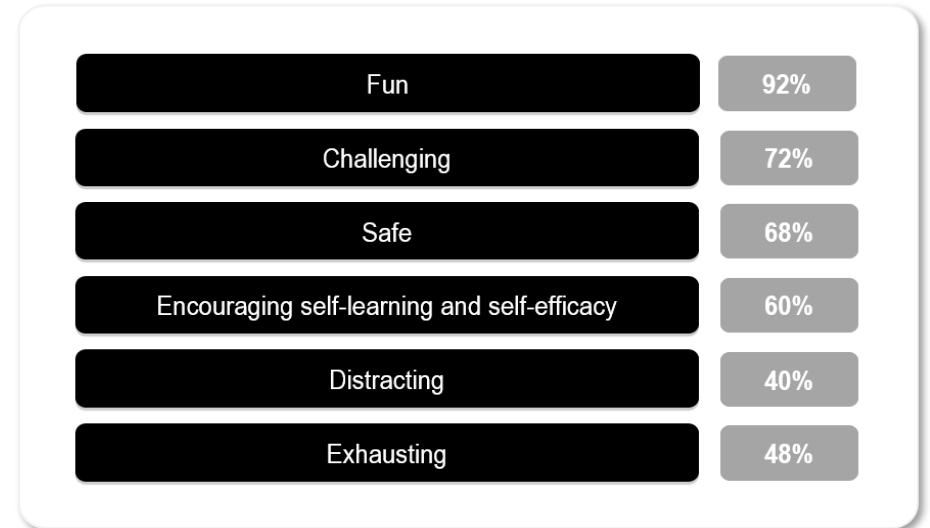
	Mean (nb steps / day) during the last week at the hospital	Nb of patients with less than mean 1000 steps / day (%)
Intervention group	2375	3 (12%)
Control group	1696	7 (44%)

- Participants admitted feeling bored at the hospital and only following along the care process routine.
- Enthusiasm towards the progress brought by technological solution were observed.
- At the end of the hospital stay, the serious game-based rehabilitation received positive feedback.
- Patients felt more active and observed significant improvement in their general condition.
- The analysis suggests that patients following the gamified rehabilitation were higher motivated.

Gamification

Gamification

RQ4: How does serious game-based rehabilitation impact elderly patients' motivation and activity at the hospital?

Conclusions

- Before using the different devices, our intent was to understand older patients' attitudes towards rehabilitation process, their motivation for physical activity as well as their readiness for innovative technology.

- At the end of the hospital stay, our study showed that patients who received the intervention demonstrated stronger engagement in the rehabilitation process and exhibited a higher motivation to be active.

- Different recommendations on designing serious game for elderly rehabilitation are outlined, especially playfulness, personalization, performance feedback and safety.

- All in all, if applied on a larger population during a longer period, our findings suggest the potential long-term impact of serious game-based intervention on elderly quality of life and independence while returning home.

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Gamification

Randriambelonoro, M., Perrin, C., Blocquet, A., Kozak, D, Fernandez, J.T., Marfaing, T., et al. (2021). **Computer-aided physical rehabilitation of older people: a pilot non-inferiority randomized clinical trial.** To be submitted to JMIR Serious Game

Type	Multicenter non-inferiority randomized clinical trial
Participants	57 elderly patients with musculoskeletal issues
Duration	6 weeks (3 weeks hospital – 3 weeks home)
Intervention	Gamified rehabilitation equipment & wearable tracker
Research question	How efficient is the gamified rehabilitation compared to the standard rehabilitation treatment?
Objectives	Explore clinical efficacy
Outcomes	Insights into efficacy and the benefits of the intervention / complexities associated with adopting new technologies in clinical practice

Gamification
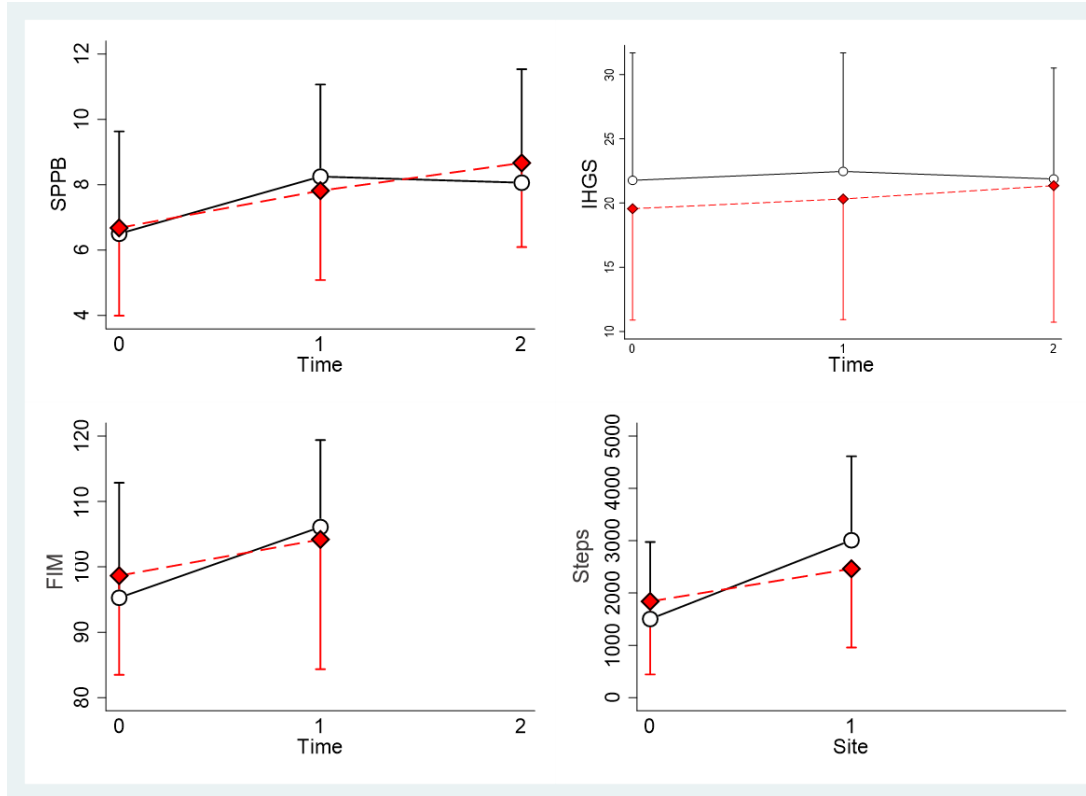
Outcomes	Time t=0	Time t=1	Time t=2
SPPB (mean score ± SD)			
▪ Intervention	6.68 ± 2.69	7.82 ± 2.74	8.67 ± 2.58
▪ Control	6.50 ± 3.13	8.25 ± 2.82	8.06 ± 3.47
IHGS (mean kg ± SD)			
Left hand			
▪ Intervention	19.71 ± 8.60	20.33 ± 9.24	21.75 ± 9.72
▪ Control	22.29 ± 8.54	22.43 ± 8.65	22.60 ± 8.07
Right hand			
▪ Intervention	19.56 ± 8.67	20.32 ± 9.40	21.35 ± 10.63
▪ Control	21.77 ± 9.93	22.46 ± 9.23	21.88 ± 8.64

- Although based on small sample size, our study has the benefit of investigating the clinical validity of a serious game-based rehabilitation in a real-world setting.

- although not statistically significant, it is worth noting that, after 6 weeks, the handgrip strength test improved by 2kg in the intervention group compared to 0.3kg in the control group.

Gamification

Contributions

- Findings show no significant differences were found between the control group and the intervention group for the primary outcome (SPPB: balance, gait speed, chair stand) or any of the secondary outcomes (IHGS, FIM and steps), which demonstrates the non-inferiority effect of the serious game-based intervention.

- In addition, patients who received the intervention demonstrated engagement in the rehabilitation process and motivation in being more active. Serious game-based rehabilitation could be a cost-effective alternative for elderly patients to regain their functional capacities.

Conversational agent

Randriambelonoro. (2019). **MiranaBot: a conversational agent to promote healthy eating.**
REACH demo & exhibition. Copenhagen.

Type	Qualitative study (Observational study / Participative design)
Participants	13 participants
Duration	1 week
Intervention	Conversational agent
Research question	What are the needs and requirements for self-monitoring technology to promote healthy eating for chronically-ill patients?
Objectives	Develop a conversational agent to promote healthy eating
Outcomes	Prototype of a personalized nutrition assistant / sets of needs and requirements

Conversational agent

Lack of regularity

Lack of variety
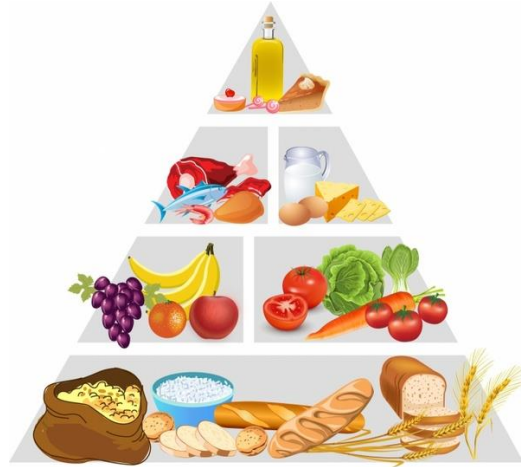
False beliefs

Hunger unawarness

Barriers to healthy nutrition

Conversational agent

Education / Enablement

Monitoring

Education / Persuasion

Education

Training / Enablement

Empowerment

Enablement

Practicality

Requirements and needs

Conversational agent

Self-monitoring
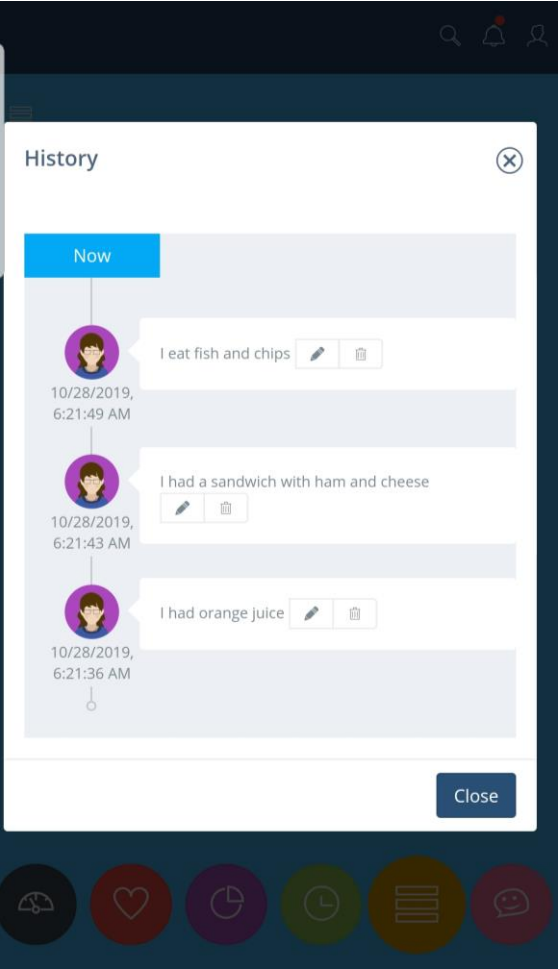
Personalized visual feedback for self-regulation

History

Now

I eat fish and chips
10/28/2019, 6:21:49 AM

I had a sandwich with ham and cheese
10/28/2019, 6:21:43 AM

I had orange juice
10/28/2019, 6:21:36 AM

Close

My BMI

Underweight Normal
Overweight Obese

27

Close

Do I eat meals regularly?

Snack

Snack

Snack

Dinner

Fermer

Is my diet correctly varied?

Vegetables Proteins Carbs

Fermer

Conversational agent

RQ6: What are the needs and requirements for self-monitoring technology to promote healthy eating for chronically-ill patients?

Conclusions

- Lack of regularity, lack of variety, false belief and hunger unawareness were identified as the main barriers to healthy nutrition; whereas monitoring, education, empowerment and practicality were identified as the main needs and requirements for nutrition behavior change.

- These findings allowed us to suggest the appropriate behavior change techniques to be used in our systems, which are self-monitoring, personalized visual feedback, goal setting, self-awareness and personalized education.

- Finally, these were translated into a set of functionalities that build up to construct our final solution: MiranaBot.

Intervention prescription

Population	Target	Intervention	Recommendations / Observations	Examples of tools / Duration
Healthy adult	Prevention	Education Persuasion Enablement	Playfulness, Practicality, Persuasiveness	Self-monitoring technologies, Conversational agent **Long-term** **Stability (60-100 days)**
Obese and diabetic adult	Treatment	Education Persuasion Incentivisation Environmental restructruring	Playfulness, Practicality, Persuasiveness, Personalization, Privacy, Collaboration within strong ties	Conversational agent, Self-monitoring technologies, Social incentives-based technologies **Min 6-month**
Elderly	Prevention	Persuasion Incentivisation Training Environmental restructruring	Reluctance introducing novelty, Need for social interaction, Need to remain in control	Self-monitoring technologies, Gamified technologies, **Long-term**
	Rehabilitation	Education Persuasion Incentivisation Training Enablement	Playfulness, Personalization, Performance Feedback, Safety	Self-monitoring technologies, Gamified technologies, Social incentives-based technologies **Min 3-month**

Recommender systems (RSs)

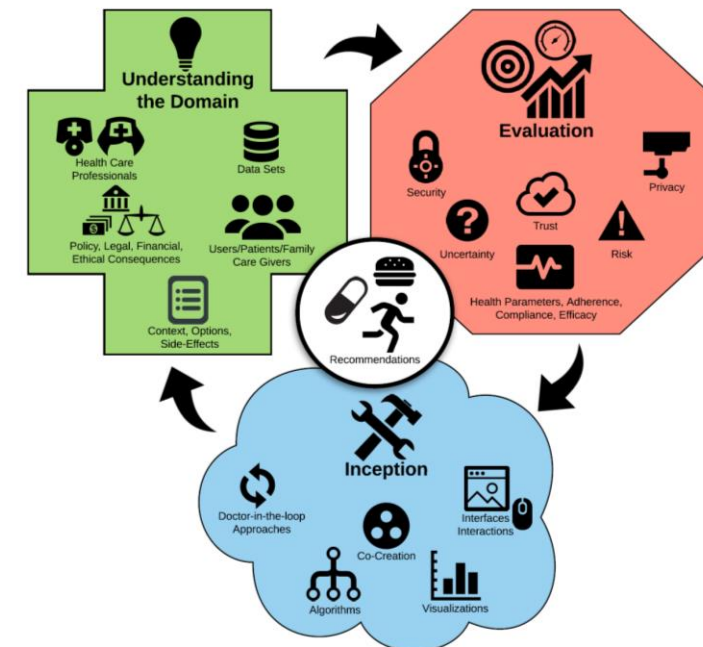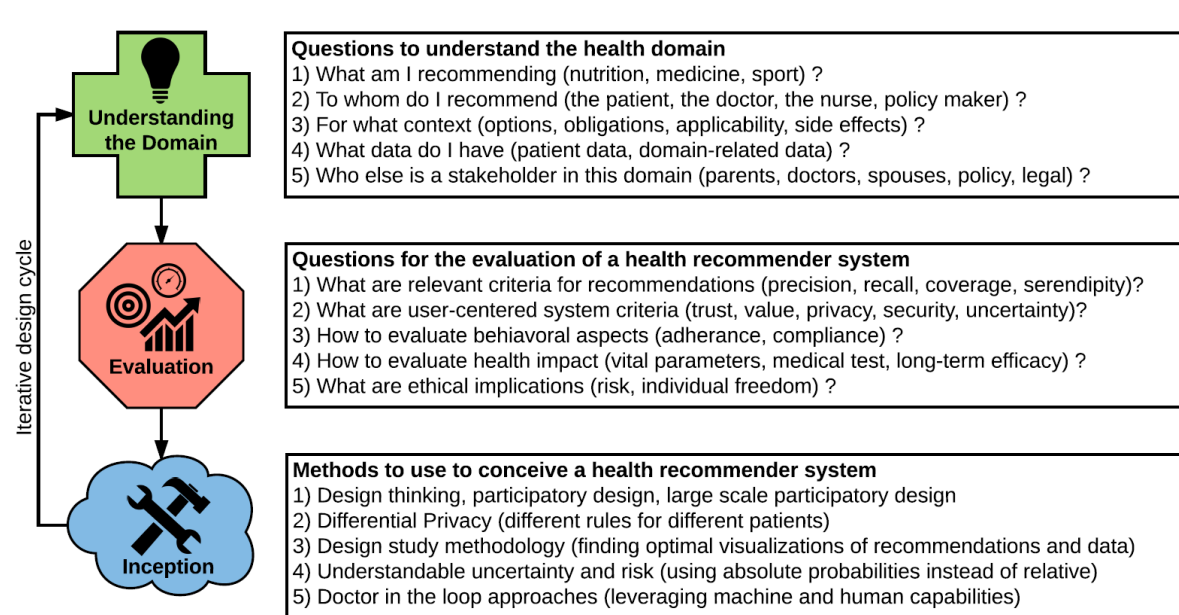# Health recommender systems (HRSs)
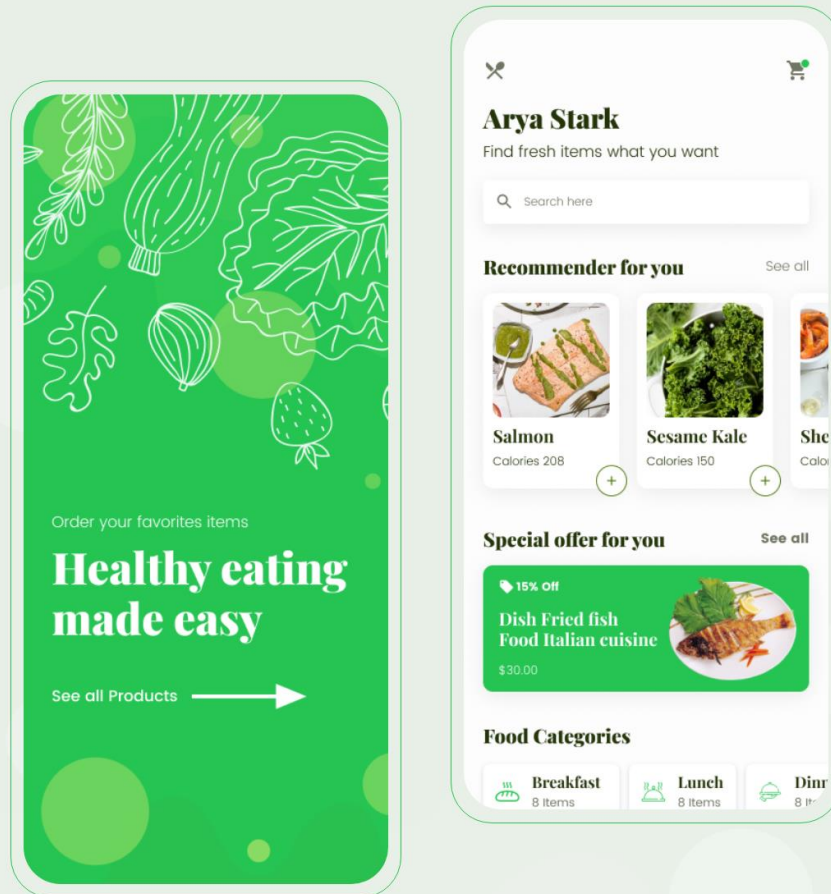
HRSs

HRSs offer the potential to motivate and engage users to change their behavior and provide people with better choices and actionable knowledge based on observed behavior.

The overall objective of the HRS is to empower people to monitor and improve their health through technology-assisted, personalized recommendations.

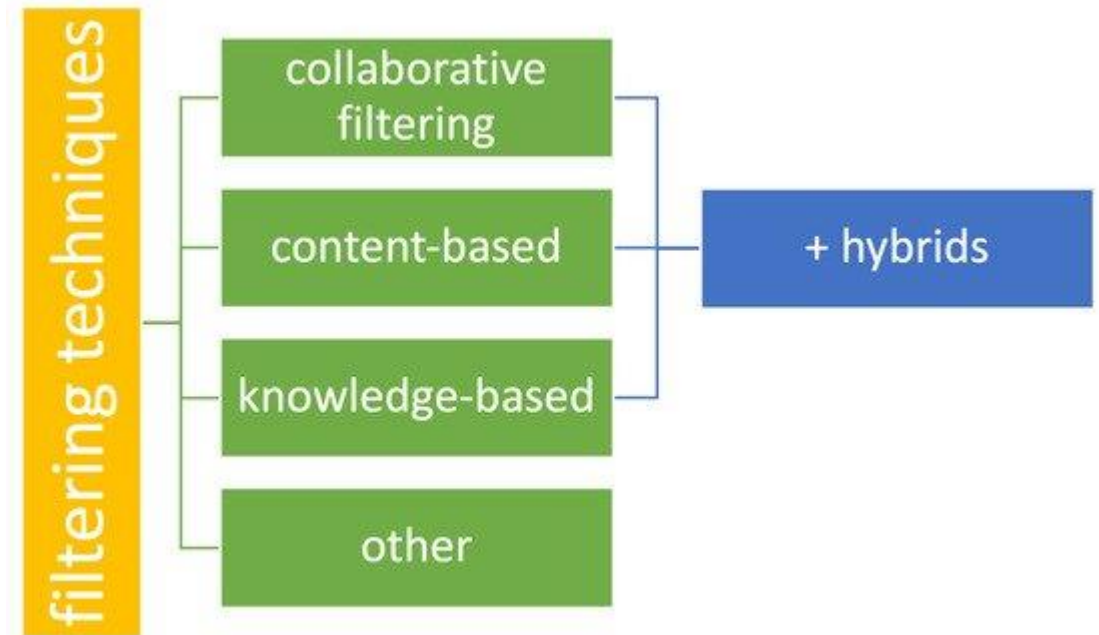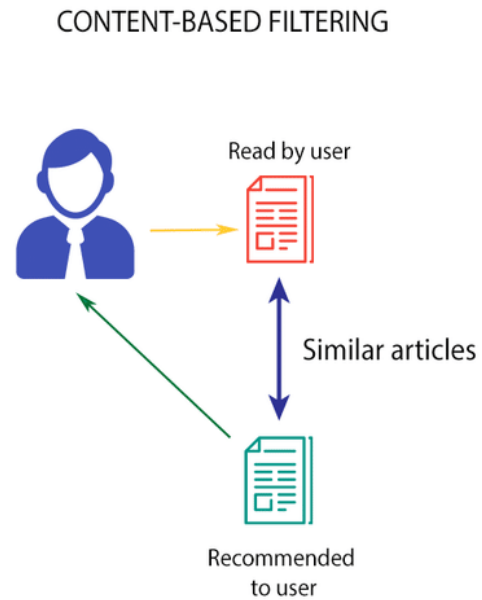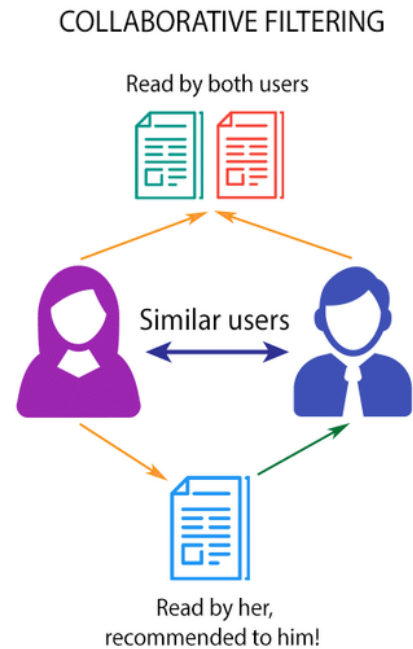RSs = "software tools and techniques providing suggestions for items to be of use to a user". Rici et al.

HRSs = "In the context of an HRS, a recommendable item of interest is a piece of nonconfidential, scientifically proven or at least generally accepted medical information." Wiesner and Pfeifer

Questions to understand the health domain
1) What am I recommending (nutrition, medicine, sport) ?
2) To whom do I recommend (the patient, the doctor, the nurse, policy maker) ?
3) For what context (options, obligations, applicability, side effects) ?
4) What data do I have (patient data, domain-related data) ?
5) Who else is a stakeholder in this domain (parents, doctors, spouses, policy, legal) ?

Questions for the evaluation of a health recommender system
1) What are relevant criteria for recommendations (precision, recall, coverage, serendipity)?
2) What are user-centered system criteria (trust, value, privacy, security, uncertainty)?
3) How to evaluate behiavoral aspects (adherance, compliance) ?
4) How to evaluate health impact (vital parameters, medical test, long-term efficacy) ?
5) What are ethical implications (risk, individual freedom) ?

Methods to use to conceive a health recommender system
1) Design thinking, participatory design, large scale participatory design
2) Differential Privacy (different rules for different patients)
3) Design study methodology (finding optimal visualizations of recommendations and data)
4) Understandable uncertainty and risk (using absolute probabilities instead of relative)
5) Doctor in the loop approaches (leveraging machine and human capabilities)

Recommender Systems for Health Informatics: State-of-the-Art and Future Perspectives. Valdez et al.

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The majority of HRSs rely on knowledge-based techniques, either directly or in a hybrid approach.

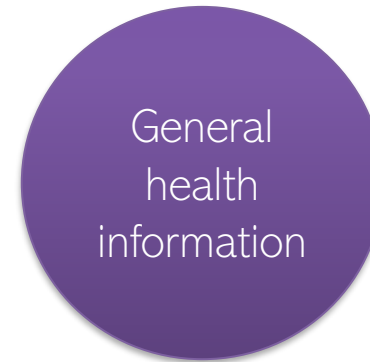Health Recommender Systems: Systematic Review. De croon et al.
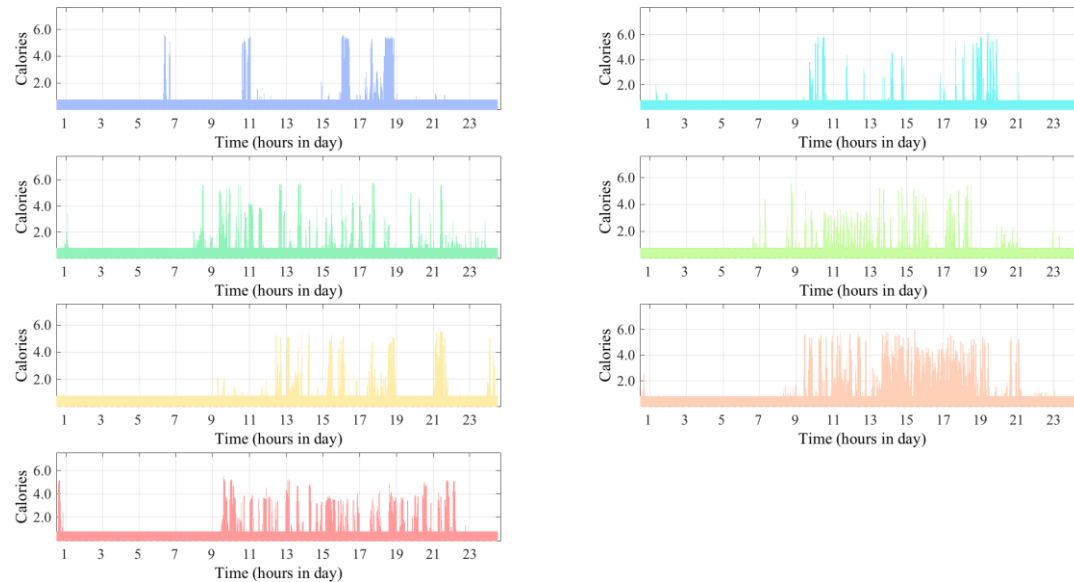
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Lifestyle

Nutrition

General health information

Specific diseases

Health Recommender Systems: Systematic Review. De croon et al.

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HRSs: e.g: REACH


The cluster prototypes for the HealthyTogether Dataset (Yürüten, O., Zhang, J., & Pu, P.,2014, June: Decomposing activities of daily living to discover routine clusters. In Twenty-Eighth AAAI Conference on Artificial Intelligence)
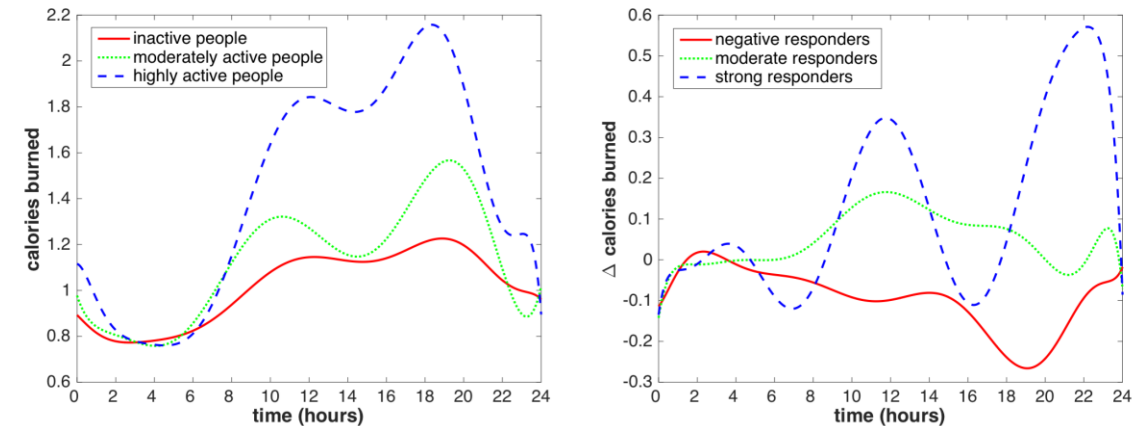
The behavior of people before the intervention (daily activity patterns) and the behavior change of people after the intervention (activity change patterns) are shown on the left and on the right correspondingly. The results suggest that inactive and moderately active people will respond positively to the intervention. Reference: Kulev, I., Pu, P., & Faltings, B., 2016, December: Discovering Persuasion Profiles Using Time Series Data. In NIPS 2016 Time Series Workshop.

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People recommender systems
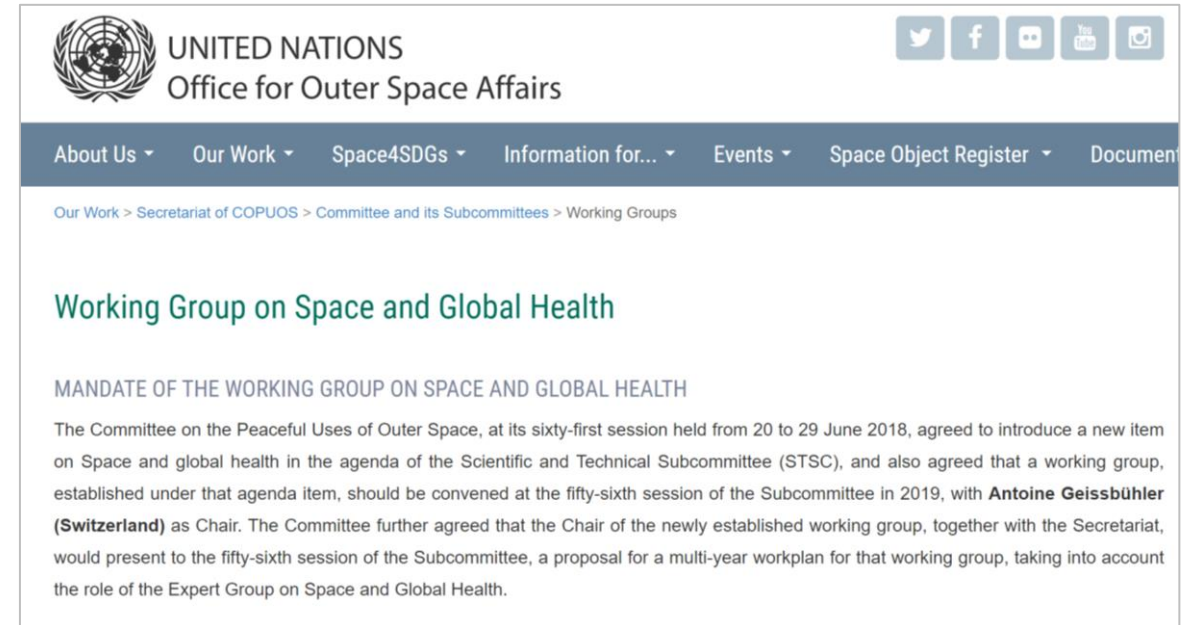
People RS: hackathon

GDH²ack
Global Digital Health Hackathon
November 26th, 2021

Challenge #7

Global health recommender systems

gdhub
Geneva Hub for
Global Digital Health

open GENEVA

Geneva SDG Solution Space

campus biotech

unitar
United Nations Institute for Training and Research

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Thank you

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