BEHAVIORAL SUPPORT FOR COMPLIANCE TO THERAPY FOR PATIENTS WITH CHRONIC DISEASES: A CASE STUDY OF ATRIAL FIBRILLATION MANAGEMENT

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Introduction

Therapy Compliance

Compliance: following therapeutic advices and recommendations from a healthcare provider

- Non-compliance is one of the most significant barriers to effective treatment: 20-30% for short-term treatment, 50% for long-term and 70-80% for lifestyle changes [Jin et al., 2008]
- Non-compliance leads to worsening condition and increased healthcare costs (US – 100-300 billion USD annually)

Therapy Compliance

- Interventions improving adherence have far greater impact on patient outcomes than improved therapies [Haynes et al., 2008]
- Successful interventions combine case management (→ participatory medicine), patient education and behavior change [Benjamin, 2012]

Our goal: to develop a **methodological** and **technological** support framework to deliver personalized interventions to patients and improve their compliance to therapies

Proposed Support Framework

Data-driven

- Identification of **psychobehavioral targets**
- Application of **DRSA** to induce rules capturing patterns associated with adherence levels

Expert-driven

- Construction and selection of **psychobehavioral interventions**
- Application of predefined generic interventions [Abraham, Michie, 2008] and domain knowledge (clinical and psychological)

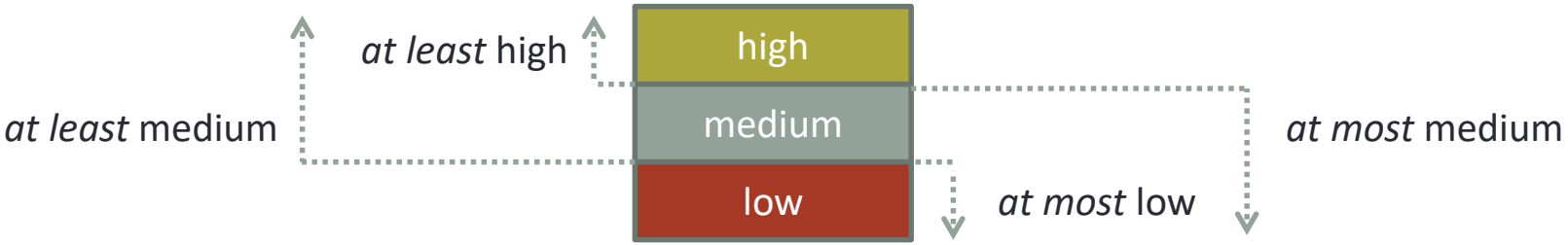
Technology-driven

- Integration with an existing guideline-based mobile decision support system
- Customization to patient's computer literacy level and available platform (smartphone, smart TV)

Data-driven Phase

Short Introduction to DRSA

- Objects categorized into **ordered** classes (from worst to best) and described using features with (possibly) ordered values



- Analysis focused on unions of classes
  - *At least* (↑) or and *at most* (↓) unions instead of individual classes
  - ↑ and ↓ and decision rules pointing at corresponding unions

Intervention-oriented Decision Rules

- Formally, r is a rule $\phi \rightarrow \psi$ derived from a set of objects U
  - ϕ is a premise and ψ is a consequence
  - r is also characterized by its confidence in U: $conf(r, U) = P_U(\psi|\phi)$

- Classification- and **intervention-oriented** perspectives associated with decision rules
- **Interventions** that may change values of object's features and affect its classification
  - ϕ defines the **intervention target** and ψ specifies the expected change in classification
  - $conf(r, U)$ gives a success rate of making the classification consistent with ψ after having attained target ϕ

Evaluation of Intervention-oriented Rules

- Target ϕ indicated in r can be evaluated using its **impact** on objects from set U' (different but homogeneous with U)

$$\delta(r) = \frac{|m(\neg\phi, U') \cap m(\neg\psi, U')|}{|U'|} \times conf(r, U)$$

  where $m(\gamma, U')$ is a set of objects from U' that do satisfy γ

- Applicability profiles ϕ_i to limit the set objects that may achieve ϕ (→ additional "filters")

$$\delta(r) = \frac{|[\cup_i m(\phi_i, U')] \cap m(\neg\phi, U') \cap m(\neg\psi, U')|}{|U'|} \times conf(r, U)$$

Types of Intervention Targets

- **Positive** (achievement) targets
  - Given as premises of ↑ decision rules
  - Associated with changes that improve class assignment, i.e., an object gets assigned to a better class after achieving the target
- **Negative** (maintenance) targets
  - Given as premises of ↓ decision rules
  - Associated with changes that result in deteriorated class assignment, i.e., an object gets assigned to a worse class after achieving the target

Positive targets should be achieved, while negative targets should be avoided

Identification of Psychobehavioral Targets

- Patients described using sociodemographic, psychological and behavioral features [IOM, 2015] – interventions can be applied only to the latter two (→ psychobehavioral features)
- Formal definition of rule changed to $\phi_{pb} \wedge \phi_{sd} \rightarrow \phi$, where
  - ϕ_{pb} is a psychobehavioral (intervention) target
  - ϕ_{sd} is a sociodemographic context (or sociodemographic characteristics)
  - ψ is a union of adherence levels

- It is possible to obtain rules of no use with empty ϕ_{pb}
- Feature selection → all psychobehavioral features combined with the remaining relevant features (*reduct*)

Evaluation of Psychobehavioral Targets

- Revised measure to evaluate the impact of ϕ_{pb} indicated by r (ϕ_{sd} acts as an applicability profile)

$$\delta(r) = \frac{|m(\phi_{sd},U') \cap m(\neg\phi_{pb},U') \cap m(\neg\psi,U')|}{|U'|} \times conf(r,U)$$

- Positive and negative psychobehavioral targets associated with improving and maintaining the level of compliance respectively

Expert-driven Phase

Construction of Psychobehavioral Interventions

- Two major components of psychobehavioral interventions: **educational** and **behavior change** actions

  - Educate on disease manifestation, prognosis and management
  - Provide information about behavior-health links
  - Emphasize the key role of the patient in a successful therapy

  - Encourage the patient for positive behavior
  - Engage the patient in goal setting
  - Provide feedback on goal attainment

- Focus on patient's autonomous motivation and competence → **self-determination theory** (SDT) [Ryan et al., 2017]

Construction of Psychobehavioral Interventions

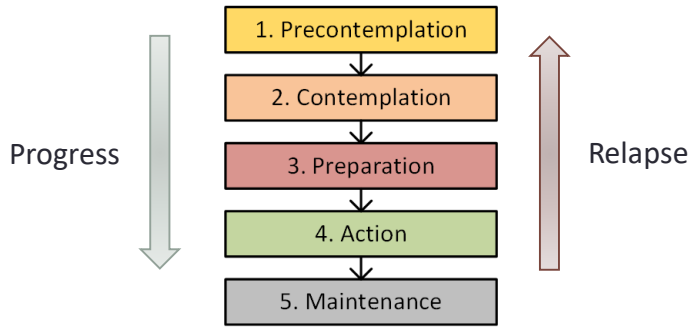
- Generic interventions [Abraham, Michie, 2008] customized to a specific domain using expert knowledge

1. Provide information about the links between behaviors and health
2. Provide information on consequences
3. Provide motivation by visibility of positive examples of others' behavior and approval of others for these behaviors
4. Prompt intention formation
5. Prompt barrier identification
6. Provide general encouragement
7. Set graded tasks
8. Provide instruction
9. Model or demonstrate the behavior
10. Prompt specific goal setting
11. Prompt review of behavioral goals
12. Prompt self-monitoring of behavior
13. Provide feedback on performance
14. Provide contingent rewards
15. Teach to use prompts or cues
16. Agree on behavioral contract
17. Prompt practice
18. Use follow-up prompts.
19. Provide opportunities for social comparison
20. Plan social support or social change
21. Prompt identification as a role model
22. Prompt self-talk. Encourage use of self-instruction and self-encouragement (aloud or silently) to support action
23. Relapse prevention
24. Stress management
25. Motivational interviewing
26. Time management

- Tying a new intervention to an existing trigger
  → **Fogg's behavioral model** (FBM) [Fogg, 2009]

Selection of Psychobehavioral Interventions

- Stages of readiness to (psychobehavioral) change
  → **trans-theoretical model** (TTM) [Prochaska, Velicer, 1997]

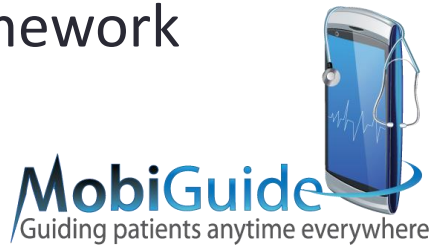


- Specific interventions applied at specific stages to enforce progress and protect from relapse
- The best outcomes (progress and retention) observed for stage-specific, computer-based and interactive interventions

Technology-driven Phase

Technological Infrastructure

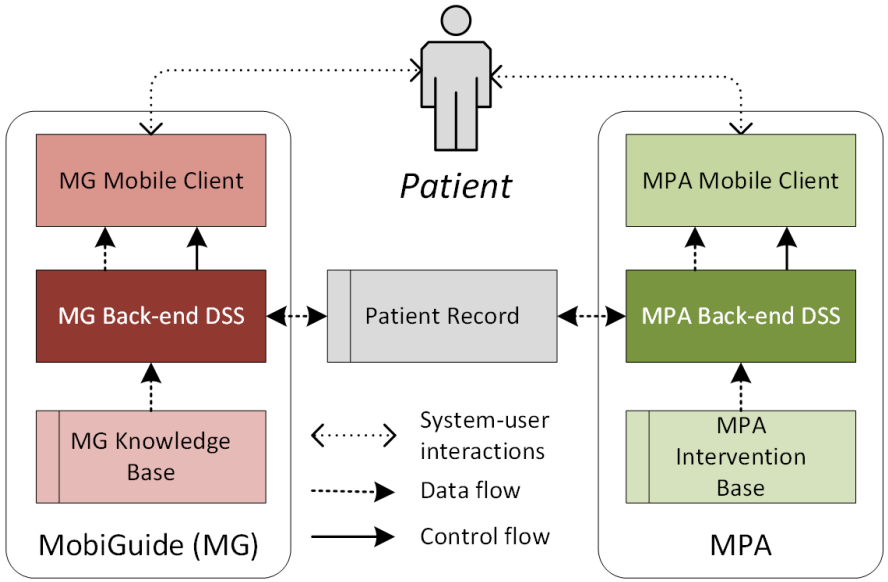
- **Mobile Patient Assistant** (MPA) – mHealth-based implementation of the proposed support framework



- Integration with the MobiGuide system
  - Guideline-based and personalized therapeutic support for patients with chronic illnesses (atrial fibrillation, gestational diabetes …)
  - Complex underlying infrastructure – integration with electronic patient record, limited use of wearable sensors
  - Support for both healthcare providers (physicians) and patients

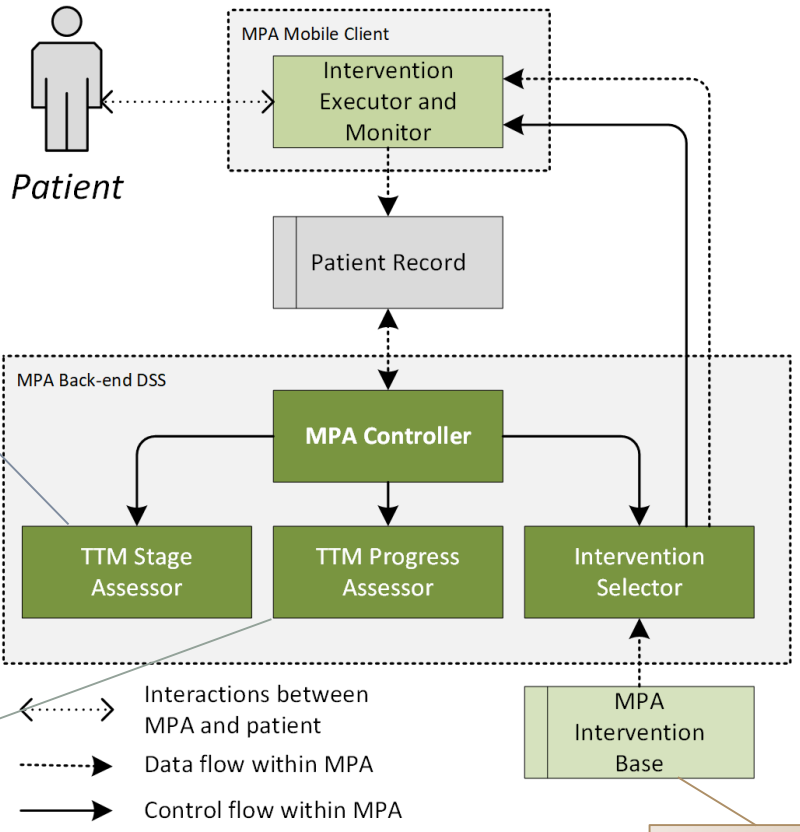
MobiGuide Project and System

Synergy between MobiGuide and MPA



	Interventions	Impact on adherence
MobiGuide	Recommendations, reminders, case management	Indirect
MPA	Education, behavior change	Direct

MPA Architecture



Infers patient's baseline TTM stage from patient record

Determines possibility of moving to the next TTM stage by checking *success condition(s)* of interventions

Interventions modeled with *applicability condition*, *activities* defining intervention, *success condition*

Management of Atrial Fibrillation

Atrial Fibrillation (AFib)

Canadian Cardiovascular Society
Leadership. Knowledge. Community.

- One of the most prevalent types of cardiac arrhythmias – approximately 30% of hospitalizations for arrhythmias
- Independently living older adults with atrial fibrillation are prescribed anticoagulation therapy – warfarin or direct oral anticoagulants (DOACs) – for primary stroke prevention
- Compliance to anticoagulation therapy ≈ 50% [Castellucci et al., 2015], remains low with introduction of the DOACs [Jackevicius et al., 2017]
- Limited support for patients to help with their compliance (compliance in MobiGuide: diabetes = 87%, AFib = 70%)

Results of Data-driven Phase

Analyzed Data and Selected Features

- 12 patient vignettes vetted and revised by the hematologist
  - Described by 10 features (consistent with recommendation of IOM for EHR) – 2 psychobehavioral and 8 sociodemographic
  - Categorized into 3 adherence levels
- A set of features further limited to three features (a reduct)

Willingness to be in charge of one's health → **engagement**

	Adherence_history	Smoking_or_alcohol	In_charge	Adherence_level
v1	(3) good	(2) moderate	(2) yes	(2) moderate
v2	(2) none_or_moderate	(1) none_or_light	(2) yes	(3) good
v3	(2) none_or_moderate	(1) none_or_light	(1) no	(2) moderate
v4	(1) poor	(1) none_or_light	(2) yes	(1) poor
v5	(2) none_or_moderate	(3) heavy	(1) no	(1) poor
v6	(1) poor	(2) moderate	(1) no	(1) poor
v7	(3) good	(1) none_or_light	(2) yes	(3) good
v8	(2) none_or_moderate	(1) none_or_light	(1) no	(2) moderate
v9	(2) none_or_moderate	(1) none_or_light	(1) no	(2) moderate
v10	(3) good	(2) moderate	(2) yes	(2) moderate
v11	(2) none_or_moderate	(1) none_or_light	(2) yes	(3) good
v12	(1) poor	(3) heavy	(1) no	(1) poor

Identified Psychobehavioral Targets

	Sociodemographic context	Psychobehavioral target			
	Adherence_history	Smoking_or_alcohol	In_charge	Adherence_level	Impact [%]
r1	>= none_or_moderate	<= none_or_light	>= yes	>= good	54.9
r2	>= good			>= moderate	
r3	>= none_or_moderate	<= none_or_light		>= moderate	9.1
r4	<= poor			<= poor	
r5		>= heavy		<= poor	66.7
r6			<= no	<= moderate	25.0
r7		>= moderate		<= moderate	25.0

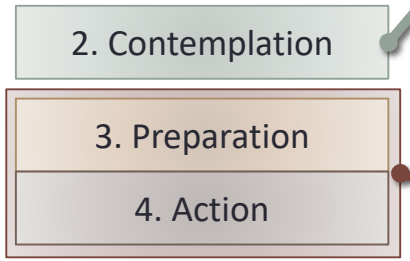
- Positive target in r_1 → limit smoking or drinking (to none or light) and improve patient's engagement
- Negative target in r_5 → maintain current (at most moderate) smoking or drinking level

Further focus on patient's engagement – factor indicated by other studies [Ream et al., 2017; Graffigna et al., 2017; Müllerová et al., 2016], multiple existing interventions for smoking/drinking cessation

Results of Expert-driven Phase

Constructed Behavioral Interventions

- Focus on 3 TTM stages (where mHealth coaching is essential)
- Interventions aimed at improving patient's engagement
- Based on generic interventions (e.g., prompt specific goal setting, provide opportunities for social comparison)



Education actions	Behavior change actions	Reporting interventions
1. Engagement (interview with an AFib patient) 2. AFib facts (e.g., etiology, therapies, management) 3. Risk of stroke	1. Exploration of pros of engagement	

Education actions	Behavior change actions	Reporting actions
As above plus 1. Lifestyle (e.g., diet, exercise); 2. Self-care (e.g., risky events)	1. Barriers and ways to re-move/mitigate them 2. Self re-evaluation questionnaire 3. Action planning and goal setting	1. Daily reporting of symptoms, diet and drug compliance, risky events, wellbeing 2. Daily and weekly engagement summaries

Constructed Behavioral Interventions

- Focus on 3 TTM stages (where mHealth coaching is essential)
- Interventions aimed at improving patient's engagement
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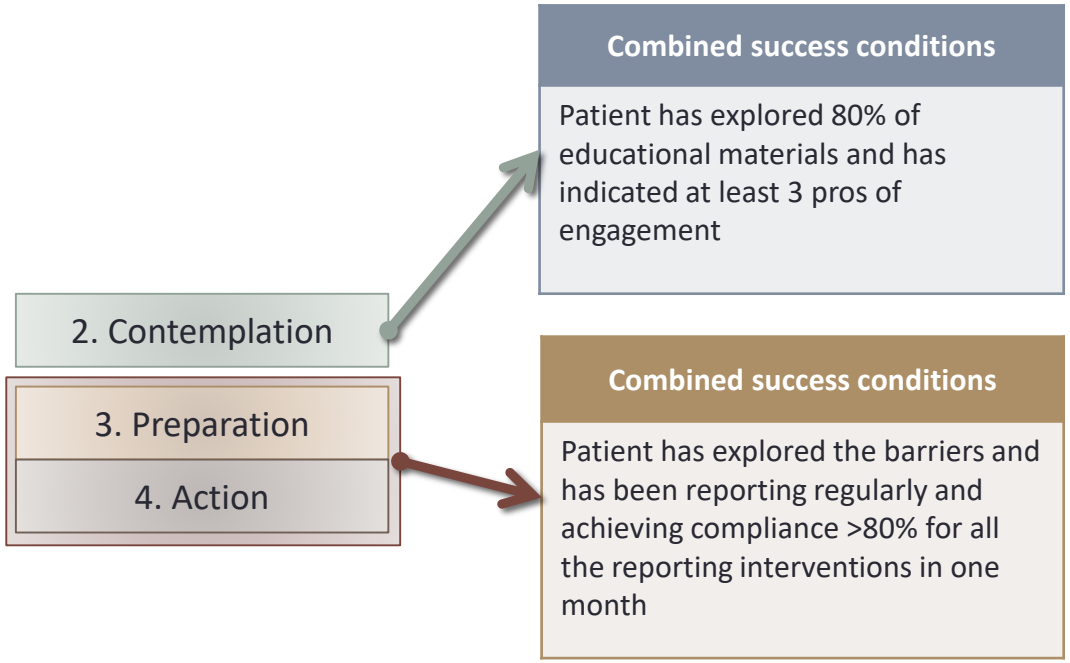


Education Actions

Back

Facts on AFib

Do I understand AFib?

AFib is an alteration of the heart rhythm in which the heart area that normally controls the electrical activation (the *sinus node*) is *overwhelmed* by the activity of other parts of the right or left atrium (the atria are the upper chambers of the four chambers that make up the heart). As a result the electrical activity of the atria becomes completely chaotic and the heartbeat (pulse) becomes irregular.

What are the symptoms of AFib?

The most common symptom is palpitation, or the feeling of an irregular, accelerated heartbeat. Other symptoms include shortness of breath (at rest or during exercise), dizziness, syncope (i.e., loss of consciousness for a few seconds with spontaneous recovery), fatigue, and tiredness. Also chest pain or pressure may occur.

Note that chest pain or pressure is a medical emergency. You may be having a heart attack - seek medical help (call 911) immediately.

Back

Facts on Anticoagulation

Why I am prescribed warfarin?

Daily dosage of warfarin may vary and it is managed by your doctor, a pharmacist, nurse practitioner or a local anticoagulation clinic. A blood test called an INR is required to ensure warfarin is working safely and effectively.

Will I experience side effects?

Anticoagulation medication does not have side effects but it may increase a bleeding risk so a doctor prior to starting a treatment assesses this risk. Patients at increased risk for bleeding, typically, are also those who will benefit the most from anticoagulation to prevent stroke, and your doctor considers a number of factors to lower bleeding risk.

How I should take Warfarin?

Warfarin should be taken exactly as prescribed and dosage may vary from week to week. It should be taken around the same time every day. It may be taken with food or on an empty stomach and may be taken with other medications.

Back

Facts on AFib

Am I at risk of stroke?

The most severe complication of AFib is caused by stagnation of blood in the atrial chambers. This promotes the formation of blood clots in a heart. If the blood clot detaches it is often dragged by the blood flow to the arteries of the brain so they can become clogged causing a stroke.

Risk of stroke depends on a number of factors and it varies between the patients and your doctor will assess it using a number of diagnostic tools. To lower risk of stroke you are prescribed anticoagulant medication.

How can I minimize risk of stroke?

In order to decrease chances of formation of the blood clots physician prescribes so called anticoagulants. "Anti" means against and "coagulate" means to thicken into a gel or solid. Therefore, anticoagulants are often also called blood thinners.

There are two common types of anticoagulants: vitamin K antagonists such as warfarin (coumadin) and direct acting oral anticoagulants (DOACs) such as apixaban, dabigatran, edoxaban, or rivaroxaban. DOACs are similar to warfarin in most clinical outcomes. They have been shown to have reduced risk of causing an intracranial hemorrhage compared with warfarin. However, the main advantage of taking the DOACs is that there is no requirement for routine monitoring of their anticoagulation effects.

Back

Lifestyle

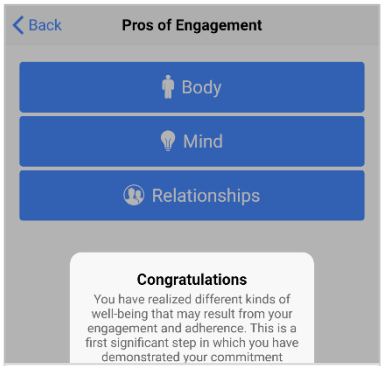
Should I watch my diet?

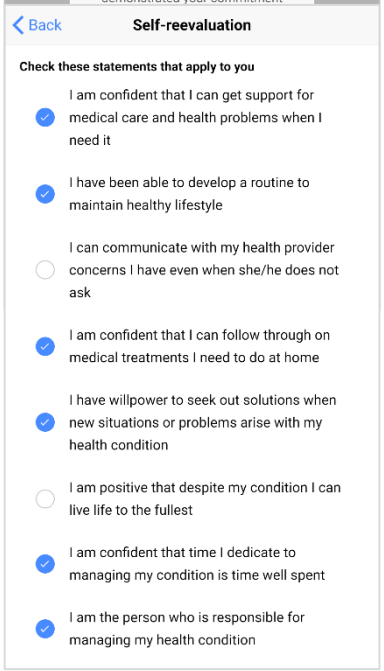
Some foods - even healthy ones can make warfarin less effective especially if your diet includes foods that are high in vitamin K. Vitamin K is found in the following foods:

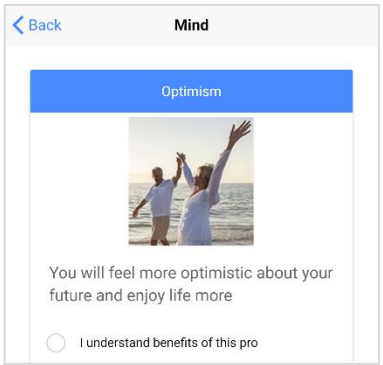
- Green leafy vegetables, such as kale, spinach, turnip greens, collards, Swiss chard, mustard greens, parsley, romaine, and green leaf lettuce,
- Vegetables such as Brussels sprouts, broccoli, cauliflower, and cabbage,
- Fish, liver, meat, eggs, and cereals (smaller amounts).

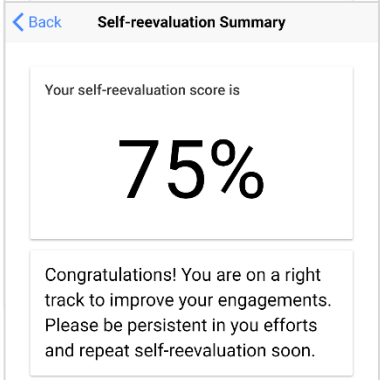
Eating a lot of such foods can counteract the Warfarin effectiveness. However, your doctor may recommend that rather than eliminating them from your diet, you eat consistent amounts of these foods each day and have your warfarin dosage adjusted to take that into consideration.

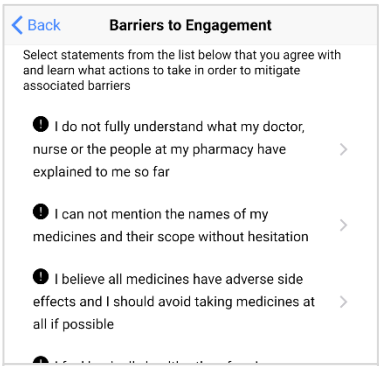
Behavior Change Actions

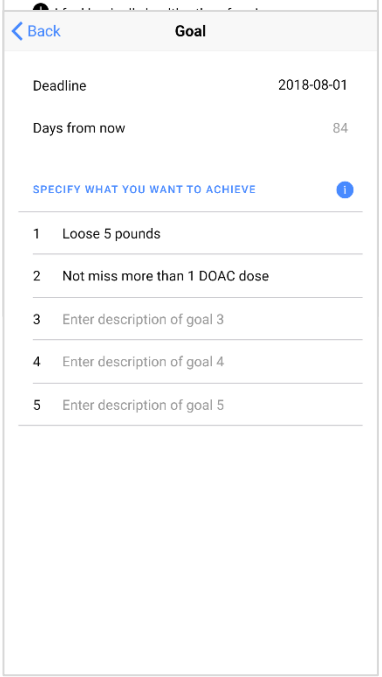


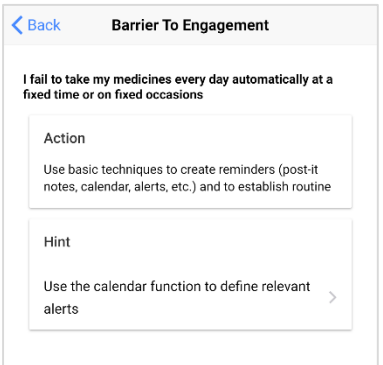


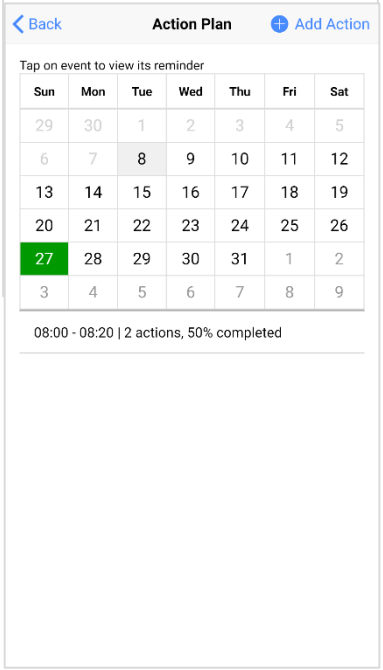




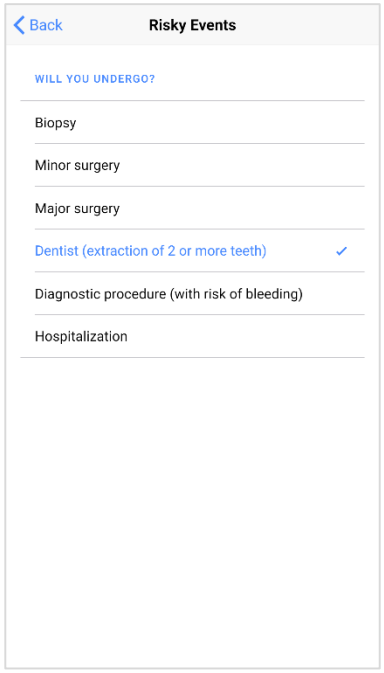


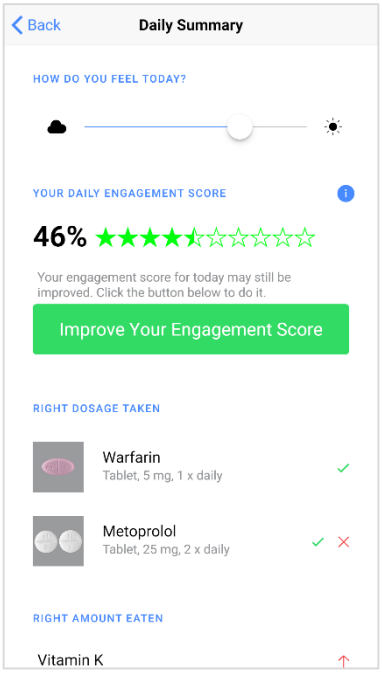


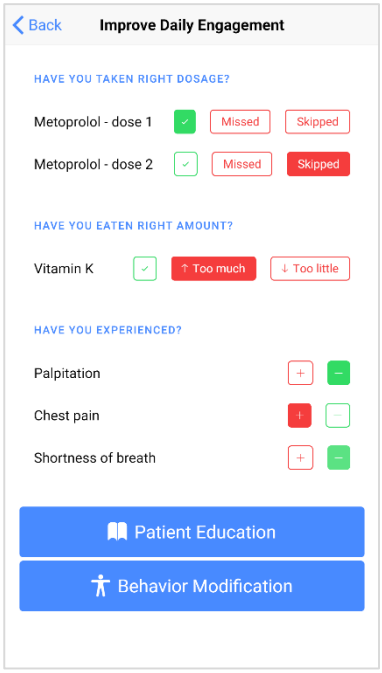


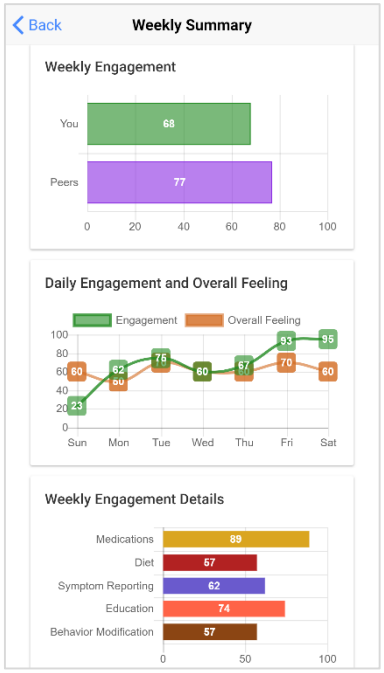


Reporting Actions









Preliminary Assessment

Preliminary Assessment

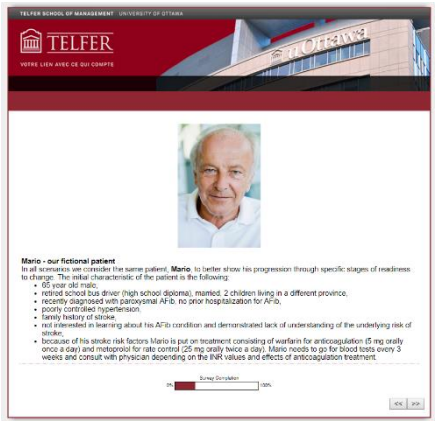
- Aimed at perceived usefulness and ease of use
- Conducted using a web-based (mobile *look-and-feel*) prototype of MPA and an on-line questionnaire
- Involved one hematologist and two patient advocates from the Ottawa Hospital (not participating in earlier development)
- Ethics approval by the review board of the hospital

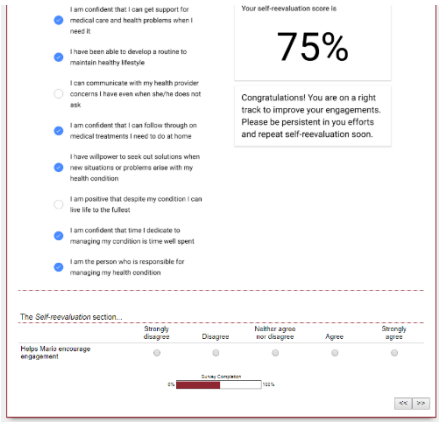
- Highly positive responses (idea, theoretical concepts, implementation) by patients and physician
- Suggestions related to the scope and complexity of educational materials (simpler language, focused on prescribed therapy)

Ongoing Work

Ongoing Work

- Preparation to a larger evaluation study (of 40+ patients)
  - Another ethics approval required (questionnaire also in French)
  - A static questionnaire (with screenshots), a fictional patient and two scenarios corresponding to two different stages in TTM





- Getting access to compliance-related data about prescriptions and purchases (proxy for “real” compliance)

Conclusions

Conclusions

- Compliance is a relevant research and practical problem – interest from clinical side and “industry”
- Multiple challenges – limited access to relevant data and reliance on expert knowledge (science or art?)

- A framework for supporting adherence that combines data-, expert-, and technology-driven phases
- Pilot implementation of the framework for AFib – preliminary evaluation and a larger prospective study

Ultimate goal is to use technology to construct and deliver comprehensive and patient-tailored interventions at the most effective time and place

Thank you for your attention
Questions?