dHealth 2019 – From eHealth to dHealth
D. Hayn et al. (Eds.)

doi:10.3233/978-1-61499-971-3-154

Empowering Diabetes Patients with Interventions Based on Behaviour Change Techniques

Oliver JUNG[a,1], Dietmar GLACHS[a], Felix STROHMEIER[a], Robert MULRENIN[a], Sasja HUISMAN[b], Ian SMITH[b], Hilde van KEULEN[c], Jacob SONT[b] and Manuela PLOESSNIG[a]
[a]*Salzburg Research Forschungsgesellschaft mbH, Salzburg, Austria*
[b]*Leids Universitair Medisch Centrum, Leiden, The Netherlands*
[c]*Netherlands Organization for Applied Scientific Research (Department Child Health), The Hague, The Netherlands*

Abstract. The number of people with diabetes is increasing in every European country and like all chronic diseases it cannot be cured. However, patient empowerment is an acknowledged strategy for improving the patients' health situation. This paper describes the Action Plan Engine developed as a tool for diabetes patients in the POWER2DM project. The Action Plan Engine offers a guided workflow based on treatment goals and activities. A periodic review evaluates how successful a patient has fulfilled these goals and activities. Part of the evaluation is detailed feedback, in particular about 170 interventions based on Behaviour Change Techniques in order to change a patient's lifestyle behaviour towards a healthier, diabetes-appropriate lifestyle. Additionally, the Action Plan Engine offers decision trees for coping with barriers regarding glucose monitoring, exercise, carbohydrate, insulin and stress.

Keywords. clinical decision support systems, early medical intervention, patient participation

1. Introduction

In 2015, diabetes affected 59.8 million people in Europe aged between 20 and 79 years. According to the International Diabetes Federation (IDF) the number of people with diabetes is increasing in every European country and it is estimated that the number of people with diabetes in Europe will rise to 71.1 million in 2040 [1]. Diabetes is basically a life-long disease and like all chronic diseases it cannot be cured. Nevertheless, there are strategies for improving the patients' health situation. One key aspect is empowering patients to put them in the position to better take care of their diabetes. Information and Communication Technologies can play a key role in better management of diabetes and in patient empowerment. Patient empowerment [2] involves patients to a greater extent in their own healthcare process and disease management becomes an integrated part of their daily life.

[1] Corresponding Author: Oliver Jung, Salzburg Research Forschungsgesellschaft mbH, Jakob-Haringer-Straße 5/3, 5020 Salzburg, Austria, E-Mail: oliver.jung@salzburgresearch.at

In this paper, we present the approach of the Action Plan Engine developed in the POWER2DM project[2]. POWER2DM started in February 2016 and the main aim is to develop a personalised self-management support system for Type 1 and Type 2 diabetes patients. It offers a guided action plan for self-management by combining decision support based on personalised results of interlinked predictive computer models, feedback functionalities based on Behavioural Change Techniques, and real-time collection and interpretation of personal data and self-management activities. The Action Plan Engine is a web-based module in POWER2DM and integrates personalized behaviour change interventions to increase adherence of the patients to their care program and improve their interaction with health professionals.

The Action Plan Engine in POWER2DM is an advancement of the self-management support system developed in the EMPOWER project [3] by means of refactoring and addition of interventions, advanced exercises and modular design approaches.

2. Overview of the Action Plan Engine

The Action Plan Engine offers a guided workflow as an iterative cycle, typically on a weekly basis. For every cycle, the patient is encouraged to specify tasks and activities he or she wants to take care of in this period. These planned activities help to adhere to medical treatment plans, e. g. measuring glucose values, but may also support the accomplishment of personal goals in planning exercises. If a patient specifies activities on a weekly basis, the likelihood that these activities are realistic is higher than planning activities for a longer period. However, the Action Plan cycle can also be bi-weekly, monthly or of another duration. Besides planning of activities, the Action Plan Engine supports writing of diaries with respect to mood or stress.

The Action Plan Engine interacts with other POWER2DM components: (i) with the component for the doctors (the Shared Decision Making application) for supporting the appointment and for specifying treatment goals and activities and (ii) with the mobile app for a convenient acquisition of patient data and integration of device data.

2.1. Conceptual Approach

Basically, the Action Plan Workflow comprises four main steps (see Figure 1): in the first step, the patient can specify long-term self-management goals based on personalised values and on the treatment plan and goals. Based on the treatment goals, the patient can also specify a treatment goal in a more detailed way (e.g. specifying the type of exercise he would like to do) but also add additional personal goals.

In the next step and based on the self-management goals, the patient specifies short-term (e.g. weekly) activities by using a calendar. Relating an activity to a goal keeps the user aware why he is performing an activity.

Next, patient data will be recorded by devices but also manually through web and/or mobile forms. This phase supports the self-monitoring of vital data and behaviour. Currently, the following patient data can be recorded via web forms: blood glucose, blood pressure, body weight, exercises, meals, problems, sleep and stress.

[2] The POWER2DM project is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 689444

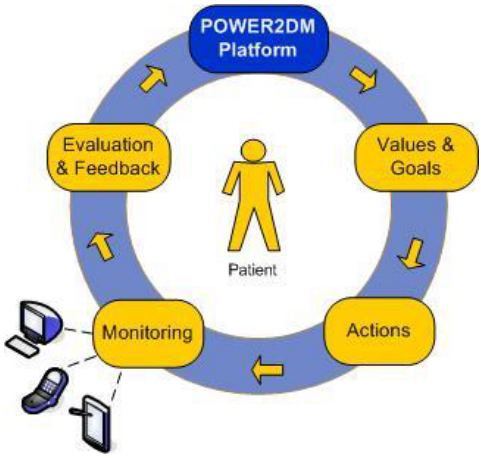

Figure 1. Patient Empowerment Workflow through POWER2DM.

In the last step, the Action Plan Engine evaluates and gives feedback how successful the patient has fulfilled his planned goals and activities. This includes feedback about the overall performance and the performance of all concerned goals and activities. Additionally, the Action Plan Engine provides hints and advices (=interventions for self-management) for all activities and goals. Interventions can be in a different context, e.g. a tip for improving self-management activities, an advice based on national guidelines (e.g. recommended duration for physical activities), a tip for coping with daily problems (e.g. sleep problems or stress) or positive reinforcement [4] by means of a motivational message (e.g. when the patient has successfully completed all his activities for a specific goal).

Furthermore, part of the Action Plan Engine are some exercises such as the Energy Battery, a metaphor in three steps for mood or energy problems (e.g. in case of low mood or too much stress, in case of sleeping problems), the Value Compass, a tool for reflecting on the importance of personal values in different life areas (e.g. to support goal definition), and the Information Material, a WordPress website including detailed articles about information and problems relevant for diabetes patients.

2.2. Technical Approach

Technically, the Action Plan Engine is a web-application which provides a fully interactive, multi-lingual[3] graphical user interface accessible with both, desktop PC and/or mobile devices (tablets and smartphones). Furthermore, an application programming interface (API) is provided for third-party applications by means of REST services exchanging JSON objects [5].

[3] Currently supported languages are English, Spanish, Dutch and German.

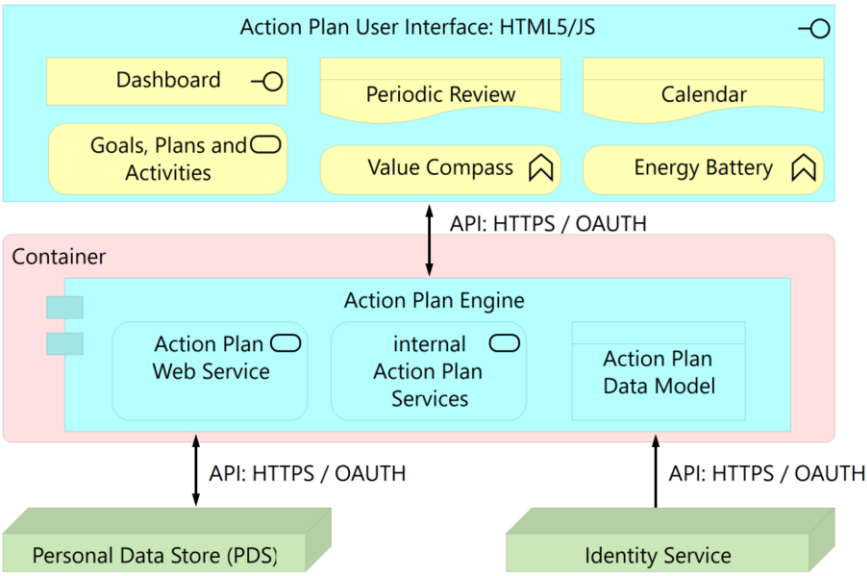

Figure 2. Action Plan Engine - General Architecture.

This API is also used by the Mobile Application developed within the POWER2DM project. Figure 2 depicts the general architecture and the main components of the Action Plan Engine. Towards the user, the Action Plan provides an HTML5/JS application. In the backend, the Action Plan Engine is implemented as a Java Servlet running inside a secure container providing controlled access via the APIs.

Separate APIs for each service are provided, such as the management of goals, planning of activities and observations or accessing the review over a specified period. For providing such information, the Action Plan Engine does not store any patient data itself, but relies on existing, secure patient data management infrastructures. In POWER2DM, the FHIR-compatible [4] personal data store (PDS) [6] and the POWER2DM identity service for authorization and authentication have been used. The Action Plan Engine only transforms patient data, calculates graphs and statistics, and creates interventions based on the action plans and results stored in the PDS. Also, all data entered via the Action Plan is stored only in the secure PDS.

Figure 3 shows the menu structure provided to the patients after authentication. Landing page is a "*Dashboard*". From that, the patient can navigate to the "*Treatment Plan*", which contains goals defined by the care provider and the patient together during a "Shared-Decision Making" process. Goals defined in the treatment plan can be adopted by the patient and further detailed in their own self-management "*Action Plan*". This menu item also contains the links to further information such as the review, or exercises like the Energy Battery and Value Compass. Daily activities can be either recorded through the mobile application, or by using the "*Journal*" pages. Finally, profile and settings are available for the patient to change personal preferences.

[4] "Fast Healthcare Interoperability Resources" (http://hl7.org/fhir) is a medical standard created by the standardisation organisation HL7.

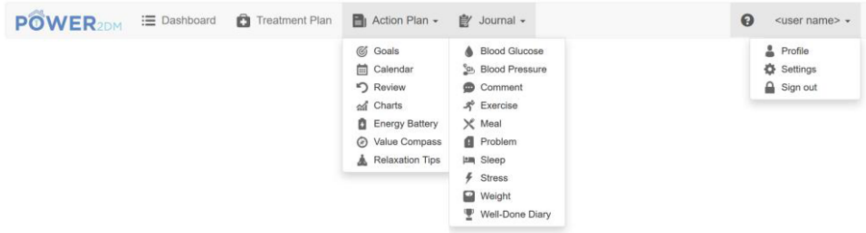

Figure 3. Action Plan Engine User Interface – Main Navigation elements.

Further technical details about the Action Plan Engine are described in a public report on the prototype architecture of POWER2DM [7].

3. Interventions for Behavioural Changes

Most theories and determinants explain behaviour, but do not describe how to change behaviour. In POWER2DM, the interventions of the Action Plan Engine are based on the Behaviour Change Techniques (BCTs) of Abraham and Michie [8]. They describe interventions to change a person's lifestyle behaviour. A BCT is an "observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour".

The Action Plan Engine provides interventions as part of the periodic review and by suggesting interventions at the end of barrier decision trees. These interventions are stored in the intervention table which is based on a dual approach and supports both a psychological and a technical approach. The starting point is the compliance with the planned goals and activities. Depending on the degree of fulfilment, different types of interventions/purposes and BCTs can be specified, e.g. positive reinforcement when a goal resp. an activity is completely achieved, a question to detect a barrier when a goal resp. an activity is almost or not achieved.

Currently, the intervention table of the Action Plan Engine includes about 170 different interventions. These interventions can be of different types. They can be plain text (e.g. positive reinforcement), they can refer to an external website (e.g. about a detailed description of diabetes and coping with emotions), they can recommend an exercise (e.g. an exercise for coping with low mood or energy problems) and they can refer to a more detailed explanation in the POWER2DM information material (e.g. an article about fear of needles).

3.1. Interventions for the Periodic Review

The periodic review collects all scheduled activities within the review period where each scheduled activity is marked as completed whenever a corresponding observation is present. Otherwise the scheduled event remains as planned in the review. As a result, the number of planned activities compared to the number of completed activities denotes the compliance or performance in completing planned activities. However, since activities are of a particular type (monitoring glucose, doing exercises etc.), the review computation is also performed for each activity type and of course for the activities

overall. Furthermore, any activity may point to one or more related goals. Hence, the performance computation is additionally performed for each goal and on an overall basis. As a result, the review shows several review categories such as overall performance, activity performance, goal performance. Besides the planned activities and goals, the review takes additional recordings such as sleeping problems, mood or stress into account. For these data, we use Likert Scales [9] as a basis for evaluation in the periodic review (sleeping problem intensity, mood level, and stress level).

From the technical point of view, the degree of the patient's compliance in planning activities and successfully completing them is the basis for interventions. Interventions in this context are motivational or informative messages shown to the patient to foster behaviour change. To support the selection of meaningful interventions, the selection of an intervention is based on several rules such as the review category (e.g. activity or goal) and the performance rule to compare with the review result in order to show only helpful messages to the patient.

For the review, the accurate evaluation of the performance with the intervention table is a crucial task. For this, the performance rule consists of an *expression constant*, a *comparator* and the *target value*. The expression constant points to the computed review performance result (e.g. performance of glucose monitoring activities) or to the recorded problem or stress intensity respectively. Since the review period covers several days or even weeks, appropriate expressions for selecting the lowest, the highest or the average intensity values are available. The comparator expression allows the comparison of the resolved review value with the given target value.

The performance however is expressed as a percentage of completed tasks compared to the number of planned tasks. The resulting percentage is transformed into a corresponding 4-step Likert Scale outlining the degree of compliance. The values for problem intensity and stress levels are aligned to a Likert Scale as well, thus specifying the performance criteria for all kinds of interventions is simple and straight forward.

Finally, when computing the review and selecting the proper interventions, eligible messages are identified by i) filtering for the review category and ii) applying the performance rule. Whenever all rules evaluate to true, the intervention is eligible to be shown to the patient. This ensures that the patient gets appropriate feedback based on his achievements.

3.2. Decision Trees for Coping with Barriers

Decision Trees are ultimately a special kind of intervention. They can be triggered by other interventions, observations or user interaction based on defined rules. In contrast to other interventions, they incorporate direct user feedback.

Since the rules and workflows of the Decision Trees are highly based on expert knowledge and defined by practitioners, a dynamic "workflow tool" has been developed using vis.js[5] and Node-RED[6]. It allows for definition by non-technicians that can be exported to a structured JSON format for integration into the Action Plan Engine subsequently.

Figure 4 shows an example workflow that covers all definable node and edge types. Nodes can be i) comments (grey) – for improving collaboration, ii) questions (dark blue)

[5] "vis.js" (http://visjs.org/) is a dynamic, browser based visualization library
[6] "Node-RED" (https://nodered.org/) is a flow-based programming tool for the Internet of Things

– asked to the user for direct feedback, iii) content (purple) – redirects to new pages or static content, iv) conditions (light blue) – for checking existing observations, v) triggers (orange) – for manually or periodically executing the workflow and vi) actions (red) – for activating existing triggers. Edges can be i) answers (light blue) – for proceeding based on user input and ii) forwards (grey) – for directly linking nodes.

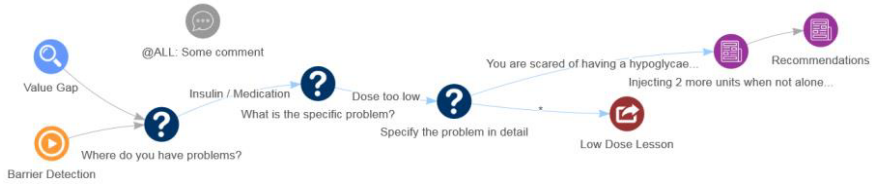

Figure 4. Action Plan Engine Workflow Tool – Example workflow.

The exported JSON file is used for creating more complex user interface elements or dialog-based select inputs dynamically generated on the front-end. Figure 5 shows an example dialog about glucose monitoring. The user is guided through the previously defined questions and answers gradually while conditions are checked and content is loaded in the background. In this example, the user states to monitor too little due to disliking needles and is provided with a link to an information page on how to overcome needle phobia.

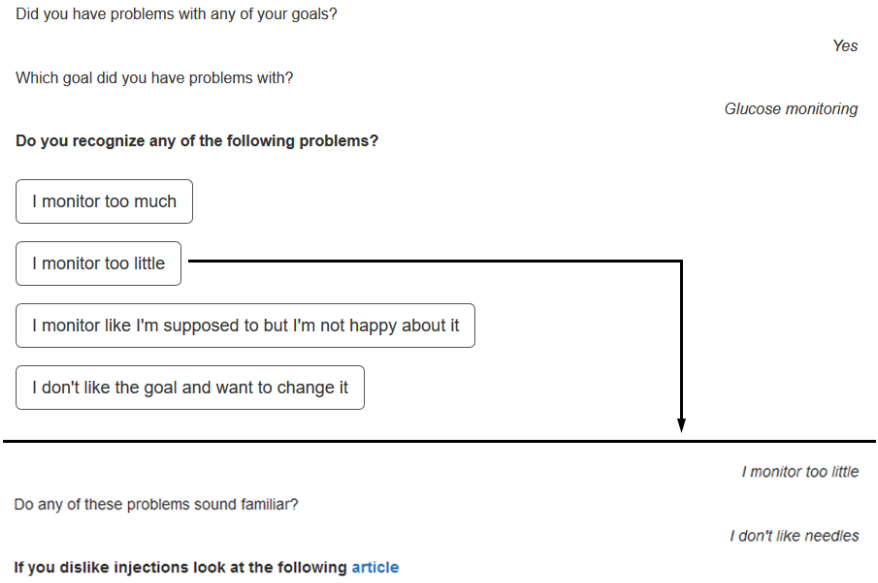

Figure 5. Action Plan Engine Decision Trees – Example dialog.

In the end, each Decision Tree can result in an intervention or trigger another Decision Tree allowing for complex and comprehensive rules and support by the use of easily definable components. In the POWER2DM project, we specified five decision

trees for coping with barriers regarding glucose monitoring, exercise, carbohydrates, insulin and stress that consist of up to 30 sub-trees.

4. Conclusions

In this paper, we presented the approach of the Action Plan Engine developed as a component in the POWER2DM project. An early prototype of POWER2DM including the Action Plan Engine is currently implemented and evaluated in a randomised trial with 9 months follow-up in total with 230 patients (115 type-1 diabetes, 115 type-2 diabetes) in pilot applications in the Netherlands and in Spain. The trial aims at evaluating the acceptance rate and effectiveness of the presented interventions as well as the HbA1c levels in comparison to a reference group. Although continuous feedback from physicians, psychologists and patients helps to improve the prototype, it is currently too early to present reliable evaluation results. So far, patients are enthusiastic about the idea of a holistic self-management support system, receiving support and feedback on physiological, behavioural and psychological parameters.

The Action Plan Engine is actually part of the POWER2DM system, integrating with the FHIR based storage and a provided single-sign-on solution. However, due to its modular design, the Action Plan Engine may be used in many environments and can be easily transferred and used in other e-Health projects, focussing on different diseases. A connection and integration to third party health systems is also possible due to the use of standardised interfaces. This also allows for integrating more natural input methods, such as voice recognition, for some exercises (e.g. decision trees).

References

[1] IDF, Across the Globe, http://www.diabetesatlas.org/across-the-globe.html, last access: 9.1.2019.
[2] Castro, E., Regenmortel, T., Vanhaecht, K., Sermeus, W., Hecke, A., Patient empowerment, patient participation and patient-centeredness in hospital care: A concept analysis based on a literature review, *Patient Education and Counseling* **99**(12) (2016), 1923-1939.
[3] Schmuhl, H., Demski, H., Lamprinos, I., Dogac, A., Ploessnig, M., Hildebrand, C., Concept of knowledge-based self-management pathways for the empowerment of diabetes patients, *EJBI* **10**(2) (2014), 12-16.
[4] Elder, J., Ayala, G., Harris, S., Theories and intervention approaches to health-behavior change in primary care, *American Journal of Preventive Medicine* **17**(4) (1999), 275-284.
[5] Kumar, D., Best Practices for Building RESTful Web Services, https://www.infosys.com/digital/insights/Documents/restful-web-services.pdf, last access: 14.1.2019.
[6] Namli, T., Köse, O., POWER2DM D4.2 Personal Data Store Service Implementation, http://power2dm.eu/wp-content/uploads/POWER2DM-D4.2.pdf, last access: 22.3.2019.
[7] Namli, T., POWER2DM D1.3 Conceptual Design of the POWER2DM Architecture, http://www.power2dm.eu/wp-content/uploads/Power2DM-D1.3-1.pdf , last access: 24.1.2019.
[8] Abraham, Ch., Michie, S., A Taxonomy of Behavior Change Techniques Used in Interventions by the American Psychological Association, *Health Psychology* **27**(3) (2008), 379–387.
[9] Joshi, A., Kale, S., Chandel, S., Pal, D., Likert Scale: Explored and Explained, *British Journal of Applied Science & Technology* **7**(4) (2015), 396-403.