Personalised Health Monitoring and Decision Support Based on Artificial Intelligence and Holistic Health Records

D5.11 – Monitoring, Alerting, Feedback and Evaluation Mechanisms I

WP5 AI for Early Risk Assessment and Personalised Recommendations

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Executive summary

This deliverable summarizes the results achieved at the beginning of T5.5 – “Monitoring, Alerting, Feedback and Evaluation Mechanisms”. This is the first version of a series of deliverables related to this task. The second and last version will be published in M32 of the iHelp project.

The objective of this task is to develop innovative mechanisms for tracking, monitoring, and evaluating health data towards building solutions for early risk prevention, decision support and personalized recommendations associated with pancreatic cancer. In addition, this task aims to provide a tool for evaluation of the impact of personalized recommendations based on the regular communication between Health-Care Professionals (HCPs), patients, and healthy individuals in order to support improvements in the advice follow-up phase.

1 Introduction

1.1 Scope

The scope of this task is to develop mechanisms for tracking, monitoring, alerting, and feedback gathering through user-centric applications. In particular, those mechanisms will monitor health data flow and will track the impact of personalised recommendations prescribed by clinicians, also known as HCPs. In addition, the system will generate personalised alerts and messages based on predefined templates to support patients and individuals reaching their targets and to improve their lifestyle, behaviour, and social interactions. Moreover, HCP will be able to review in advance and approve automatically generated messages in order to meet specific requirements for validating the influence of AI-based technology. Finally, the system will create a continuous feedback loop to allow HCP to further evaluate risk factors, the accuracy of predictions, as well as the impact of the targeted recommendations.

The monitoring mechanism will expose an advanced rule-based engine executed on certain configurable time intervals (daily, weekly, or monthly) that will perform an assessment of the progress towards reaching individual targets. In its core functionality, the mechanism will evaluate health data (Primary and Secondary Healthcare Records) and will compare certain target values defined in the personalized recommendation against real values. Furthermore, the alerting module will be activated to distribute evaluation and feedback messages. Different escalation policies and threshold values will be considered when distributing the proper message to the recipient (individual or HCP) in order to achieve best results in risk communication in the context of pancreatic cancer.

1.2 Approach

The Monitoring, Alerting, Feedback and Evaluation component will utilize the scalability, flexibility, modularity, containerization, virtualization, and automated deployments offered by the Function-as-a-Service (FaaS) paradigm, microservices architecture and serverless computing. This paradigm encourages loosely the coupling of system modules and the use of service choreography that allows building effective complex system based on clear and well-defined elements. Demonstrated effectiveness of such approach is one of the reasons for its increasing usage in modern applications demanding big data as well as high volume complex processing.

In this deliverable we present the first phase of our work focusing on the pilot and technical requirements developed in WP2 – “Requirements, State of the Art Analysis and User Scenarios in iHelp”. Following the Proof-of-Concept approach we have built a prototype of advanced rule-based module to meet those requirements. Furthermore, this module was embedded as an additional functionality into the User Interface (UI) of the Decision Support System Suite (DSS), as designed and implemented in the context of T4.3 – “DSS Suite with Visual Analytic Tools”. As a result, we will achieve the implementation of a single access point for HCP to perform all activities in the context of risk communication and risk mitigation plans.

The prototype as well as the underlaying concepts were demonstrated to contributing partners for initial alignment and feedback gathering. In its core design, the prototype consists of Back-End services communicating with a Graphic User Interface (GUI). It provides an intuitive UI for HCP that has been aligned with the UI/UX recommendations in T2.4 – “User Centered Design”. This UI allows HCP to set different

monitoring parameters and evaluation conditions for a specific patient. Further collaboration was undertaken with partners from T5.2 – "Design of Personalised Prevention and Intervention Measures" to define options for customizing the content for alert messages considering different user behaviour types. Finally, the modules in this task will be integrated with the user-facing mobile application developed in the context of T5.3 – "Delivery Mechanisms for Personalised Healthcare and Real-time Feedback" as well as with the Big Data Platform developed in the context of T4.4 – "Big Data Platform and Knowledge Management System".

1.3 iHelp Architecture and components specification

The Monitoring, Alerting, Feedback and Evaluation component is part of the overall iHelp architecture. This architecture is comprised of numerous components each of which encapsulates a well-defined functionality. Each such component is containerized into a Docker container image. An image is a lightweight, standalone, executable package of an application that contains all its software dependencies and artefacts. Afterwards, a container can be started from the image which represents a runnable instance of the component. Thus, each component runs in a separate container with its own dependencies and its own libraries all on the same operating system.

The containers themselves are managed by Kubernetes platform that is being provided within the iHelp infrastructure. Kubernetes is an open-source container orchestrator which has become the de facto standard for deploying and operating containerized applications. It automates tasks like application scaling, load balancing, self-healing, restarting, etc.

The communication between the components is realized by means of Apache Kafka. It is an open-source distributed platform where separate services can communicate to each other via publishing to or subscribing to data topics. Kafka is also a streaming platform that is used to build real-time streaming data pipelines via which applications can publish to or subscribe to data streams.

The objective of the Monitoring, Alerting, Feedback and Evaluation component is to give HCP the ability to assign a mitigation plan to a given patient and then to monitor and assess the progress of the patient. A mitigation plan is essentially an action plan assigned to a patient which execution aims to bring concrete health improvements and to lower the risk of developing pancreatic cancer. It is comprised of several rules some of which can be turned off depending on the personalized configuration for the patient. The HCP will assign a goal value to each active rule of the mitigation plan selected for the patient. For example, a goal for a given patient can be to decrease the cigarettes smoked per day or to increase his/her physical activity on weekly basis. Then, the component will monitor and evaluate the progress of the patients by collecting and aggregating secondary data (questionaries via mobile phone and data collected from wearable devices) and then comparing the calculated values towards the set goals.

The result of this evaluation process will then be communicated to the user by sending it via a request to the Personalised Advisor component which, on the other hand, will be responsible for delivering a properly formed message to the respective patient. Each content for a message will be created as a pre-defined template. The user will be additionally categorized based on behaviour type. As a result, different content will be communicated to the user in order to facilitate risk prevention or healthier lifestyle changes. An example of such specific profile can be if the patient has a prevention-oriented or achievement-oriented behaviour.

The Monitoring, Alerting, Feedback and Evaluation component will be integrated into the DSS platform where it will be visually displayed and where the HCP will manage the assignment of mitigation plans and goal values to patients. In addition, it will be possible to also approve the messages before being sent to the respective users. The following diagram in Figure 1 depicts visually the iHelp architecture with a highlight on the Monitoring and Alerting component:

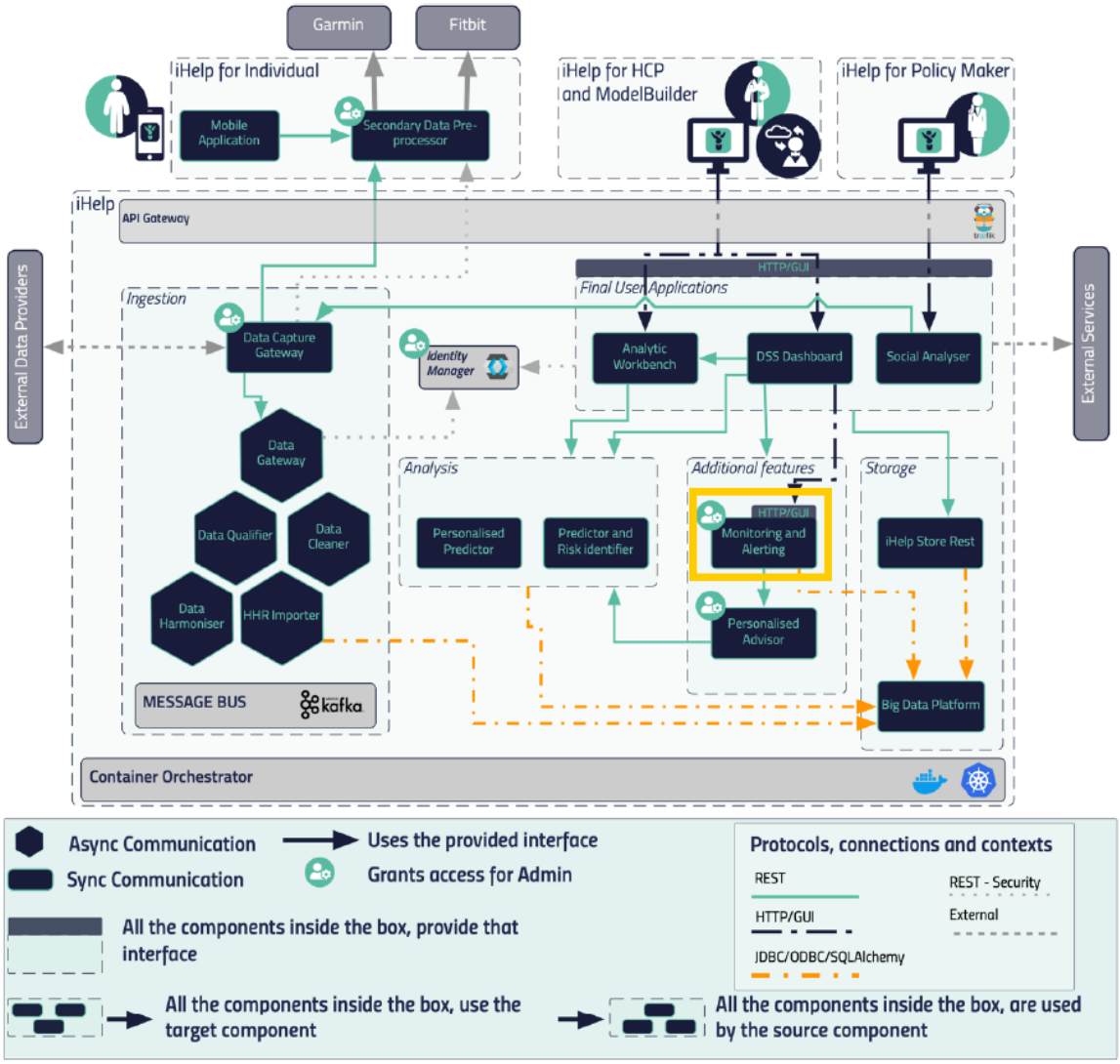

Figure 1: High level component architecture view as taken from iHelp D2.5.

2 Interactions with other WPs and tasks

In general, the key interaction in this task relates to the in-depth research about the needs and gaps in the field of risk prevention in developing pancreatic cancer. Therefore, the first level of interactions showcases the link of our concept and prototype to pilot requirements as well as the initial technical requirements developed in WP2 – "Requirements, State of the Art Analysis and User Scenarios in iHelp". Moreover, the prototype is part of a system architecture which requires major integrations between different modules and components. Thus, the second level of interactions showcases the integration to other components within the iHelp system.

Our most important work builds on collaboration with the tasks and deliverables, described in the following sub-chapters.

2.1 Relationship with other tasks within WP5

The T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" focuses on the mechanisms for monitoring, alerting, feedback, and evaluation. This is closely related the other tasks of WP5 – "AI for Early Risk Assessment and Personalized Recommendations", i.e., T5.2 – "Design of Personalised Prevention and Intervention Measures" and T5.3 – "Delivery Mechanisms for Personalised Healthcare and Real-Time Feedback". Where T5.2 – "Design of Personalised Prevention and Intervention Measures" focusses on a personalisation framework for communications, while T5.3 – "Delivery Mechanisms for Personalised Healthcare and Real-Time Feedback" seeks to develop delivery mechanisms for these personalised communications through their user-centric application. The modules developed by T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" will communicate with the Personalised Advisor for the retrieval of notification messages, which then can be approved by the HCP before they are sent to the patient.

Consequently, the functionalities provided by T5.3 – "Delivery Mechanisms for Personalised Healthcare and Real-Time Feedback" and T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" will enable us to optimise the designed personalisation algorithms and ensure that we collect any piece of data that can support functionality and effectiveness of iHelp interventions.

2.2 Relationship with WP2

The WP2 – "Requirements, State of Art Analysis and Pilot Scenarios in iHelp" provides a specification of the requirements and state-of-the-art analysis for the iHelp system to guide system development activities including those in T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms". WP2 – "Requirements, State of Art Analysis and Pilot Scenarios in iHelp" specifies also the details of the overall architecture of the iHelp platform and hence the interactions between the monitoring component developed by T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" and the rest of the system. The software development for clinicians that will take place in T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" is to monitor the patient's progress against the pre-defined goals and to create an alert to arrange a review when the user is not meeting the goals. The work done in WP2 –

"Requirements, State of Art Analysis and Pilot Scenarios in iHelp" provides a baseline for the software development in the context of T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms".

Within the requirements, T2.4 – "User Centered Design" sets also the principles for user-centric design aligned with the specific requirements for medical software by collaborating closely with pilot partners. The interactions between the monitoring component and its users are also specified in T2.4 – "User Centered Design". The guidelines of WP2 – "Requirements, State of Art Analysis and Pilot Scenarios in iHelp" suggest the use of personalised recommendation and gamification to keep the user interested and ensure long-term use. These include Key Performance Indicators (KPIs) for usability evaluation and guidelines for user interface design produced in T2.4 – "User Centered Design", and these have been used to guide the development of clinicians-facing interfaces within T5.5 – Monitoring, Alerting, Feedback and Evaluation Mechanisms". In actual fact, the user-centred design work which started in the context of WP2 – "Requirements, State of Art Analysis and Pilot Scenarios in iHelp" will continue in T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" by performing formative usability evaluation i.e., by arranging user-facing workshops to get feedback from users and evaluate the developed user interface.

2.3 Relationship with WP3

The WP3 – "Personalised Holistic Health Records" sets the mechanisms for the personalized holistic health records (primary and secondary data) to be mapped and standardized into the in the Big Data Platform in order to be accessible for any subsequent consumption by all the components and models in the iHelp ecosystem.

The Monitoring, Alerting, Feedback and Evaluation component will utilize the measurable secondary data collected from wearable devices and questionaries in the Healthentia mobile application to aggregate and evaluate it towards predefined rules and goals set by the HCP for each patient.

2.4 Relationship with WP4

The Monitoring, Alerting, Feedback and Evaluation component is integrated into the iHelp's DSS. The interface developed in the scope of T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" has been integrated into the risk mitigation dashboard under the Patient Visualization interface of the DSS. When a patient is specified in the Patient Visualization interface, the primary and secondary data of that particular patient are represented and, by clicking on the Risk Mitigation button, the interface that allows the HCP to create the risk mitigation plan for that patient is displayed as shown in the Figure 2. The DSS is implemented in Angular, and the UI of the Monitoring and Alerting component has been embedded into the DSS using iframe.

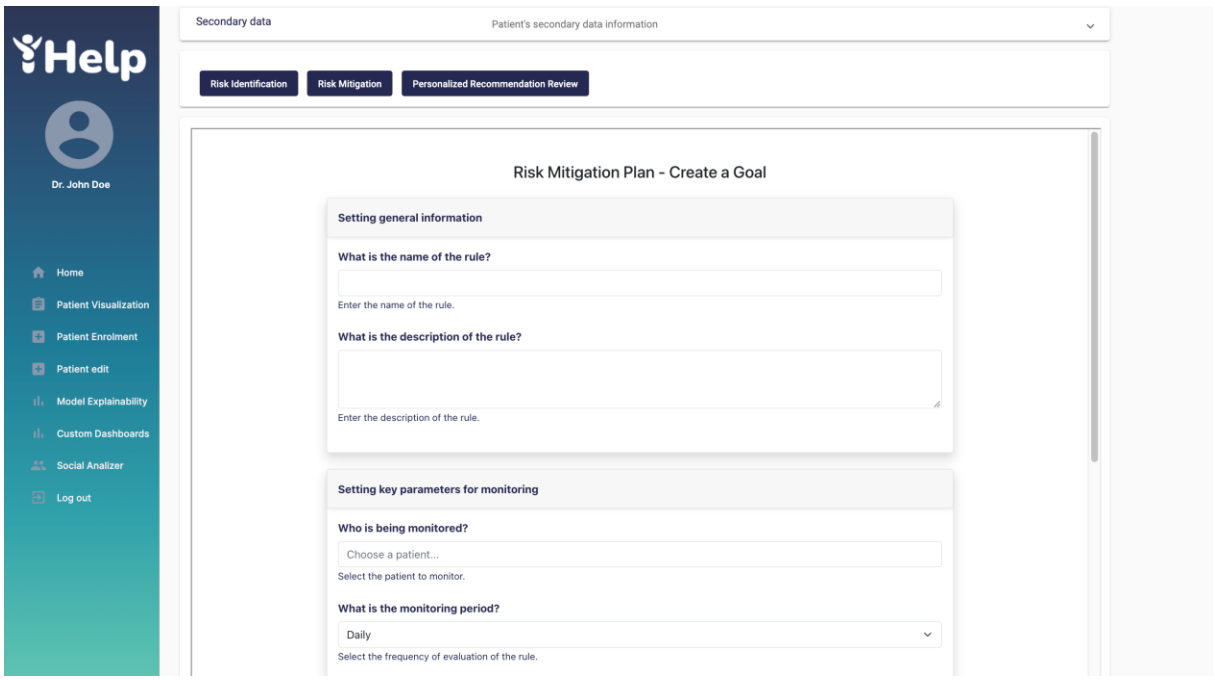

Figure 2: Decision Support System - Risk Mitigation Plan interface

3 Component design

The Monitoring, Alerting, Feedback and Evaluation component is comprised of four building blocks:

- *Data Aggregator* that collects and aggregates secondary data coming from mobile or wearable devices.
- *Data Evaluator* that evaluates the goals towards the values calculated by the Data Aggregator.
- *Alert Generator* that initiates communication of the evaluation process results to the patient.
- *User Interface* that provides UI for the healthcare professionals for assigning mitigation plans to patients and setting goal values to their respective rules.

3.1 Architecture

The Monitoring, Alerting, Feedback and Evaluation component is built on top of the microservices architecture where the application is developed as a collection of services. This architectural approach provides the ability to develop, deploy, and maintain microservices architecture diagrams and services independently. Within a microservices architecture, each service is built to accommodate an application specific functionality and handle discrete tasks. Thus, it conforms to the separation of concert principle where each business task is implemented and packaged as a separate functional unit.

Each microservice communicates with the other services through interfaces to combine functionalities into solving different business problems. Apache Kafka is utilized for enabling the communication between the Data Aggregator, Data Evaluator and Alert Generator Java-based microservices which are at the core of the monitoring, evaluating and alerting mechanisms in the component.

The monitoring and evaluation process for the different rules will be executed on pre-configurable intervals (daily, weekly or monthly). Firstly, the aggregation service will collect secondary data for the respective patients, calculate it according to the monitoring period chosen for the respective users and preserve the resulting aggregated data into the database. Then, the evaluator will assess the aggregated values towards the goals set for each rule in the mitigation plans for the patients. This process is represented on the following Figure 3:

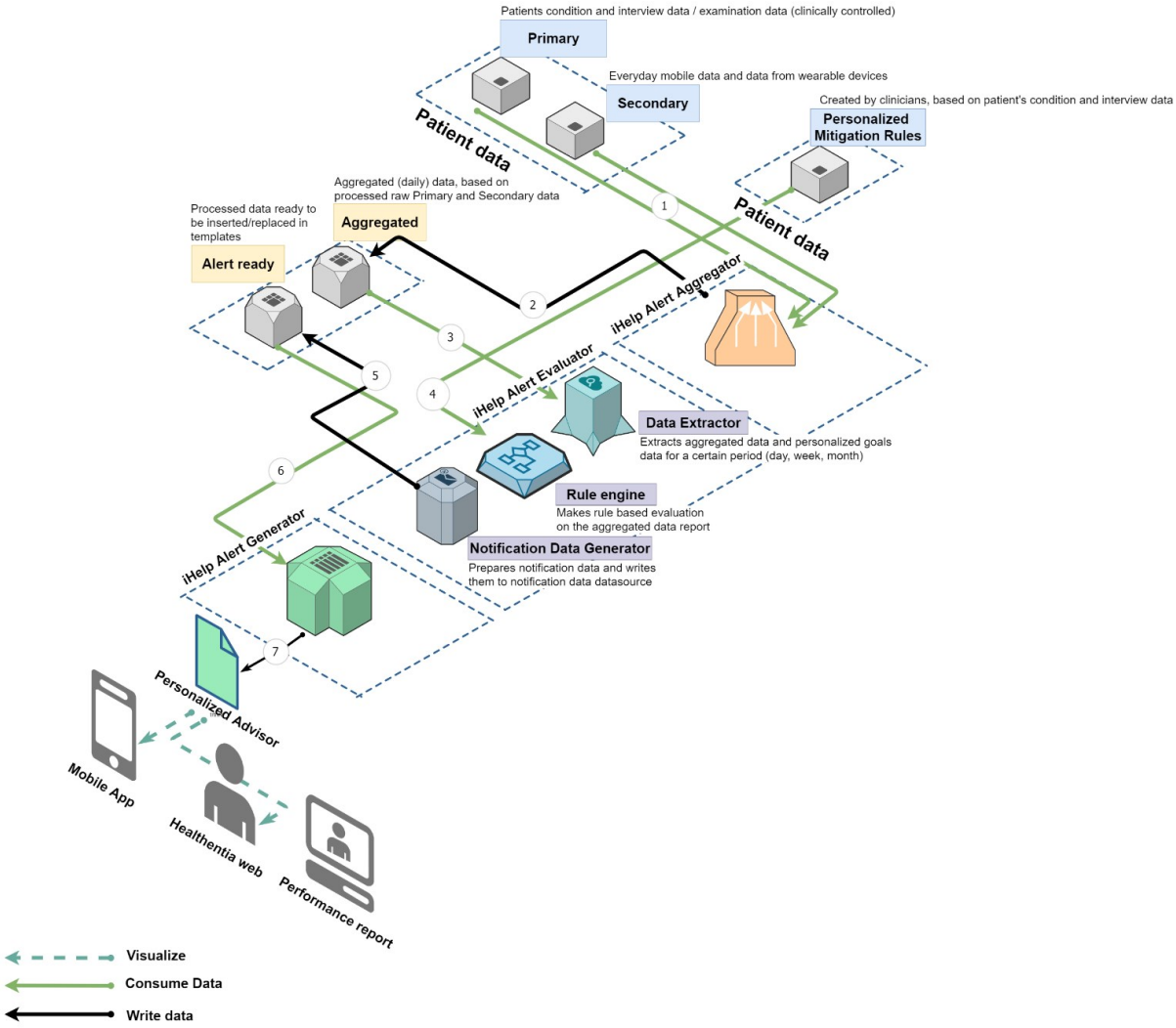

Figure 3: Monitoring, Alerting, Feedback and Evaluation Component Architecture

The main flow can be described as follows:

1. Secondary data (and primary, if necessary) is obtained from the Big Data Platform for each patient to which there are rules assigned.
2. For each existing rule and each patient to which this rule is assigned, the Aggregator service aggregates the obtained data according to the formula defined in the rule. The calculated data is published in a Kafka topic.
3. The Evaluation service reads the aggregated data from the Kafka topic and evaluates it towards the goals defined in the rules. The evaluated information is published in a Kafka topic.
4. The Aggregator service reads the evaluated data from the Kafka topic, constructs the data in a proper format and transmits it to the Personalized Advisor via a specially defined for the purpose API endpoint.

3.2 Advanced rule engine

The advanced rule engine is at the heart of the Monitoring, Alerting, Feedback and Evaluation component. It works with the following main entities:

1. *Rule* – contains the unique identifier of the rule and the formula that is used in the evaluation process. For example, *STEPS<numberSteps*, where *STEPS* is the accumulated value for the patient and given period and the *numberSteps* is the goal value. The basic rules can be combined to form more complex formulas.
2. *Rule Target* – contains the patient id, the frequency (daily/weekly/monthly), the aggregation type (sum/min/max/average) and the target value (goal) of the rule.
3. *Rule Settings* – the id of the Healthentia message or dialog that will be used for the alert and feedback communication with the client.

The rule engine is based on the *Java Easy Rules* library. This library provides rule abstraction to create rules with conditions, and then run through the predefined set of rules to evaluate them towards a list of facts and possibly execute actions.

Simple rule creation example:

```
Rule dailyCigarretesRule = new RuleBuilder()
        .name("Daily cigarretes rule")
        .description("Decrease cigarettes smoked per day")
        .when(facts -> facts.get("cigarettes") > 10)
        .then(() -> sendAlert(“You can do better! Please, try to smoke less today.”))
        .build();
```

3.2.1 Back-End technology

The Data Aggregator, Data Evaluator and Alert Generator are Java-based containerized services implemented by means of the Spring Boot framework which makes it easy to create stand-alone, production-grade Spring-based applications. The usage of this framework reduces the development time as it provides minimum configuration and boilerplate source code necessary for the services to run without the need of full Spring configuration setup.

The services are documented (including its available endpoints and operations on each endpoint, operation parameters, input and output for each operation, authentication methods and more) via the Swagger tool which is in charge of auto-generating and maintaining the up-to-date API endpoints specifications.

The communication and the data exchange between the services is realized via Kafka.

3.2.2 Web services

In the next sub-sections, the Data Aggregator, Data Evaluator and Alert Generator services are described in more details.

3.2.2.1 Data Aggregator

As shown on Figure 4 below, the Data Aggregator generates aggregated data based on the patient's primary and secondary data - that may be extracted from various data sources - its purpose is to prepare the data needed for the evaluation process.

The primary endpoint of the service is as follows:

POST/ihelp-alert-data-aggregator/aggregate

Input parameters:

```
{
   "from": "2021-11-19",
   "to": "2021-11-19",
   "ihelpAccountId": 0,
   "frequencyTypeId": 0
}
```

- *ihelpAccountId* – user identifier, if null - then the aggregation is performed for all patients.
- *from / to* – time interval for aggregation. If dates are not given, then *frequencyTypeId* will be considered.
- *frequencyTypeId* - if both dates are set - *frequencyTypeId* is not mandatory and vice versa, but if both parameters are available, the dates have a higher priority. There are 5 different frequency types:
    - **DAILY** - uses the previous day for the aggregation period.
    - **WEEKLY** - uses the previous week for the aggregation period.
    - **WEEK_TO_DATE** - from the beginning of this week to today.
    - **MONTHLY** - uses the previous month for the aggregation period.
    - **MONTH_TO_DATE** - from the beginning of the month to today.

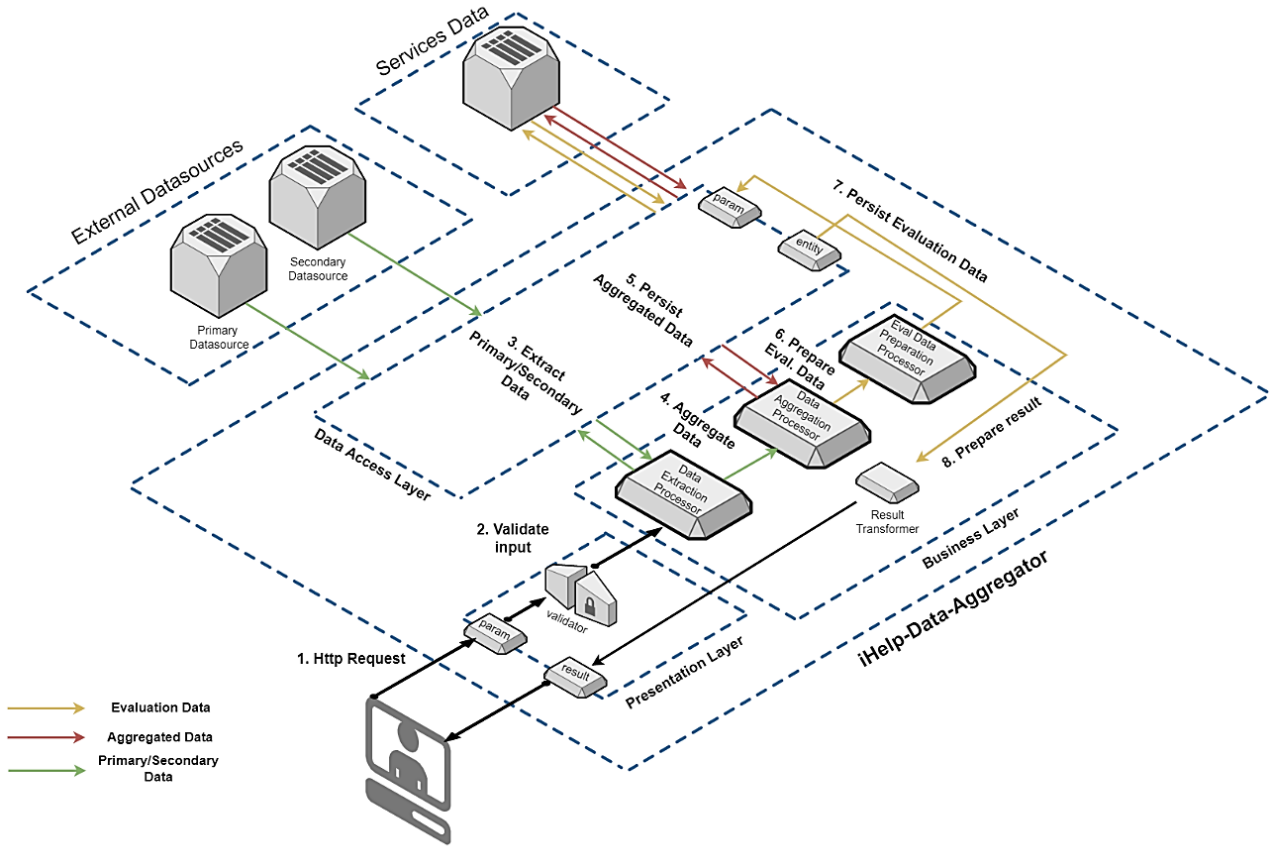

Figure 4: iHelp Data Aggregator

3.2.2.2 Data Evaluator

As shown on Figure 5 below, the Data Evaluator processes the aggregated data with the corresponding rules/targets and evaluates the alert or feedback that needs to be issued to the patient.

The primary endpoints of the service are as follows:

POST/ihelp-alert-evaluator/evaluate/alerting

This endpoint has a void return type, and its purpose is to be used for automated schedules of the evaluation process and notifications (alert/feedback) generation.

POST/ihelp-alert-evaluator/evaluate/monitoring

This endpoint returns the alert/feedback data that has been evaluated but does not persist the data in the database for later alert generation. Its purpose is to monitor patient activity.

Input parameters:

```
{
   “from”: “2021-12-01”,
   “to”: “2021-12-01”,
   “ihelpAccountId”: 0,
   “frequencyTypeId”: 0
   “groupId”: 0
}
```

- *ihelpAccountId* – user identifier, if null - then the evaluation is performed for all patients in the group (groupId).
- *from / to* – time interval for evaluation. If dates are not given, then *frequencyTypeId* will be considered.
- *frequencyTypeId* - if not present, all rules will be considered. There are 5 different frequency types:
    - **DAILY** - uses only the daily rules for the evaluation process.
    - **WEEKLY** - uses only the weekly rules for the evaluation process.
    - **WEEK_TO_DATE** – uses the weekly dynamic rules(include target percentages calculated based on the day of the week) for the evaluation process.
    - **MONTHLY** - uses only the monthly rules for the evaluation process.
    - **MONTH_TO_DATE** - uses the monthly dynamic rules(include target percentages calculated based on the day of the month) for the evaluation process.
- *groupId* – this is for both - patients and rules. Evaluation will be made for all patients with this group ID against all rules that have the corresponding group ID.

Other important endpoints:

GET/ihelp-alert-evaluator/alertrule

This endpoint returns all the existing rules that have been created by the HCP for the patients.

GET/ihelp-alert-evaluator/alerttarget

This endpoint returns all the existing targets for all rules that have been created by the HCP for the patients.

POST/ihelp-alert-evaluator/alertrule

This endpoint creates a new rule.

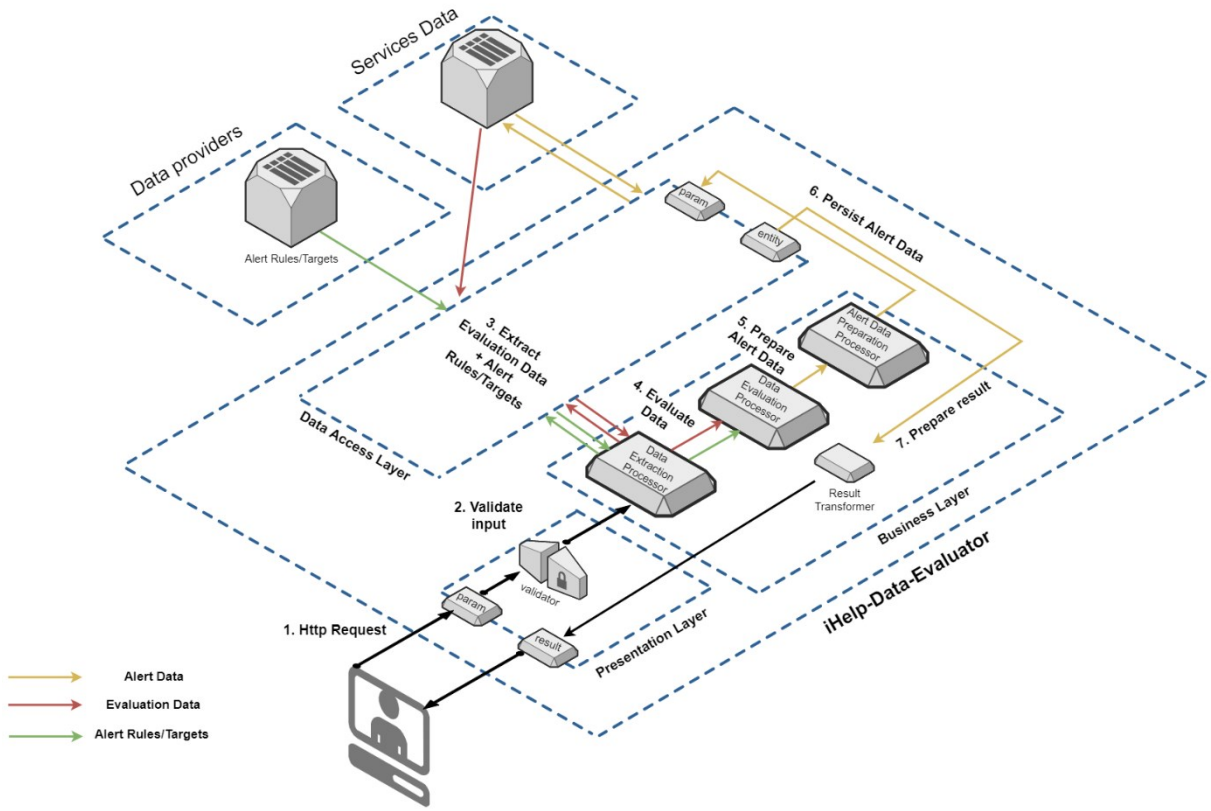

Figure 5: iHelp Data Evaluator

3.2.2.3 Alert Generator

As shown in Figure 6 below, the Alert Generator Initiates the communication with the patient (alerts and feedback) based on the alert data that has been created by the evaluation process and the message/dialog template assigned to the mitigation plan and user. The service prepares the data for the positive or negative notifications based on patients' secondary data that has been marked as notification data by the evaluation process and passes it to the Personalized Advisor via a specified API endpoint.

Input parameters:

```
{
   “from”: “2021-11-19”,
   “to”: “2021-11-19”,
   “ihelpAccountId”: 0,
   “frequencyTypeId”: 0
}
```

- *ihelpAccountId* – user identifier if null - then the alerting is performed for all patients.
- *from / to* – time interval for alerting. If dates are not given, then *frequencyTypeId* will be considered.
- *frequencyTypeId* - if both dates are set - *frequencyTypeId* is not required and vice versa, but if both parameters are available, the dates have a higher priority. There are 5 different frequency types:

- **DAILY** - uses the previous day for the alerting period.
- **WEEKLY** - uses the previous week for the alerting period.
- **WEEK_TO_DATE** - from the beginning of this week to today.
- **MONTHLY** - uses the previous month for the alerting period.
- **MONTH_TO_DATE** - from the beginning of the month to today.

The primary endpoint of the service is as follows:

POST/ihelp-alert-generator/alert

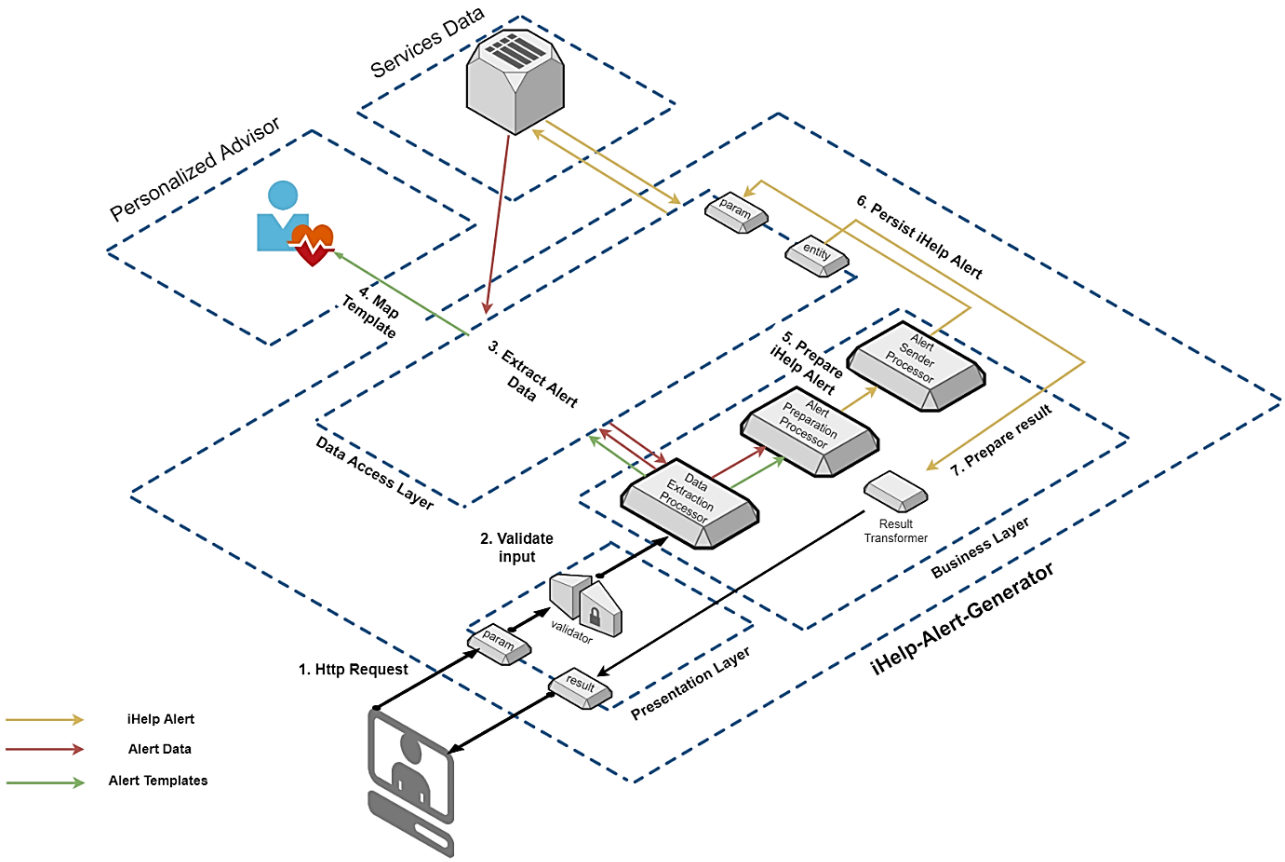

Figure 6: iHelp Alert Generator

3.3 User interface

The user interface is the starting point of the Monitoring, Alerting, Feedback and Evaluation component. It provides HCP the ability to assign personalized mitigation plans to patients. Each such mitigation plan is comprised of user-specific rules which aim at providing the patient with a concrete goal which achievement will lead to a healthier life. Such a goal can be the decrease of smoked cigarettes per day or the increase of weekly sports activity.

The user interface consumes API endpoints from the Data Evaluator service for the rules and targets creation as part from a given mitigation plan and assigned to a given patient. As shown in Figure 7 below,

the UI for the creation of a single rule currently provides the ability to set basic properties to the rule like name and description configuration:

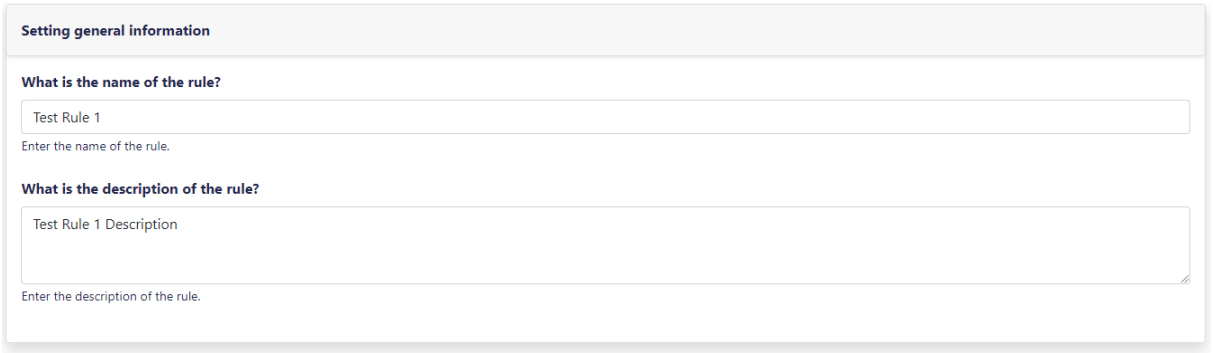

Figure 7: Rule Basic Properties

Then, assign a rule to a patient by using his/her iHelp ID and setup properties like the monitoring period (daily, weekly or monthly) as shown in Figure 8 below:

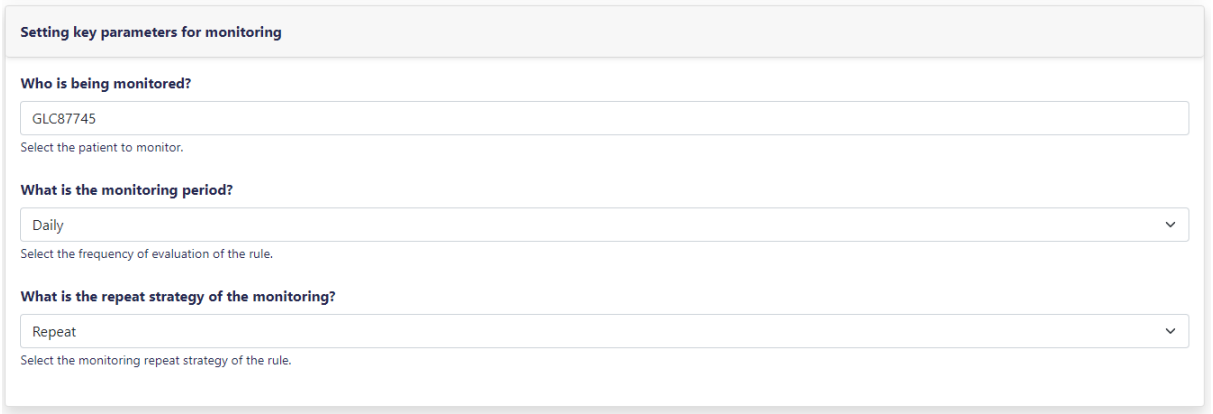

Figure 8: Rule Monitoring Period

And finally, there is a section for formula and communication configuration, as shown in Figure 9 below:

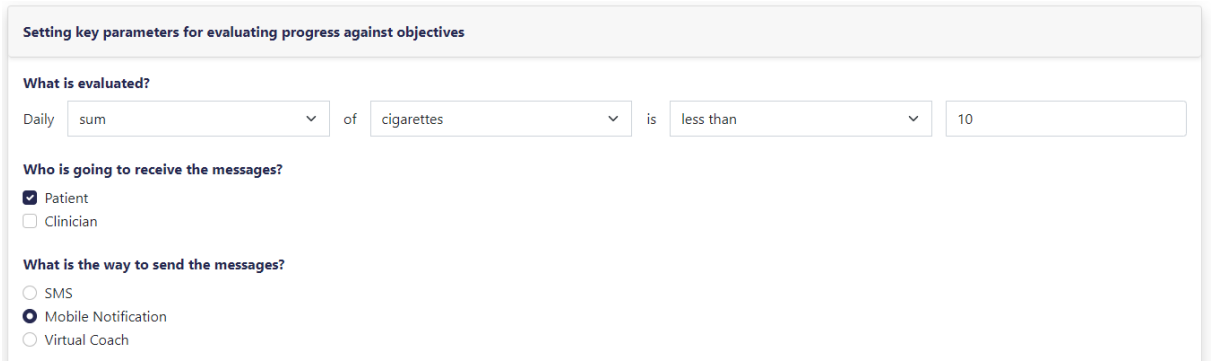

Figure 9: Rule Formula

3.3.1 Front-End Technology

The main technology used for the Front-End part is ReactJS which is a JavaScript library for creating dynamic and performant web and mobile applications. Each functional unit in the Monitoring, Alerting, Feedback and Evaluation component's UI is encapsulated in a reusable component which manages its own state and logic and thus following the principle for separation of concerns.

For the communication with the Backend services, the Frontend part has its own services implemented in TypeScript which adds additional features like strong static typing, compilation, and object-oriented programming and compiles to plain JavaScript. Http requests realized with the Axios JavaScript library are used for sending direct requests to the Backend services.

The React Context API is utilized for sharing common states and functionalities. It allows accessing common data throughout the separate components and plays the role of a middleman between the presentation and business layers. The communication between the services is represented in the Figure 10 below:

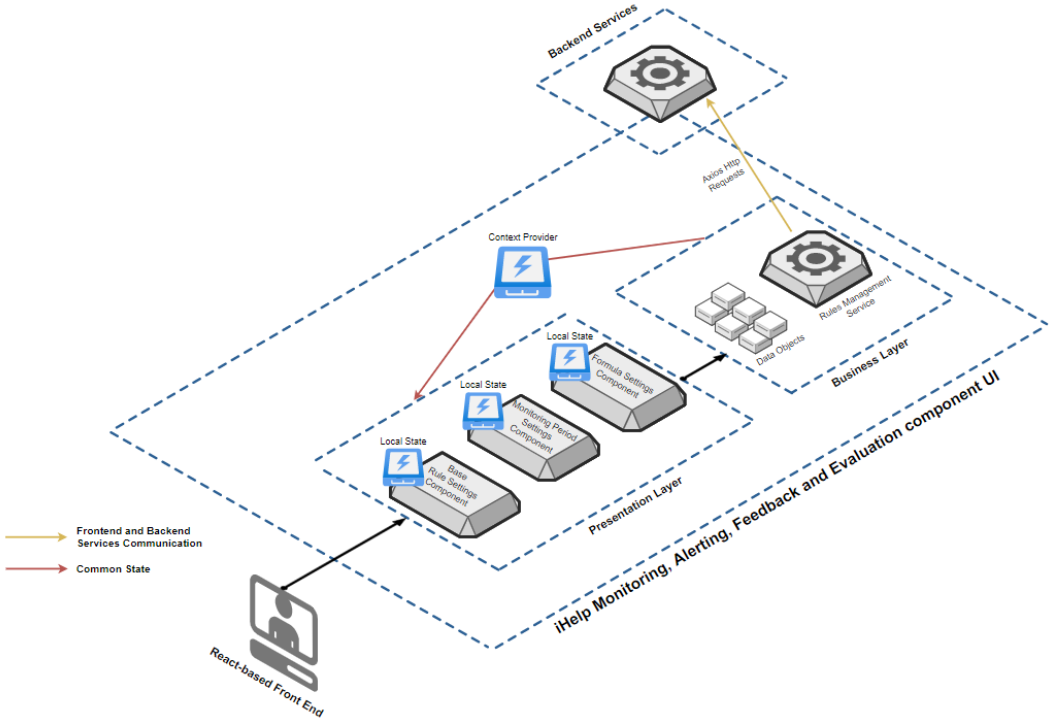

Figure 10: iHelp Monitoring, Alerting, Feedback and Evaluation Component UI

4 User Journey and communication flow

In the context of User Experience (UX) design, a journey map is a visual representation of all the steps a user undertakes to complete a task or reach a goal. Figure 11 below illustrates a simple journey map.

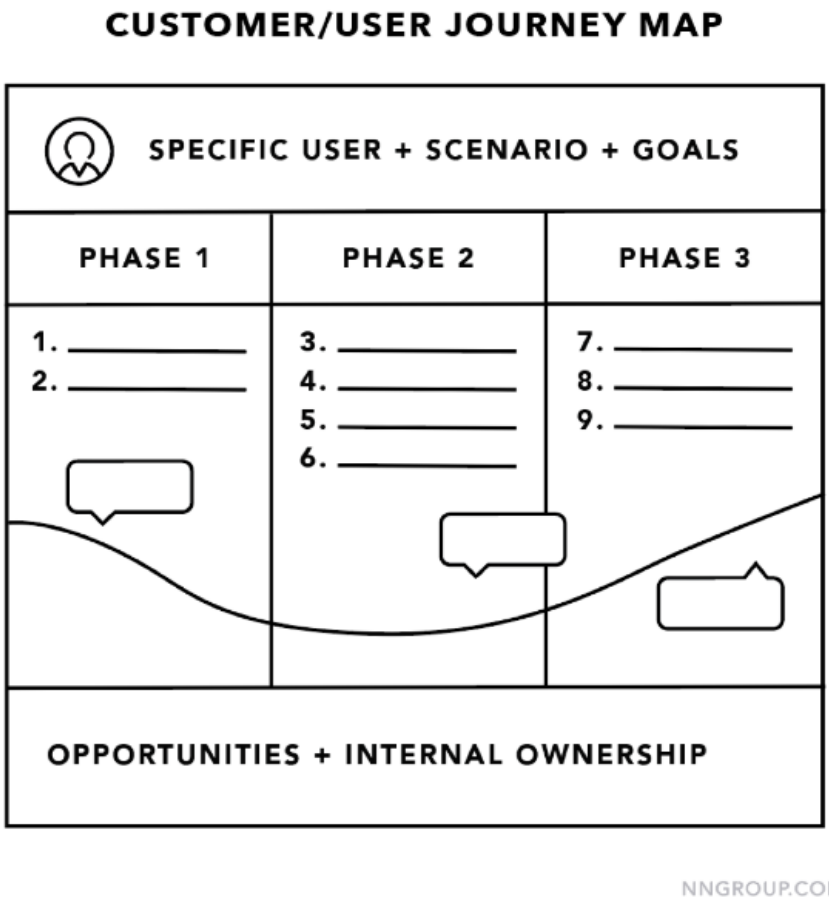

Figure 11: Basic form for Customer/User Journey Map, Nngroup.com

In the process of designing an interactive functionality in iHelp, a set of wireframes will be designed to illustrate how users will navigate the platform. This process can be illustrated with a wireframe flowchart, as presented in an example below (Figure 12). In the UX field, wireframes are a common deliverable used to show interface and page-level layout ideas, whereas flowcharts are useful for documenting complex workflows and user tasks.

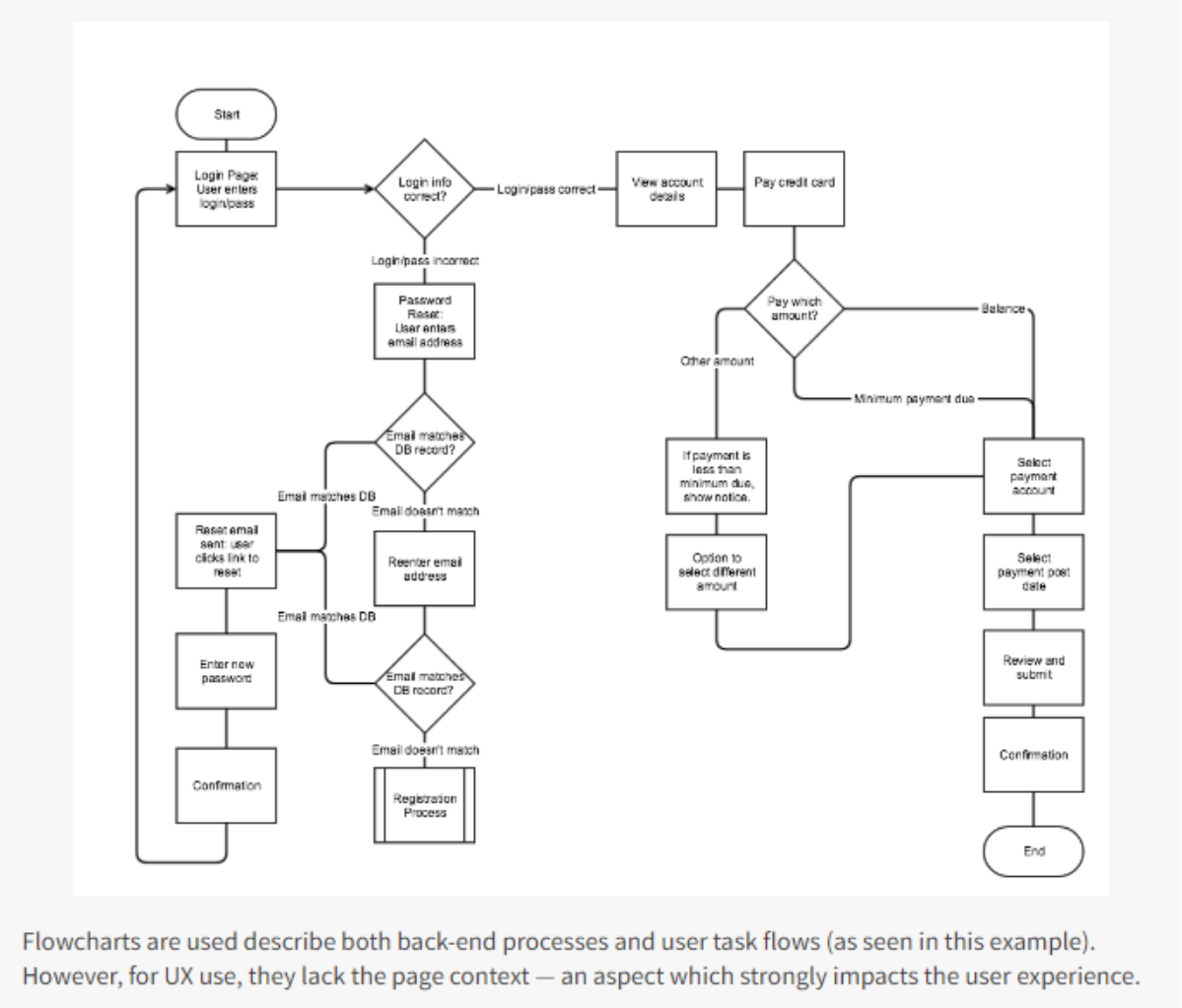

Figure 12: Example for a wireframe flowchart, Nngroup.com

Together with our partners we will design flowcharts to ensure that iHelp users enjoy seamless and useful experience. The proposed flowcharts will account for complexities of the user journeys, as illustrated by the advanced version of the personalisation framework in the context of the iHelp domain (see Figure 13 below).

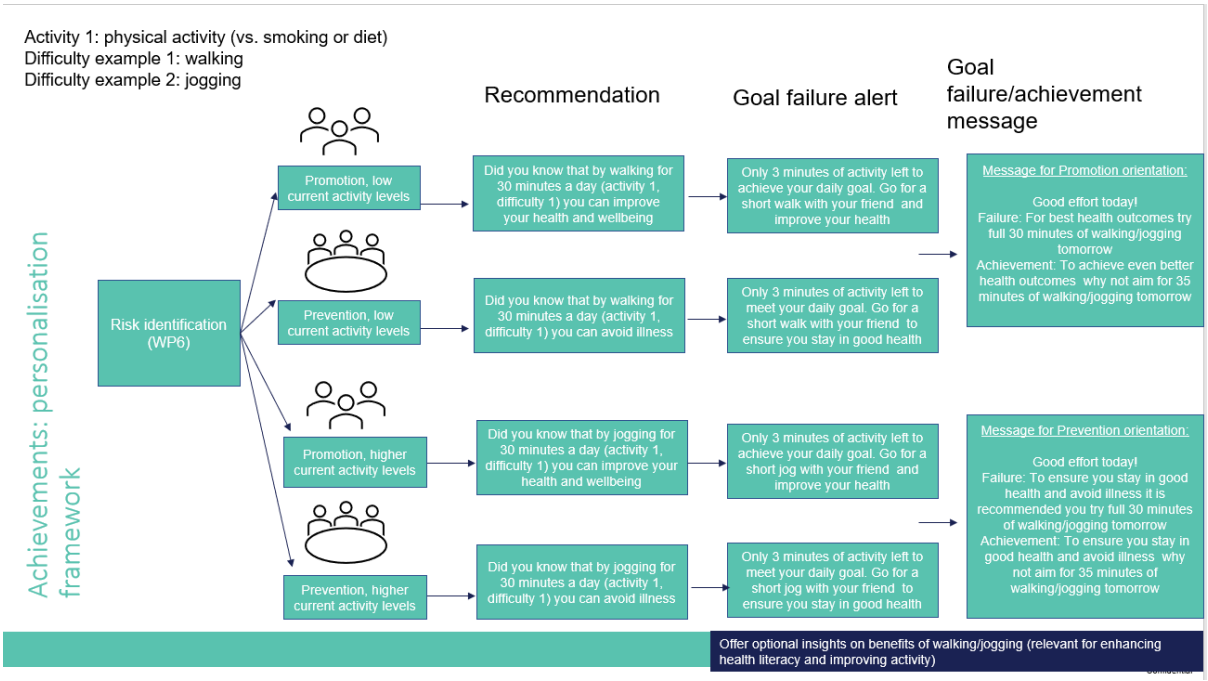

Figure 13: Personalisation framework for Achievements

4.1 UI/UX Design

The user interface design reflected in the Monitoring, Alerting, Feedback and Evaluation Mechanisms has been initially developed within WP2 – "Requirements, State of the Art Analysis and User Scenarios in iHelp" and proposed as general guidelines. This has been made concrete within the work on T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" using data and examples provided by pilot partners. It also uses the principles of regulatory profiling, where the users are divided into achievement-driven and prevention-driven, and for the two groups different messages are sent to maximise the impact of the proposed actions by the system.

The interfaces have been developed in alignment with the general guidelines whilst using the example data and messages collated through collaborative workshops with the pilot partners. The first draft of the interfaces has been subjected to formative evaluation in M19, aiming to highlight any inconsistencies of implementation, and any deviations from the general usability guidelines and from the iHelp-specific guidelines developed within WP2 – "Requirements, State of the Art Analysis and User Scenarios in iHelp". Specific suggestions included replacement of abstract formula-like mathematical concepts with English rendition of the relationships implied by them, for example replacing ">" with "is greater than" and so on.

The second version of the interface reflected the suggestions for improvement and was then used to demonstrate the functionality of the module to pilots and users.

5 State of implementation

The following points depict the status of the implementation and what needs to be accomplished as part of the future roadmap:

- Currently, the rules are defined per patient, but they are not part of any mitigation plans. Therefore, the mitigation plans themselves need to be defined in cooperation with other partners and pilots. As a result:
  - The Front-End component will have to be modified accordingly.
  - The database schema for some of the entities may need to be modified accordingly.
  - The Back-End services may need to be modified accordingly.
- The database schema of the rules, the aggregated and evaluated data may need to be changed. Now, this information is preserved in a local for the Back-End services database as part of the initial proof of concept. There are ongoing discussions if this might be a good idea to move the data to the Big Data Platform. Thus, it would be accessible by other components and can be used as a baseline for further analysis and models build.
- The Monitoring, Alerting, Feedback and Evaluation component is currently using test dummy data from its database for the aggregation and evaluation processes. The connection and retrieval of the secondary data from the Big Data Platform needs to be implemented.
- The mechanism for fetching the secondary data from the Big Data Platform and then aggregate and evaluate it at predefined intervals is yet to be discussed in cooperation with other partners and pilots and then implemented.
- The proper format and wording of the messages and dialogs used for communicating the alert and feedback outcome to the patients need to be discussed and carefully defined according to the determined patients' behavior types in cooperation with other partners in T5.5.

6 Testing and verification

This chapter describes our approach for ensuring that the concept and the prototype meet the expected outcomes in the iHelp platform. On the one side, we are using agile methodologies like iterative development and ad-hoc feedback meetings, but also planning dedicated online meetings to review, discuss and validate qualitative as well as quantitative factors in T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms". In the first stage of the project, we did the following steps considering all the challenges of the remote business environment:

- Developing a prototype based on components specification published in D2.6 – "Functional and Non-Functional Specifications I"
- Presenting to pilot partners initial concepts, state of the art analysis and gathering feedback during dedicated online meetings
- Gathering ad-hoc feedback in different stages of the prototype development during regular T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" online meeting
- Using online collaboration tools to support brainstorming and mind mapping activities during the course of the project
- Dedicated online meetings with partners from T2.4 – "User Centered Design" to verify the usability of the prototype UI
- Dedicated online meetings with partners from T4.4 – "Big Data Platform and Knowledge Management System" to validate data types and data mappings

In the next stage of the project, we plan to fine-tune the concept and the prototype using real datasets as well as real user feedback. Part of this data is expected to be gathered by our pilot partners during the clinical studies that will unfold within iHelp. In particular, we plan the following steps in order to ensure continuous testing and verification:

- Implementing Feedback Pop up forms in the prototype UI to gather real time feedback from users during the clinical studies
- Gathering ad-hoc feedback in the next stages of prototype development during regular T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" online meetings
- Collaboration with partners from T5.2 – "Design of Personalised Prevention and Intervention Measures" to analyse the impact of personalized recommendations and improve the content of the messages
- Collaboration with partners from T4.3 – "DSS Suite with Visual Analytic Tools" and T5.3 – "Delivery Mechanism for Personalised Healthcare and Real-Time Feedback" to ensure seamless integration between the components
- Continuously using online collaboration tools to support design finetuning activities during the next stage of the project

7 Conclusions

This document summarizes the conceptual work as well as the progress on the prototype development carried out in the scope of T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms". The work implemented so far is on track and based on the overall planning of the iHelp project. The core component in the T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" prototype has been developed, dockerized and deployed on the official iHelp Kubernetes cluster. It is currently available as a standalone application, while the overall integration with other components like the Big Data Platform and the mobile application Healthentia will follow in the next project phase.

Next, the core component will be enhanced, and additional features will be further developed in the context of the iHelp project to cover the scenarios and needs of HCP, as identified in WP2 – "Requirements, State of the Art Analysis and User Scenarios in iHelp".

Moreover, new opportunities for additional features have been identified and recently discussed. In the sub-sections below there is a high-level introduction to their scope, expected results as well as the benefits in the context of the iHelp project. The aim is to accomplish a higher degree of automatization, personalization and interaction with the overall iHelp platform.

Finally, the second and last Deliverable within T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms" is expected to be created and published in M32 of the project.

7.1 Further work leading to D5.12

This is the first iteration of two documents that are scheduled to be published through the project lifecycle. In this Deliverable we introduce the progress on the conceptual work as well as the state of the prototype development until M23. While in the second iteration we plan to focus on prototype adjustments and integrations with other components. Moreover, during the recent workshops we have identified new topics and we started investigating on new sub-components with high potential to be applied in the overall Mechanism for Monitoring, Alerting, Feedback and Evaluation. In the following sections we provide a high-level description of their main scope. More details will be published in the second and final version of this series of deliverables, i.e., D5.12 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms II".

7.1.1 Impact Evaluator

In the next period, the subcomponent named Impact Evaluator will be designed and developed. This software artefact, integrated in the Monitoring & Alerting component, has the aim to provide the health care professionals, with some insights into the motivational messages generated from the iHelp platform.

More in detail, the software could offer a REST API, that can be invoked by the DSS Dashboard in order to show the main results about the motivational messages sent, and the way in which those impacted the actual behaviour of the individuals.

The idea is to understand if and how the messages help to change the lifestyle behaviours of the individuals. For doing so, the component will analyse all the information available about the messages, for example,

the kind of messages, if are related to an improvement or a congratulatory one, and the behavioural category they are referring to (e.g., smoking cessation, steps per day, etc.).

The main goal that we are planning to achieve, is to read the data present in the Big Data Platform, cluster the individuals' information in groups, based on age and gender, and for each group to analyse the sent messages and the secondary data collected through the mobile application. The result should be the impact of the messages actually sent, on the behaviour of the individuals. For instance, a specific cluster (Male 30-40 years old) the week after receiving the "improving" messages about the "steps per day" incremented the actual "steps per day" by 15% on average.

Other possible end-point methods provided by the sub-module, could be the overview of all the messages produced by the iHelp platform, highlighting the status as sent, received, or not approved (by the HCP), and the entire set of messages produced for a specific individual in a specific range of time. The latter list could also be shown in combination with the secondary data related to the behavioural category that the messages are referring to.

7.1.2 Incentive Marketing and Bounce Mitigation

Incentive Marketing and Bounce Mitigation approaches are proposed to be investigated in order to motivate patients in improving their lifestyle choices and keep them engaged in the iHelp platform and mitigate the risk of quitting the platform. To this goal, it is known that gamification increases user engagement and retention with the mobile health applications.

The two propositions will be analyzed in the consortium and due to time constraints regarding implementation, the most beneficial between the two will be approached in more detail as experimental approaches, a prototype or research publication dissemination, as appropriate. The investigation of the two propositions will include and refer adequately also to state-of-the-art market implementations.

7.1.2.1 Incentive Marketing

In the context of T5.5 – "Monitoring, Alerting, Feedback and Evaluation Mechanisms", SIE will experiment with the gamification approach to motivate patient engagement to use the iHelp mobile application. The patients will be motivated by incentives depending on their needs. Some incentives ideas could involve health connected business such as pharmacies, sport and wellbeing firms, insurance companies, and can comprise: discounts for some of the medicine they need, discounts for firms that provide sport or stress reducing activities, vouchers for sport equipment, etc. In terms of motivation for changing and improving their lifestyle, virtual health coins can be awarded with each achievement made, that could be further transformed in gifts, or financial remuneration for insurance contribution, etc. The specific patients motivation triggers and the metrics that will be monitored from the application user interaction will be established with the pilot partners, while the incentives procedure and their format will be decided with technical partners. This approach can contribute to the overall project success since it has high potential market and investors traction with the inclusion of health connected businesses.

7.1.2.2 Bounce Mitigation

Bounce Mitigation proposition aims to predict if a patient is at risk of quitting the enrolled health plan and to perform the necessary actions to prevent this from happening. This can be achieved by following patients' activity and interaction with the platform and use intelligent AI/ML models to early predict their possible behavior, offering the opportunity to act in time and mitigate the risk of quitting. To this scope, an alert will be sent to the interested parties (e.g., doctors) to contact the patient to find the reasons for quitting the plan and try to support and motivate further in their health plan. This action will be personalized, since it needs to relate to each individual capabilities, circumstances, interests, personal/family life and so on. This will be not only beneficial to the patients' quality of life but also in the doctor-patient relation. SIE will investigate this proposition further together with the involved parties.

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List of Acronyms

AI	Artificial Intelligence
API	Application Programming Interface
DSS	Decision Support System
DS4	Digital Systems 4.0
ENG	Engineering Ingegneria Informatica
EU	European Union
FaaS	Function-as-a-Service
GUI	Graphic User Interface
HCP	Health-Care Professionals
HHRs	Holistic Health Records
INS	Innovation Sprint
IoT	Internet of Things
JSON	JavaScript Object Notation
KOD	Kodar
M	Month
ML	Machine Learning
PoC	Proof of Concept
REST	REpresentational State Transfer
SIE	Siemens
STR	Strypes
UI	User Interface
UNIMAN	University of Manchester
UPM	Universidad Politécnica de Madrid
UPRC	University of Piraeus Research Center
UX	User Experience
WP	Work Package