ASCAPE

Artificial intelligence Supporting CAncer Patients across Europe

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0.9	05.07.2021	Manos Athanatos (FORTH), Mirjana Ivanovic (UNSPMF)	Second document review. Minor text amendments.
1.0	05.07.2021	Final Version	Miltiadis Kokkonidis

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List of acronyms

AI	Artificial Intelligence
API	Application Programming Interface
EHR	Electronic Health Record
EMR	Electronic Medical Record
HIS	Healthcare Information System
IT	Information Technology
PCC	Primary Care Centre
QoL	Quality of Life
UI	User Interface

Executive Summary

The present report accompanies the first version of the *ASCAPE Dashboard*. The report and the software created mark an important landmark in the progress of the project, half-way through its duration (M18) and provide a concrete visual design and implementation for a very important aspect of the project: the User Interface (UI) that the ASCAPE Consortium has prepared for doctors that will use ASCAPE in its first trial run and beyond.

This work follows closely the requirements specification work of D1.1 and the wireframe designs of D1.3. It improves significantly on the latter, by providing a cleaner, less cluttered and more intuitive layout, populated by visualization elements capable of conveying more information to the doctors. The current version of the ASCAPE Dashboard supports doctors by: (a) providing a list of intervention suggestions and predictions from the ASCAPE AI (b) offering a quick, intuitive, and easy way of testing the effect of different intervention choices on ASCAPE's predicted QoL issue and overall QoL indices. Thus, it meets the core D1.1 functional requirements for it and supports the relevant use cases in full. This report goes a step further than describing the current version; it also provides a glimpse on future developments that will lead to an even more powerful but equally intuitive second version of the ASCAPE Dashboard.

While an ASCAPE Dashboard web application has a number of uses, there are many cases where doctors are better served if its functionality is embedded into systems, they already use. To support such scenarios, at least when the system doctors use is a web-based application, the core functionality of the ASCAPE Dashboard has been packaged into the *ASCAPE Visualizations Library*. This standalone Javascript/CSS library has been designed and coded so that it can easily be integrated into existing or new web-based applications.

By examining ASCAPE's four pilots and using them as case studies, this report also presents how the provision of both a web-based application, the ASCAPE Dashboard, and a web front-end visualizations library, the ASCAPE Visualizations Library, have helped provide access to ASCAPE visualizations to doctors at the different pilot sites. This technical achievement is evidence that the architectural design of ASCAPE contributes to the fulfilment of ASCAPE's ambitious goals as it clearly demonstrates the feasibility of the proposition of integrating diverse existing systems with the ASCAPE platform and making ASCAPE UI functionality available to doctors at different sites, using different systems.

1 Introduction

By paying attention to privacy considerations and using appropriate privacy-preserving AI technologies [1], ASCAPE aims to transform the field of e-Health into a field where Big Data and AI have a significant role to play. Technical excellence, if restricted to architecture and AI capabilities, is not enough though.

For patients and doctors, their experience of ASCAPE is primarily determined by their interaction with it. This interaction was described in the relevant use cases for patients (PAT.1) and doctors (HP.1 and HP.2) in the project's requirements deliverable (D1.1). The focus of the present deliverable is on the latter, namely on the user interface provided by ASCAPE to doctors, specifically the ASCAPE visualizations that are meant to summarise and/or show in detail historical data about the patient's Quality of Life (QoL) trajectory on one hand and show the predicted effect of selected interventions on the other.

Given that in ASCAPE it is the doctor that is on the driver's seat and makes final decisions about interventions suggested to the patient, ASCAPE visualizations are an important factor in the success or failure of ASCAPE in helping doctors make better decisions. As per the title of the present deliverable, ASCAPE visualizations must be user-centric, i.e. designed with a focus on what their user, the doctor, needs to see and how. Moreover, they are meant to aid the doctor provide interventions to a specific patient, which implies they should help him/her focus on the most important aspects of the available information. The methodological approach followed for achieving these goals, as well as the current results of the (ongoing) design process will be presented in the present deliverable.

The design of the ASCAPE visualizations is embodied in the *ASCAPE Dashboard for Doctors* (often simply referred to as "the Dashboard"), a web application that communicates with the local ASCAPE Edge Node to make ASCAPE AI functionality available to the intended end-users (doctors). As it is inconvenient for doctors to add one more information system to their daily routine, there is also a provision for integrating the visualizations offered by the Dashboard inside web-based systems that doctors already use. This involves the *ASCAPE Visualizations Library*, the core element of the Dashboard, which has been designed so that it can be used not only by it, but also by third-party Healthcare Information Systems in their UIs for doctors. The present deliverable documents both and discusses their use in the ASCAPE pilots and beyond.

1.1 Aim and Scope

D4.1 is a deliverable of Task 4.1. The main aim of the task is to design and implement the User Interface items to be presented to doctors and compose a cohesive, well-designed user interface aiming at minimising the Doctor's effort in discovering useful insights computed by the ASCAPE AI. D4.1 presents the progress achieved half-way through the project (M18) and marks an important milestone within it, alongside D4.2,

documenting the actions for preparing the project's four pilots at clinical sites at Athens, Barcelona, Orebro/Uppsala, as well as the purely online CareAcross pilot. These two deliverables combined mark the transition from initial thoughts and planning to a concrete understanding of how the ASCAPE pilots will unfold. Specifically, D4.1 marks the transition from the use cases and requirements of D1.1 and the wireframe diagrams of D1.3 to concrete visualizations, designed, implemented, and optimised for use by the doctors participating in the ASCAPE pilots.

Task 4.1, a technical task, intentionally constitutes part of the ASCAPE Pilot's Work Package (WP4). The task's focus has been to bridge the world of data and AI results with the world of clinical practice, and this is best done in a work package focusing on the clinical/pilot partners contributions to the project. Indeed, as detailed below in the methodological approach followed, the clinical/pilot partners have played a crucial role in shaping the ASCAPE visualizations for doctors.

D4.1 reflects the combined efforts of technical and clinical partners for defining the initial set of ASCAPE visualizations for doctors. While our current effort both achieves the usability targets set and can support the initially foreseen use cases, it is best viewed as the foundation upon which all further refinements and enhancements will be made. During the first trial run of ASCAPE in the project pilots, the clinicians who participated in the design of ASCAPE visualizations for doctors, will get to use them in the context of their (in-person or remote) contact with their patients, a process that is bound to lead to feedback for improvements. These clinicians will also be joined by colleagues who have not participated in the design process and will be able to provide valuable feedback from a different viewpoint. Finally, the technical partners' experience with the ASCAPE data and the ability to experiment with visualising the data from the pilots will also be able to contribute to improvements. All the aforementioned improvements, enabled and facilitated by experience gained by both clinicians and ASCAPE's technical partners during the first trial run which ends on M24, fall in the scope of Task 4.1 which also ends on the same month. Thus, the current version of the ASCAPE visualizations will serve the first (shorter) trial run of ASCAPE, whereas experience gained with this first version, the ASCAPE platform, and the ASCAPE pilots during the first trial run, will contribute to a second version which will be used in the second trial run.

1.2 Methodological Approach

There have been three discrete stages in the evolution of the user-centric design of the ASCAPE visualizations for doctors as embodied in the ASCAPE Dashboard and made available for integration into existing Healthcare Information Systems through the ASCAPE Visualizations Library.

Stage 1: Initial requirements (T1.1)

The first stage in reaching the current design of the ASCAPE visualizations dates to the first six months of the project where an intensive schedule of coordination and co-design calls between technical and clinical partners and productive dialogue resulted

in the aforementioned use cases (HP.1 and HP.2) focusing on the interaction of doctors with ASCAPE, as well as a set of relevant functional and non-functional requirements. The methodology followed and the requirements can be found in D1.1 (in Sections 4 and 6 respectively).

An important outcome of the T1.1 requirements specification process was the identification of the requirement for the ASCAPE UI for doctors to not only present the results of ASCAPE's AI, but to use these results in order to make intelligent decisions about what information to present and how. The D1.1 excerpt below clearly demonstrates the direction taken early in the project and the concerns that drove both the relevant use cases (HP.1 and HP.2) and the overall requirements specification.

> *The requirements gathering process confirmed the Consortium's understanding of doctor's needs, namely the need to have quick access to all relevant information, which resulted in a functional requirements specification focused on providing doctors with the information they need to focus on as well as very efficient means of exploring alternative intervention recommendations:*
>
> - *When a Doctor visits the Patient's record, the most important information about that patient should be presented to the Doctor, prioritised by importance and with minimal, if any, additional input; additional user actions will be required for exploring alternatives and/or obtaining explanatory details about a result provided by ASCAPE's AI*
> - *When the Doctor enters the System, ASCAPE is to provide a list of patients the cases of which ASCAPE AI believes the Doctor should review, either because there is an actual or predicted deterioration in their health and quality of life or because ASCAPE predicts an intervention will have a significant effect.*

Stage 2: Initial Visual Design (T1.4)

Following the theme of tight collaboration between technical and clinical partners, and with the benefit of the understanding that T1.2/D1.2 (M8) brought to the table regarding the data that will be available to the ASCAPE Platform, T1.4/D1.3 reached another important milestone by creating middle-fidelity wireframe diagrams for the ASCAPE Dashboard.

Wireframe diagrams are an important aspect of the requirements gathering process as they allow stakeholders to get a clear understanding of how the software designers interpret the requirements and then allow both sides to engage in meaningful dialogue based on a still somewhat abstract, but nevertheless visual representation of the UI design.

The middle-fidelity wireframe diagram in Figure 1 (D1.3, Section 6.2) offers a concrete proposal for what the doctor will be seeing while carrying out the key task in the use case HP.1 (D1.1, Section 5.1) (looking at a patient's historical data, ASCAPE AI's intervention suggestions and predictions).

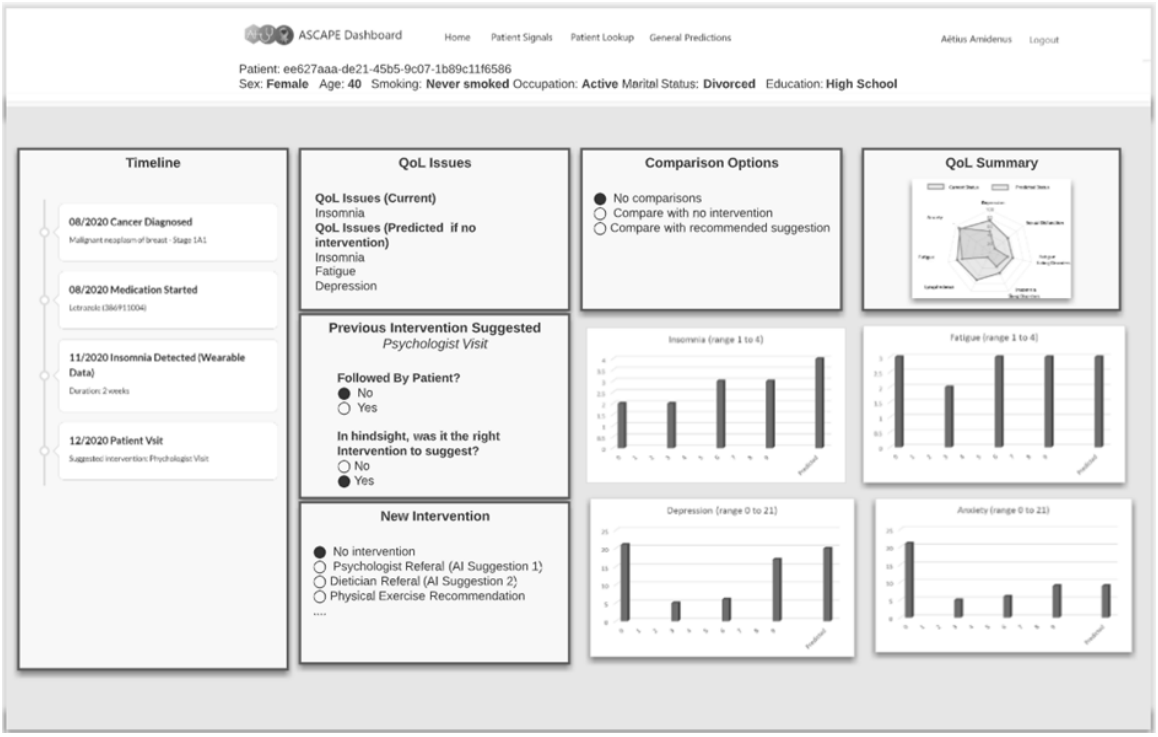

Figure 1 ASCAPE Dashboard Patient Overview middle fidelity wireframe diagram

Likewise, Figure 2 (D1.3, Section 6.1), provides a (rather minimalistic) concrete design proposal for the functionality that is at the core of use case HP.2 (D1.1, Section 1.2) (the doctor being informed by the ASCAPE AI of which patients it judges to require the doctor's attention).

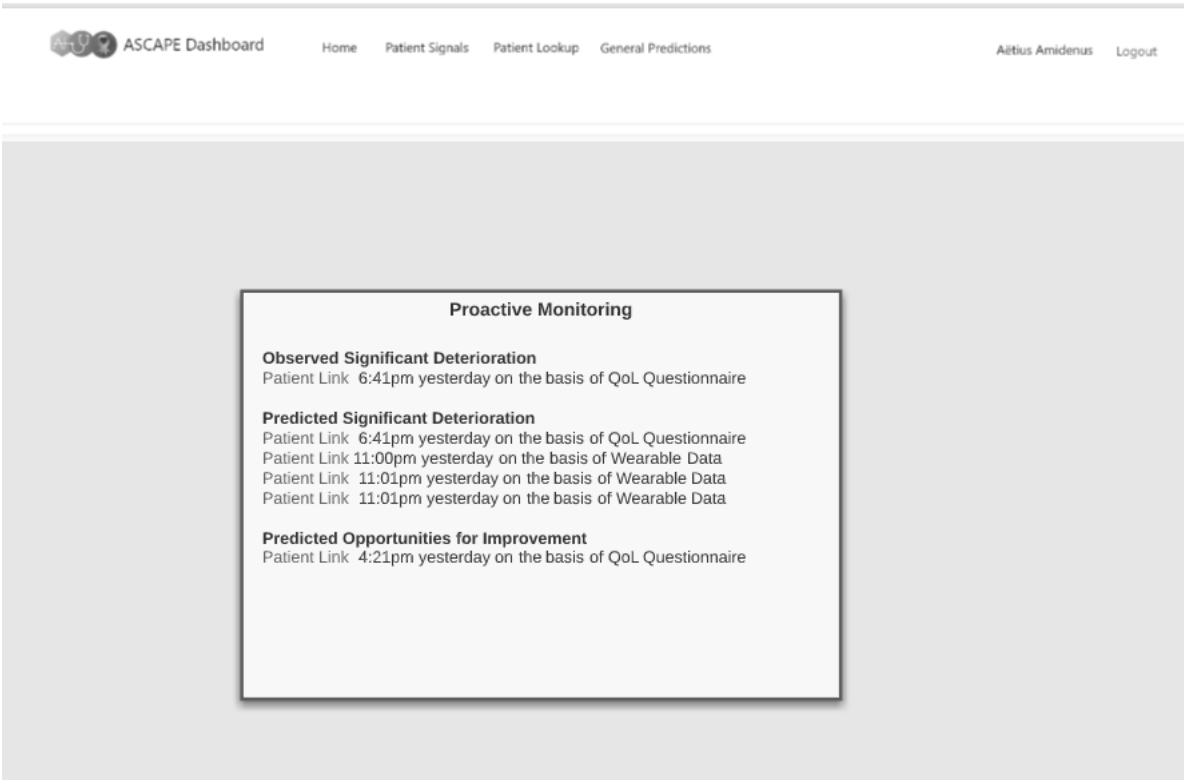

Figure 2 ASCAPE Proactive Monitoring List middle fidelity wireframe diagram

D1.3 provided a thorough analysis of the elements in both wireframe diagrams. The wireframe diagrams were discussed with both clinical and technical partners and helped to establish that the vision D1.3 set forth was one on which both sides agreed.

Stage 3: Design and Implementation of the First Version of the ASCAPE Visualizations Library and Dashboard (T4.1 – Phase I)

The wireframe designs of D1.3 together an ever-evolving prototype of the ASCAPE Dashboard were heavily used in the discussions that lead to the final design and implementation of the first version of the UI for Doctors. This design, presented in the present deliverable (in Section 2), departs from the wireframe diagrams of D1.3 in several details, some important others less so, while staying remarkably faithful to their key ideas.

The aforementioned differences are due to two factors:

1. Decisions reached in a series of T4.1 calls, WP2 calls and Technical Coordination Calls that allowed further progress to be made
2. Differences in purpose: whereas the wireframe diagrams were meant primarily as a visual aid for discussing the design of ASCAPE UIs (and ASCAPE in general) within the Consortium, the design of the first version of the ASCAPE Visualizations Library and the first version of the ASCAPE Dashboard was

meant to be used, by (busy) doctors, some of whom had not participated in its design.

For instance, the first version of the ASCAPE Visualizations Library and of the first version of the Dashboard provide a simpler user interface with richer visualizations (see Section 2) than foreseen in the corresponding wireframe diagram. An important improvement is that interventions are visualizations include interventions with a chronological start and end point, which allows doctors to visually correlate the intervention with certain QoL issues and attempt to determine if there is a causal relation, in say, the amelioration of QoL issues the patient had.

Task 4.1 design work is a continuation of the user-centric design effort initiated in Task 1.1. Significant effort went into discussions between the partner responsible for the UI design and pilot partners, especially doctors. Discussions also involved AI experts, both in determining the utility of proposals for additional input from the doctors, as well as in discussing the direction for future enhancements focusing on providing doctors with explanations.

This type of effort will continue during the first trial of ASCAPE, but it will be enriched with data and experiences from the first trial run as it progresses.

1.3 ASCAPE Visualizations and the ASCAPE Architecture

The aim of the ASCAPE Architecture (D1.3) was to provide a blueprint for the creation of an ASCAPE Platform that would be flexible enough to be deployed in a wide range of clinical (and possibly other) settings, thus maximising the impact of the project and helping realise its potential and vision. It will clarify the relation of the ASCAPE Dashboard, the ASCAPE Visualization Library, Healthcare Information Systems using it, and the Edge Node.

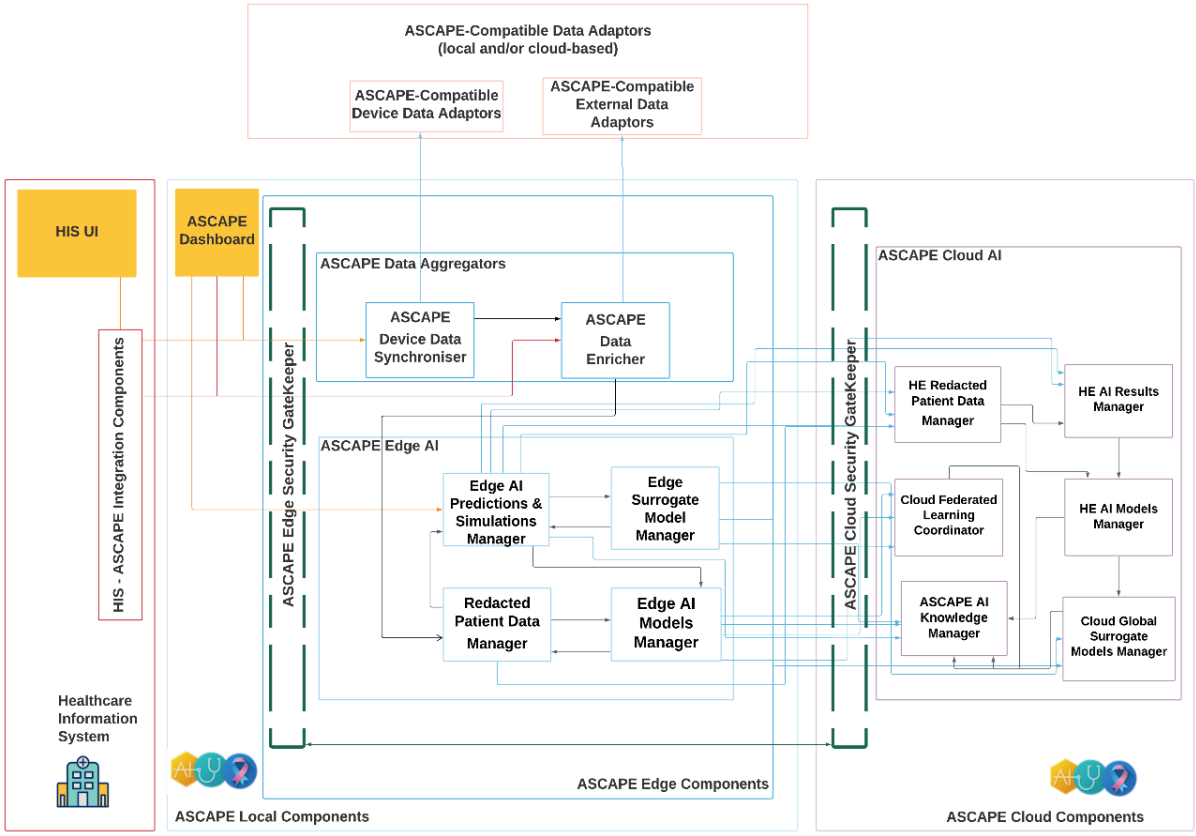

Figure 3 The ASCAPE Framework Architecture

Assuming an environment with a Healthcare Information System that holds basic information about a patient but can also collect answers to questionnaires submitted by patients, ASCAPE can be used to enhance the Information Technology (IT) services offered to doctors with AI-based intervention suggestions, predictions, and their visualizations in one of two ways:

- either by using the standalone ASCAPE Dashboard alongside the Healthcare Information System, or
- by embedding ASCAPE Dashboard-like functionality and visualizations within the Healthcare Information System.

The latter option may provide significant usability benefits to users where it can be applied.

One way the ASCAPE Architectural design facilitates the option of integrating ASCAPE Visualizations into an existing (or new) Healthcare Information System is by means of providing a simple, clean API for obtaining the relevant data from the ASCAPE Edge Node. This is the exact same API that the Dashboard uses.

But the ASCAPE Architecture went a quite a bit further by also factoring out the core

functionality of the ASCAPE Virtualizations to create the ASCAPE Visualizations Library. Further than that, the library was designed in a manner that requires minimal integration effort.

Key to understanding how the design of the ASCAPE Visualizations Library has addressed the minimal-effort integration requirement, is the fact that it is tailored to the part of the ASCAPE Edge API responsible for data for visualization. That API returns complex objects with a specific meaning in the context of ASCAPE, which the ASCAPE Visualizations Library can interpret and use appropriately. Whereas general-purpose libraries are designed around primitive domain-agnostic concepts such as axes, data series and labels, the ASCAPE Visualization Library works at the level of concepts such as patient, QoL issue, Intervention and so on and so forth.

The only configuration required on the side of library is to be provided with a data request callback function which it can use for requesting the data to visualise from; in most cases, the library's own facilities configured to use a specific URL for obtaining the data from the server will suffice. A web application using the library, such as the web applications in the two pilot sites that use it, simply need to include the library, set up the data request callback function, and add the required visualization placeholder elements in the pages where ASCAPE visualizations are to appear. When the page loads in a browser, the library's page initialisation code runs and performs the following actions:

- it locates the placeholder elements it is meant to bring to life,
- it retrieves any parameters they include from the placeholder elements' HTML5 data attributes:
    - for the Proactive Monitoring functionality only the Visualization API Handler URL no parameters are required
    - for the Patient Overview visualizations, the patient's External ID (discussed in D1.3 Sections 3.1.2 and 7.4.1) is the only required parameter
- it issues data requests (using the relevant parameters),
- it obtains data from the back end
- it uses that data to the visualization placeholders into interactive visualizations based on low-level visualization elements it includes.

On the web-application's back end (at the server), minimal additional code is required to support the operation of the library; specifically, a simple request handler needs to be built. The URL of this handler on the web application's server is where the ASCAPE Visualizations Library will be instructed to obtain data from. This handler will do the following:

- perform authentication and authorisation checks on the basis of the credentials for the request sent by the data request callback function on the browser and block further processing if they are not in order (e.g. if the request to get patient details did not come from a doctor with access to a patient's record)

- perform any logging of the request in accordance with the web application's practices for logging requests
- make a request with the same content as the one received to the local ASCAPE Edge Node's endpoint for obtaining data, passing the appropriate credentials for that request[1], obtain the response from the Edge Node to the browser as the response to the request it had issued

One web application that uses the ASCAPE Visualizations Library in exactly this manner is the ASCAPE Dashboard. Two others to do so are the Healthcare Information Systems of the Athens and Barcelona pilots, as discussed in Section 3.

1.4 Structure of Deliverable

The present section introduced the deliverable, highlighting its aim and scope in the context of the overall workplan of the project, presented an overview of the methodological approach used to reach the design of the first version of the ASCAPE Dashboard and the corresponding version of the ASCAPE Visualizations Library as well as their place in the ASCAPE architecture.

Section 2 is will present ASCAPE visualizations as provided by the first version of the ASCAPE Dashboard based on the work carried out in the task thus far. It discusses both the overall setup and the visualization elements in detail and presents the overall design direction taken.

Section 3 discusses the context (information systems available, integration limitations, usability requirements, etc.) in which ASCAPE visualizations were to be made available to doctors in the four pilots, how the ASCAPE visualizations are to be integrated in each case, and how the diversity of the pilots foreshadows future integration and deployment scenarios.

Section 4 outlines the key points of this deliverable and considers the next steps in the task and beyond.

[1] The credentials sent by the web application's backend to the ASCAPE Edge Node may be the user credentials received from the browser, or alternative credentials; for instance, they could be credentials for the web application's back end (in which case the ASCAPE Edge Node will serve or reject the request on the basis of the web application's rather that a specific user's credentials).

2 ASCAPE Patient Data and Visualizations

There are two main types of data that are visualized within the ASCAPE Dashboard:

- redacted patient data kept in the local ASCAPE Edge Node (originating from the Healthcare Information System and possibly additional data sources)
- AI results (such as predictions and intervention suggestions) generated by ASCAPE

ASCAPE aims to offer the ASCAPE AI capabilities in a manner that is meaningful, useful, effective, and aligned with the needs of doctors seeking to provide better support to their patients. The ASCAPE Visualizations Library, which serves as the basis for making the ASCAPE AI results accessible to doctors in the ASCAPE Dashboard (and any other system that uses this library), translates the ASCAPE AI results into appropriate visualizations (as discussed in Section 1.3) and offers meaningful ways of interacting with them.

ASCAPE focuses on monitoring and aiming to provide support to doctors for improving the quality of life of patients that have undergone breast cancer or prostate cancer treatment. The ASCAPE platform is extensible, but the focus here will be on the data and the visualizations that stem from the original aims of the project. The focus will be on highlighting the key aspects of the ASCAPE Visualizations Library based on different scenarios of visualizations for breast cancer and prostate cancer patients. Moreover, while the ASCAPE Visualizations Library can be used in a variety of web-based systems, as will be discussed in Section 3, the present section will focus on the ASCAPE Dashboard.

This section is closely related to the description of the middle-fidelity wireframe diagrams in D1.3 which acted as a guide for initial progress in Task 4.1. Section 2.1 presents what the Proactive Monitoring List of D1.3 has evolved into, based on utilising visualization elements originally created for the Patient Overview Page. Section 2.2 presents the result of days of collective effort by the involved partners in improving on the initial Patient Overview Page design. Section 2.4 departs from that pattern as it moves beyond both D1.3 and the current version of the ASCAPE Dashboard but offers a glimpse into possible new visualizations to be seen in its second version.

2.1 Proactive Monitoring Visualizations

ASCAPE is not meant as a health-emergency detection service. However, it is meant to help doctors keep an eye on their patient's evolving health status. When input from a patient (such as a QoL questionnaire) or a patient device (such as a wearable), or any other change to the patient's data reaches ASCAPE, it is processed and AI results for the patient are updated.

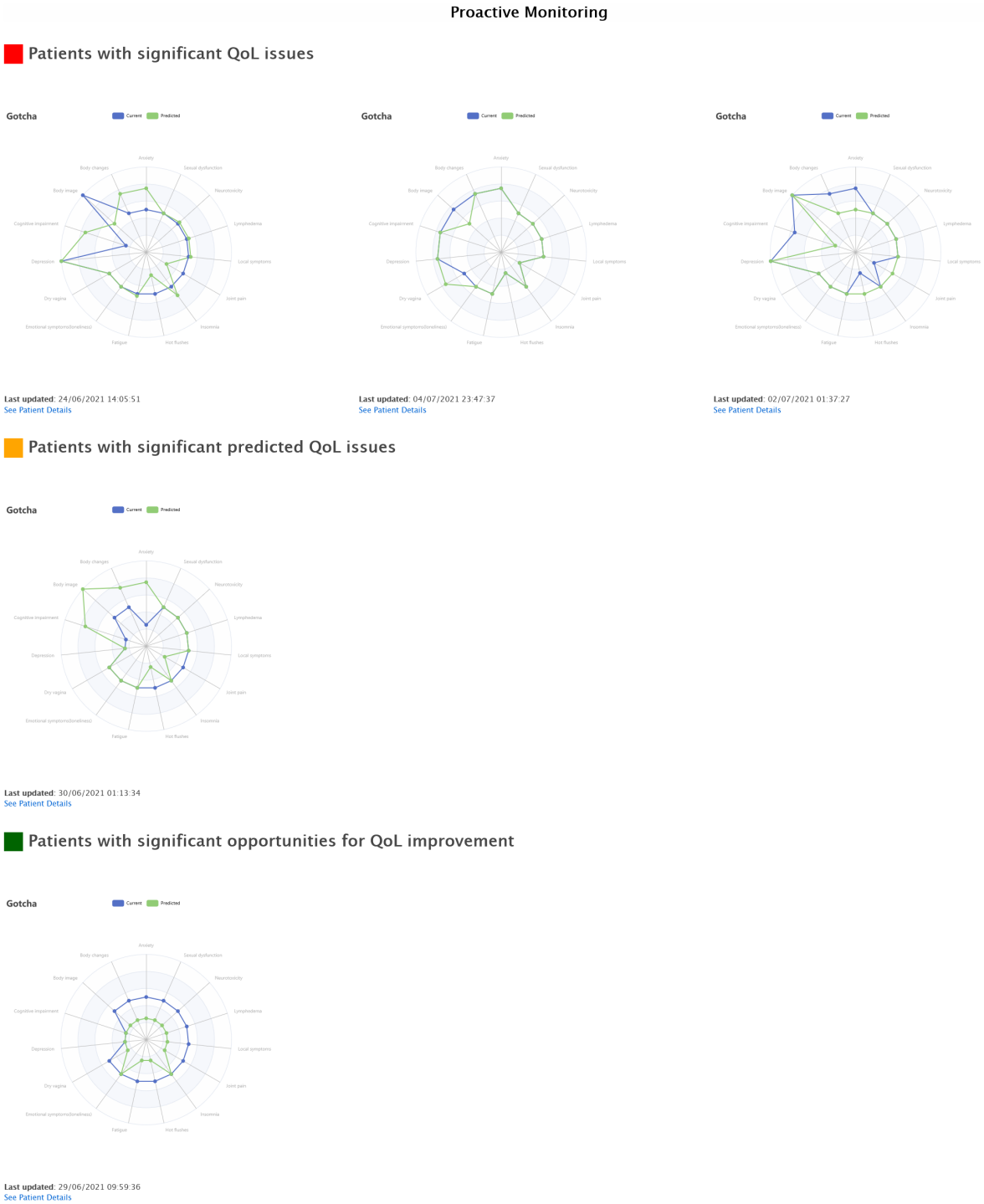

Figure 4 ASCAPE Dashboard Home Page – Proactive Monitoring List

The relevant results may identify patients who belong in one of the following categories:

- Patients with significant reported Quality of Life issues

- Patients with significant predicted (by ASCAPE) Quality of Life issues
- Patients for whom (according to ASCAPE) an intervention could lead to a significant improvement in their Quality-of-Life issues

In such cases, the patient is included in the Proactive Monitoring List (Figure 4). The entry for each patient includes a link to the patient's Patient Overview Page as well as a summary visualization of their current and predicted QoL indicators. The visualization element used to show the current and predicted QoL issues of each patient in the Proactive Monitoring List is the same radar chart used also in the Patient Overview Page (see below); it has the advantage of both providing information about individual QoL issues (the further away from the centre a QoL indicator is located, the more severe the issue is), but also giving an overview of the patient's QoL (the smaller the area occupied, the better overall Quality of Life the patient has).

The Proactive Monitoring List appears (only to the authenticated doctors of the Healthcare Provider) in the Home Page of the ASCAPE Dashboard (Figure 5). This is the first page the doctor will see upon logging into the Dashboard and the page to which he/she will return after completing any patient-specific use of the Dashboard.

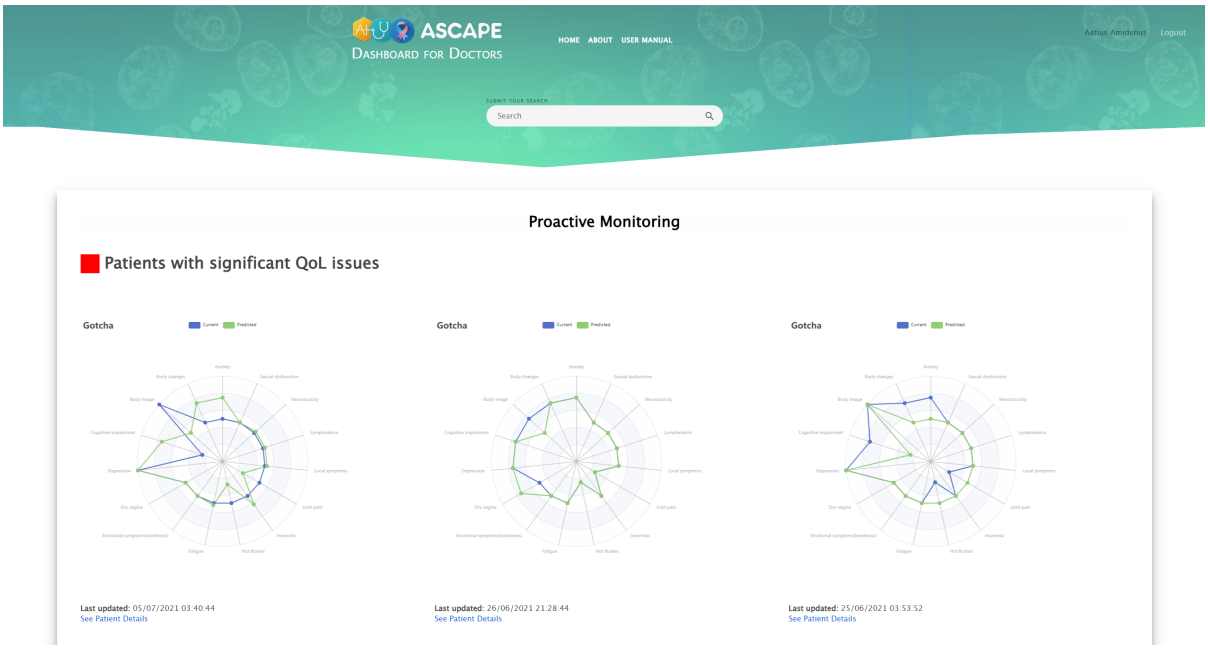

Figure 5 ASCAPE Dashboard Home Page

2.2 Patient Overview Page

The ASCAPE Dashboard's Patient Overview Page focuses on a single patient and aims to give to the doctor a visual summary of the patient's health status and display the most relevant information provided by the ASCAPE AI.

The Patient Overview Page was central to use case HP.1 in D1.1 and was designed

and implemented so as to satisfy the relevant requirements (including high usability and responsiveness requirements). It includes the following UI elements:

- **Patient Details:** Patient identification information, information about the patient that may be directly medically relevant or indirectly relevant (e.g., socio-economic status, education level). The latter type of information may affect the baseline QoL, their QoL sensitivity to external factors, as well as the likelihood they will follow the doctor's suggestions.

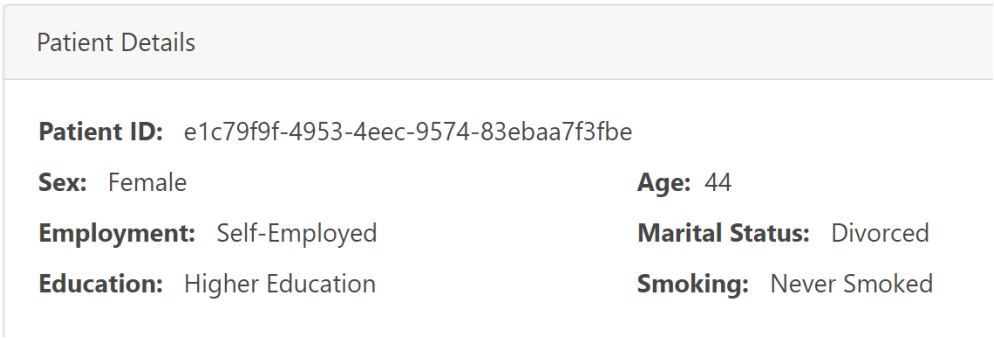

Figure 6 Patient Overview Page Elements: Patient Details

- **ASCAPE Participation Information:** Information on the patient's participation in ASCAPE (when it started, its status (if the patient is still an active participant or else when their participation ended), the number of questionnaires they have answered and the status of data update from their wearable device (if one has been registered)). This element also includes a simple interface for registering and unregistering a wearable device to provide activity data for the patient.

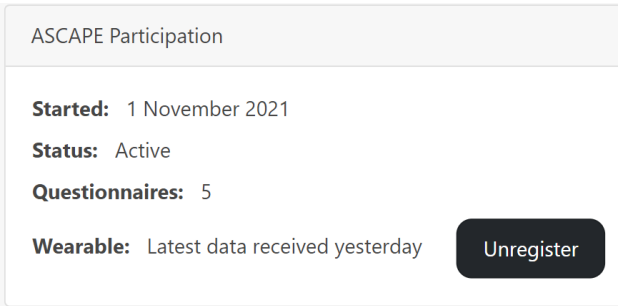

Figure 7 Patient Overview Page Elements: Participation Details

- **Information on Previously Suggested Interventions** (**Optional**)
Whether an intervention was followed or rather to what extent, and until when, is information collected from the patients. To support settings where this piece of data collection is not possible to obtain directly from the patients, but needs to be provided by their doctors, the ASCAPE Dashboard has a configuration option enabling an additional UI element where this additional bit of data entry can be made.

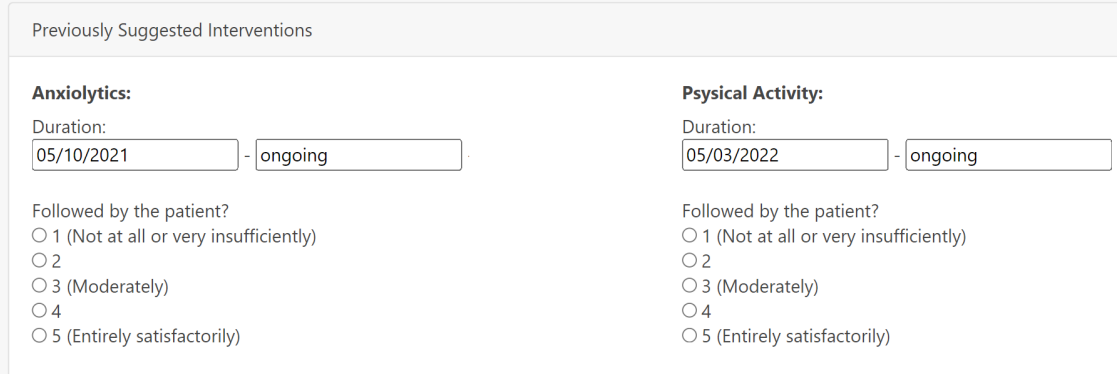

Figure 8 Patient Overview Page Elements: Previously Suggested Interventions

- **QoL Timeline:** The QoL timeline shows the changes of the patient's QoL (together with its predicted value, when ASCAPE is confident it can safely make such a prediction), in conjunction with the periods of different interventions.

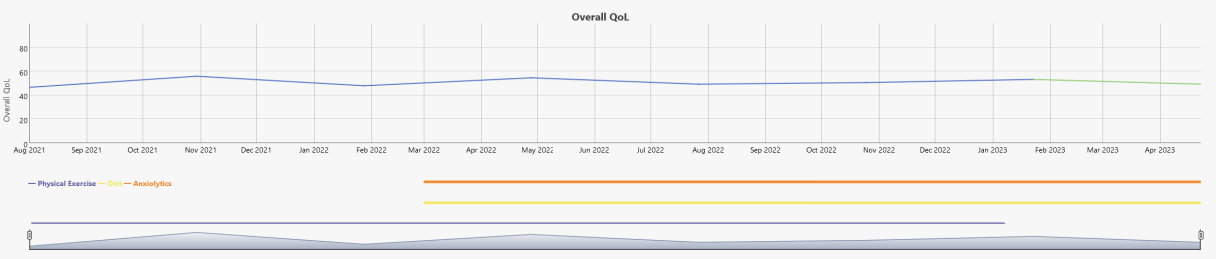

Figure 9 Patient Overview Page Elements: QoL Timeline

- **Intelligently prioritised QoL Issue Timelines:** Each QoL Issue timeline shows the changes of that issue's indicator (together with its predicted value, when ASCAPE is confident it can safely make such a prediction), in conjunction with the periods of different interventions. To help the doctor to focus his/her attention on the more relevant QoL issues the graphs are prioritised thus: first, the current severe QoL issues are displayed, followed by the QoL issues predicted to become severe (based on the current set of selected interventions), followed by moderate current QoL issues, followed by mid issues predicted to become moderate on the basis of the current set of selected interventions, followed by the remaining QoL issues.

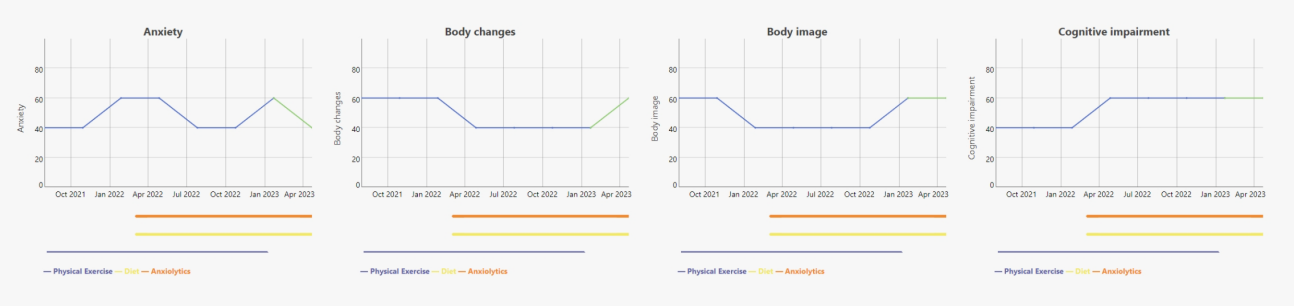

Figure 10 Patient Overview Page Elements: QoL Issues Timelines

- **QoL Issues Radar Chart:** A radar chart displaying simultaneously both the current QoL issue indicators and the corresponding indicators predicted by ASCAPE based on the currently selected list of interventions. The graph is accompanied by a textual listing of the current and predicted (non-mild) QoL issues meant as an aid of quickly deciphering the relevant information in the graph and will also be particularly useful to doctors not familiar with radar charts.

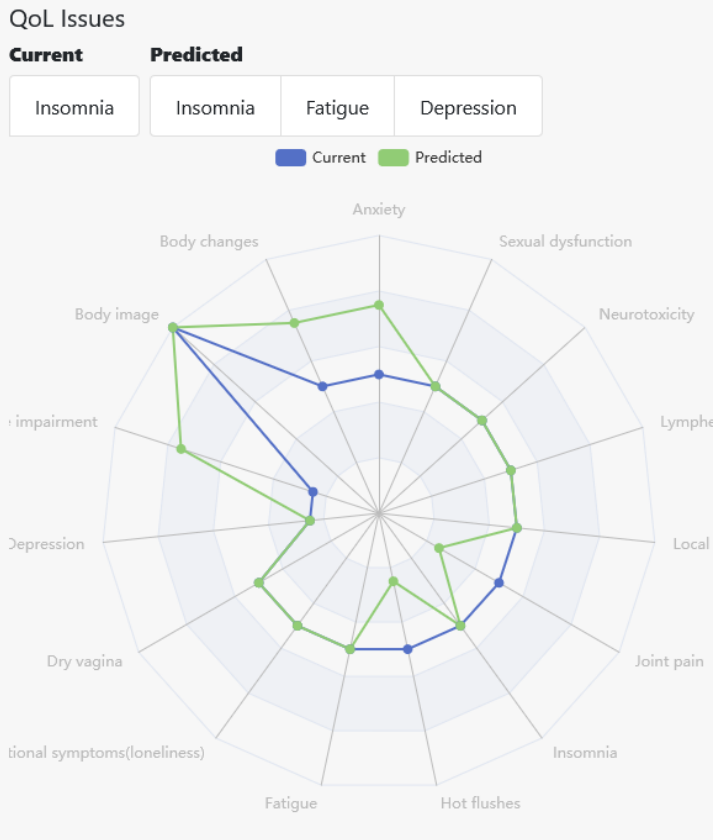

Figure 11 Patient Overview Page Elements:QoL Radar Chart

- **Interventions' catalogue:** A list of all available interventions foreseen by ASCAPE. Initially the currently active interventions from the previous follow up (if any) will be selected. Then, as the doctor selects and deselects

interventions, the predicted Overall QoL indicator and individual predicted QoL Issue indicators values change, and the aforementioned graphs depicting them get updated. This provides a very simple and effective way for doctors to query ASCAPE about its view on particular interventions (or combinations of interventions).

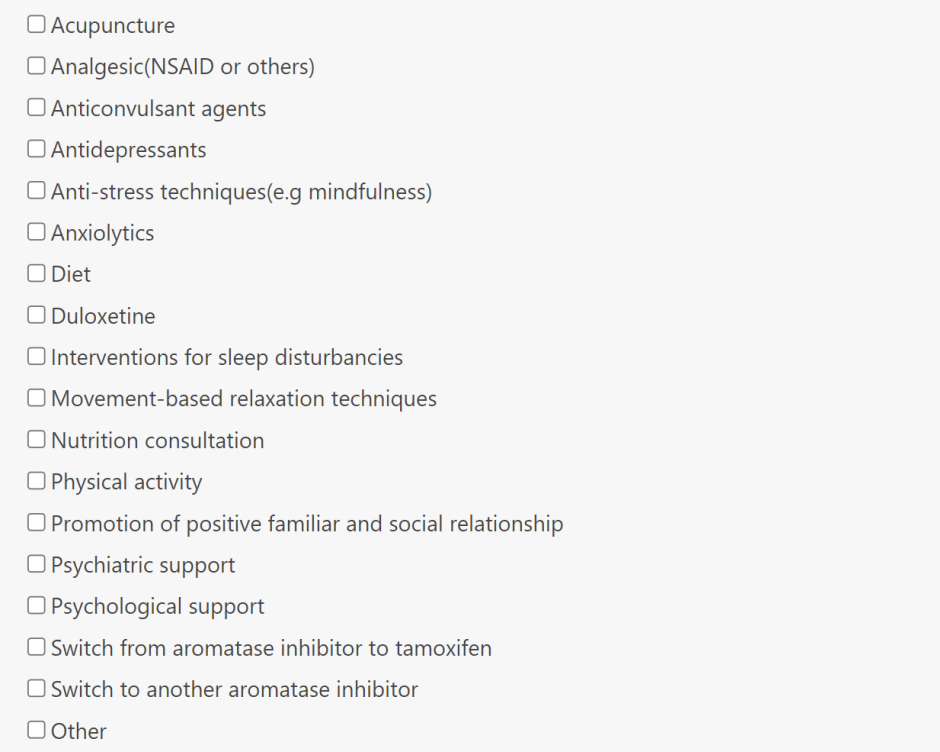

Figure 12 Patient Overview Page Elements: New Interventions

- **Interventions' selection shortcuts:** The list of interventions is followed by three shortcut links which change the selection of interventions in exactly the way their names suggest: No interventions (clears all intervention checkboxes), Currently active (ensures only the interventions followed by the patient at the moment they are selected), Proposed by ASCAPE (ensures only the interventions proposed by the ASCAPE AI are selected).

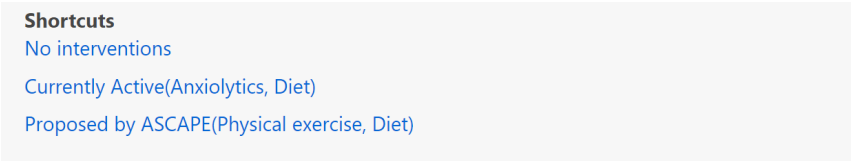

Figure 13 Patient Overview Page Elements: Interventions Selections Shortcuts

The overall arrangement of the components aims to provide a functional, intuitive, and uncluttered interface that at the same time provides interactivity where needed.

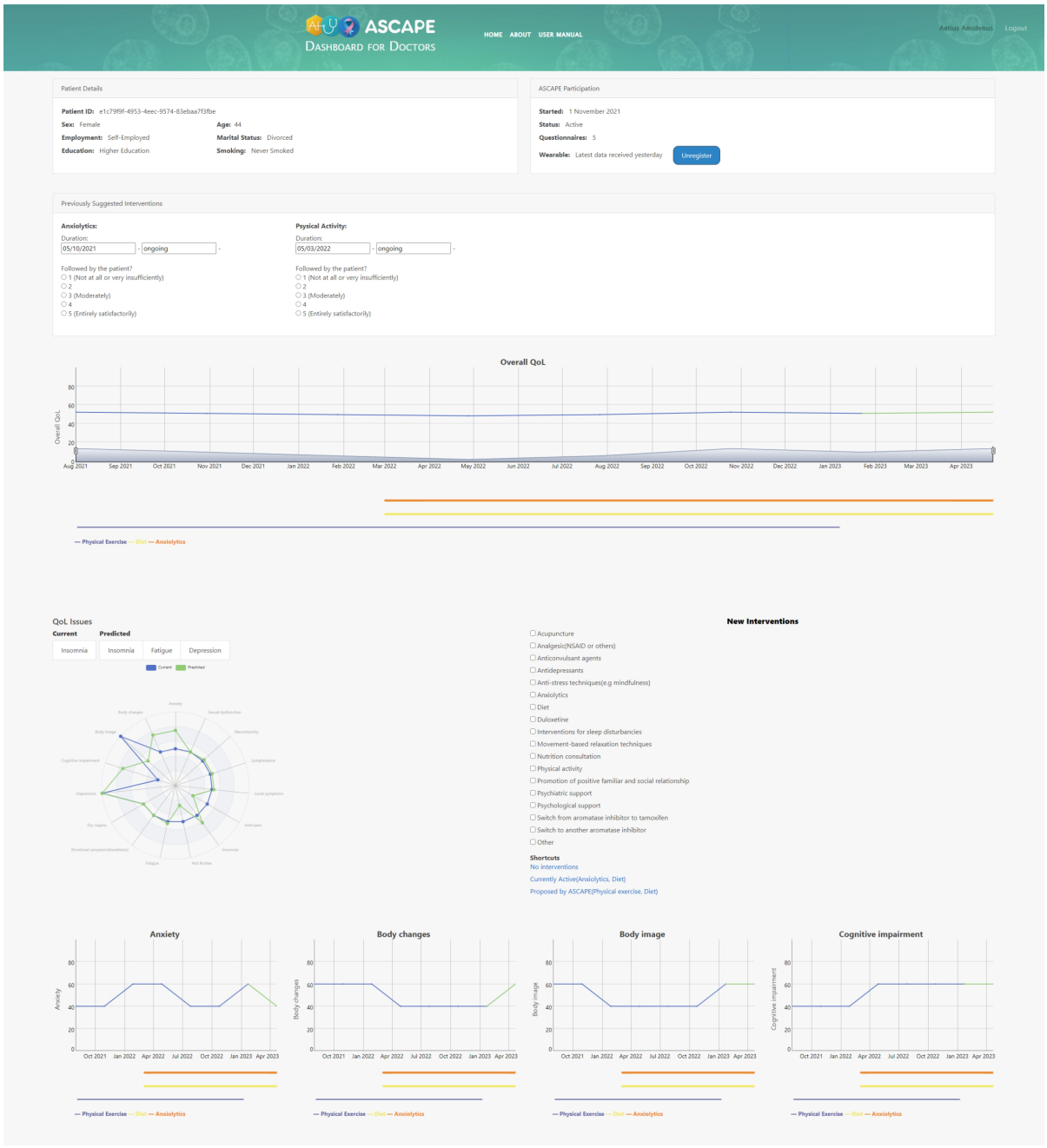

Figure 14 ASCAPE Dashboard Patient Overview Page

This interface is meant to:

1. Provide a quick overview of the patient's characteristics and their history (QoL and QoL Issues Timelines).
2. Enable the doctor to enter details regarding interventions suggested in the previous follow up (where the corresponding UI elements are enabled)

3. Present to the Doctor information that comes out of ASCAPE AI in a meaningful manner that helps the relevant information stand out. For instance, results for which ASCAPE is not confident will not appear. Results for which ASCAPE is confident and are judged by ASCAPE to represent a significant threat (of deterioration or continued low level) or opportunity (for improvement) for the various aspects of a patient's QoL will appear higher up and be displayed in a more prominent manner than results without those characteristics. In other words, ASCAPE AI is not only used for predictions and intervention suggestions, but also for dynamically shaping the UI for the Doctor in the Patient Overview Page.
4. Provide means of easily experimenting with different scenarios (different intervention suggestions) and seeing their effect on the ASCAPE predictions.
5. Provide an easy means for the doctor to record the interventions they suggested to the patient.

2.3 Visualization Elements in the ASCAPE Visualization Library

Given that the present section presented both the ASCAPE Dashboard and the ASCAPE Visualization Library concurrently, there need to be clarifications as to how much of the ASCAPE Dashboard UI is included inside the ASCAPE Visualization Library as this relates to the amount of work that will need to go into embedding ASCAPE visualizations into new or existing web applications. The present subsection will also present HTML code samples using the ASCAPE Visualizations Library to offer a better understanding of its technical design.

As explained in Section 1.3, the ASCAPE Visualizations Library automatically transforms visualization element placeholders into interactive visualization elements. Placeholders are HTML elements given a CSS class which allows the ASCAPE Visualizations Library to know what to turn them into. This process is initiated when a page is loaded. Moreover, the visualization elements are automatically synchronised with each other; thus, if the user clicks on an intervention, the QoL timeline visualization, the QoL issues timeline visualizations, the QoL issues radar chart visualization all automatically update to display the new prediction and if the user focuses on a different time period within the QoL timeline visualization, the timeline visualizations for the QoL issues automatically adjust to display the same time period.

This makes it possible to implement a large portion of the ASCAPE Dashboard functionality, by simply inserting a few lines in an HTML page, (or server-side code dynamically generating an HTML page). Figure 15 demonstrates how the library can be used to display the QoL timeline for a patient.

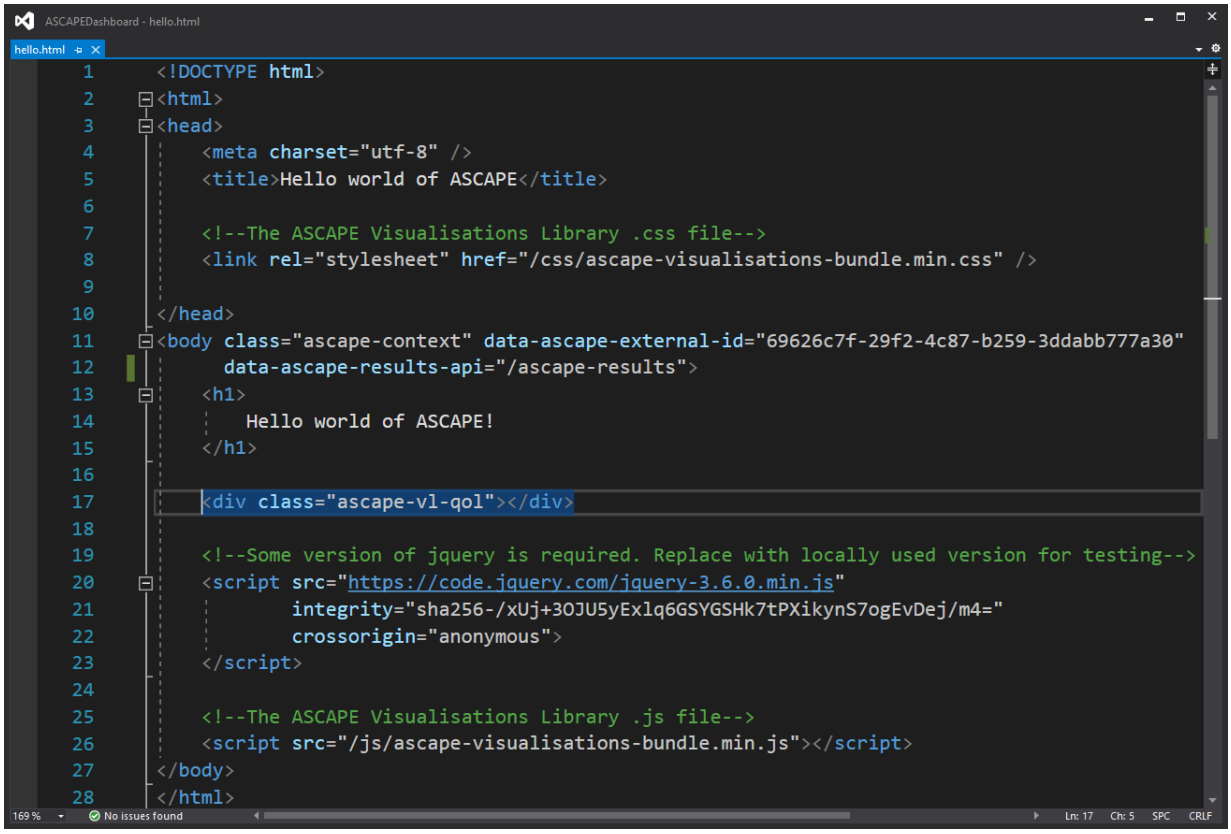

Figure 15 A minimalist example of using the ASCAPE Visualizations Library

The full list of currently supported visualizations in the ASCAPE Visualizations Library is presented in Table 1.

Table 1 Visualizations supported by ASCAPE Visualizations Library 1.0

Class	Visualization Element type
ascape-vl-proactive-monitoring	Figure 4 ASCAPE Dashboard Home Page – Proactive Monitoring List
ascape-vl-qol	Figure 9 Patient Overview Page Elements: QoL Timeline
ascape-vl-qol-radar	Figure 11 Patient Overview Page Elements:QoL Radar Chart
ascape-vl-qol-issues	Figure 10 Patient Overview Page Elements: QoL Issues Timelines
ascape-vl-interventions	Figure 12 Patient Overview Page Elements: New Interventions
ascape-vl-shortcuts	Figure 13 Patient Overview Page Elements: Interventions Selections Shortcuts

Figure 16 shows the portion of the ASCAPE Dasboard Patient Overview UI provided by the ASCAPE Visualizations Liibrary; it includes the core visualization and

interaction elements that doctors will be using on a regular basis.[2]

Figure 16 Patient Overview section implemented via the ASCAPE Visualizations Library

Figure 17 highlights the code required to add this functionality to the ASCAPE Dashboard ‘s Patient Overview Page.

[2] ASCAPE Visualizations Library v1.0 does not include functionality for the Patient Details element (Figure 6) as the content there comes from the extant Healthcare Information Systems and they already have a way of displaying it that is familiar to doctors. The ASCAPE Participation element (Figure 7) will be included in an upcoming version of the library.

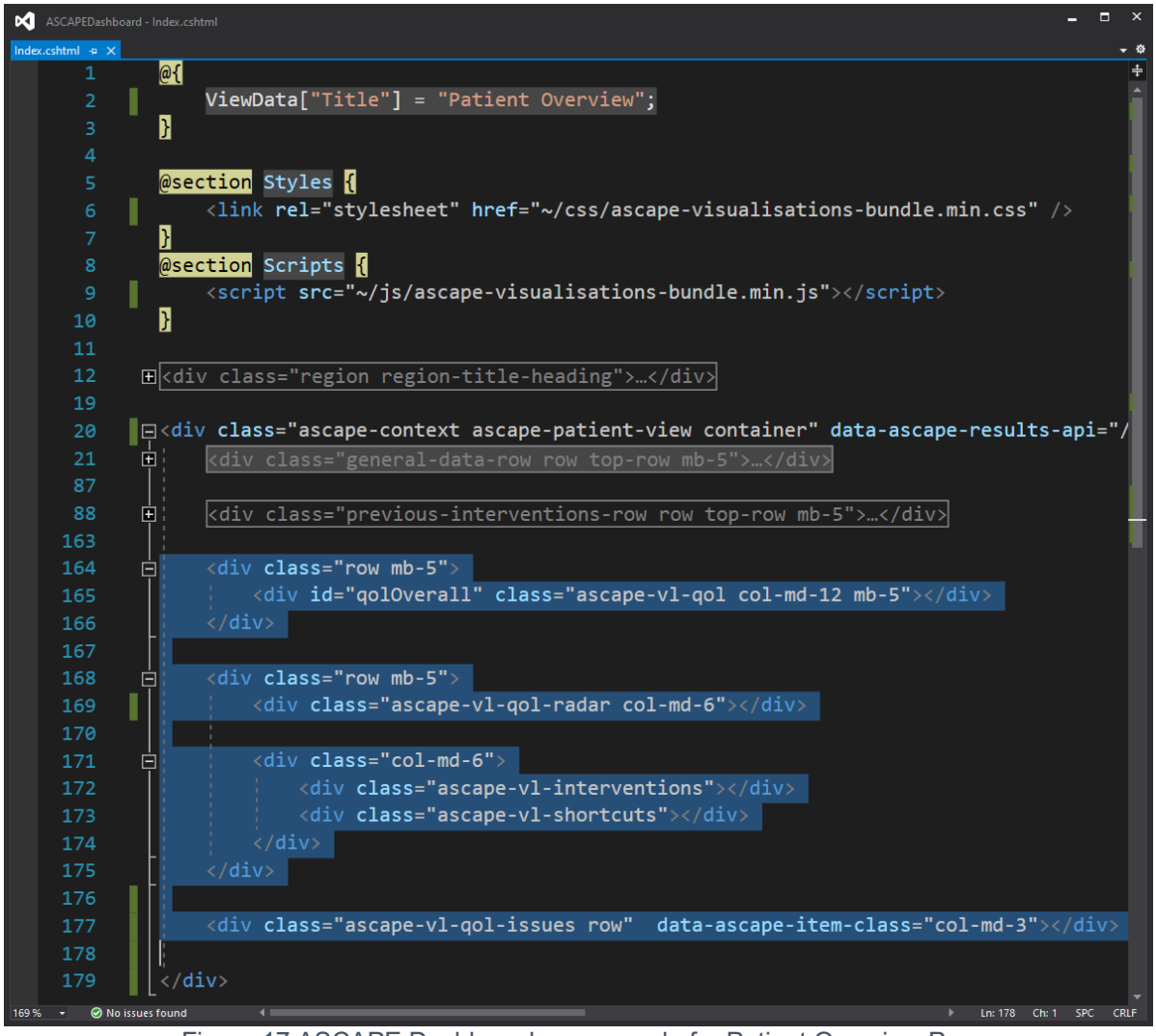

Figure 17 ASCAPE Dashboard source code for Patient Overview Page

Just as there was an aim to hide the complexity of the ASCAPE AI infrastructure behind an intuitive user interface, there was a similar aim to hide that complexity and the complexity of the ASCAPE UI from software engineers integrating that UI inside existing Healthcare Information Systems. This simplicity can be demonstrated both with the simple HTML page example of Figure 15 but also with the source code of the ASCAPE Dashboard's Patient Overview Page in Figure 17. Moreover, if additional cancer types, attributes, QoL issues or interventions, or even translations of literals in different languages are added to ASCAPE, the visualizations will be capable working with these automatically, without any need to change the code or upgrade the library. This is because the library uses meta-data from the Edge Node rather than hard-code QoL issues, interventions etc. Finally, if additional visualizations are available in the future, they will be very easy to add to a web page and they will interact in the appropriate manner with existing elements powered by the library.

2.4 Features Under Development

A number of developments are underway within Task 4.1 and the overall project workplan, which are considered for inclusion in the second version of the Dashboard and the ASCAPE Visualizations Library. As the report is focused on their first versions, below we offer a short glimpse of that work.

2.4.1 Explainability

The AI predictions for Quality of Life and the proposal of interventions were developed with intention of being explainable and interpretable by the patient and the medical staff. These explanations require no technical knowledge about the inference of the result carried out via machine learning models and instead only references terminology from the medical domain. Our current work on explainability evolves in three directions:

1. **Feature Attribution:** It is intended, that for each prediction, Feature Attribution will be supported, using the SHAP [2] library. For each variable used for a prediction (medical data, environmental data, reported QoL from past, etc.) a value will be assigned. This value will determine how strongly the feature contributed to the prediction. It can be interpreted as “compared to the of this average value, this value increased/decreased to prediction by <feature attribution>”. To visualise these features, they can be plotted, for example as a bar chart or waterfall diagram as shown in Figure 18 created using the “SHAP” python library. Each feature increases or decreases the predicted QoL according to the LiSat-11 questionnaire. The final prediction is 49,9 points. For better readability, the feature attributions of multiple variables can also be summed up and be shown as a single value (Figure 19).

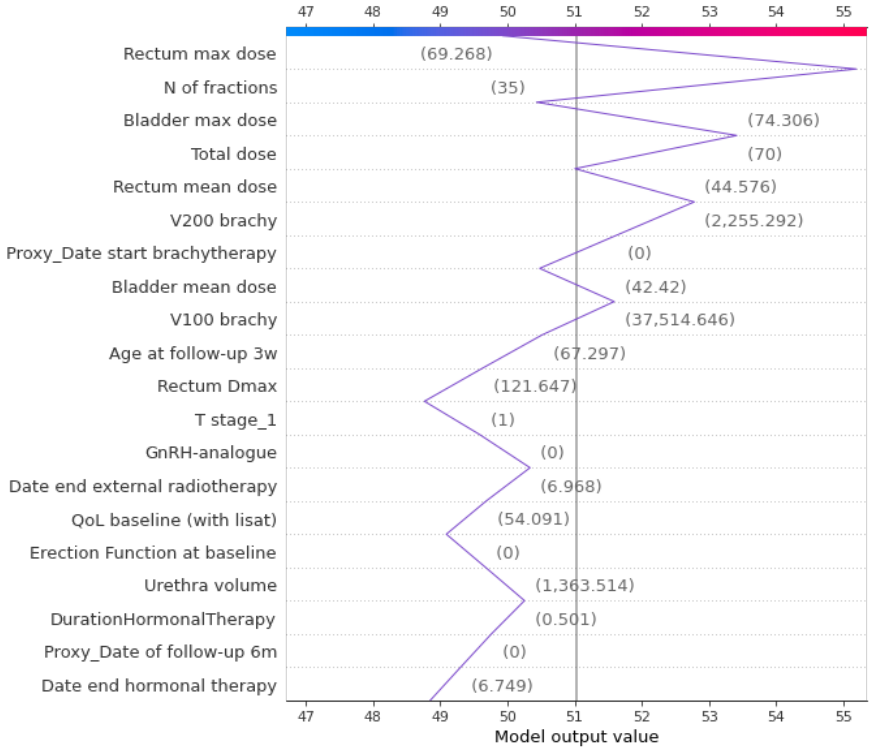

Figure 18 Example of a visualization of feature attribution values

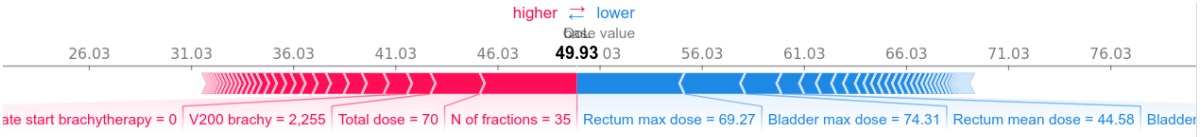

Figure 19 An alternative way to present feature attribution.

2. **Simulations:** A central part of the ASCAPE platform is highlighting treatments and medical interventions and showing them on the dashboard. By inferring these values with simulations, more information can be provided to the user. First, for each medical intervention the average treatment effect is determined. Then, a prediction is being made on how these changes are expected to change the predicted quality of life and risk of quality-of-life-issues. This way the dashboard can not only highlight the recommended interventions, but also give an estimation on how accurate these are.

3. **Surrogate Models:** Surrogate models are interpretable AI models that approximate the output behaviour of any model used in ASCAPE. While the surrogate models are not essential for the personalised predictions of a patient, they can provide insight to the decision mechanisms of an AI model. ASCAPE will make use of two different types of surrogate models: (a) Linear/Logistic Regression Models where every input feature is weighted by a factor and (b) Decision Trees which use simple “if…then…”-rules to infer a prediction.

2.4.2 Other Ongoing Work

Explainability-oriented visualizations may be the major technical feature of the second version of the ASCAPE Dashboard, but there is also additional ongoing work in a number of different directions. The different areas of focus of this work are described below:

Visualising Wearable Data and Weather Data:
During the past few months, significant effort has been made to finalise the ASCAPE Data Model, especially with regards to Wearable Data and Weather Data. D2.2 also to be delivered by M18 of the project details the decisions reached. These decisions mark an important milestone and enable Task 4.1 to continue as planned with the design of appropriate ways of incorporating those additional data into Patient Overview visualizations, as well as explainability visualizations.

Comparisons:
The one feature foreseen in the D1.3 wireframe diagram for the Patient Overview Page that is missing in the current implementation is the feature of comparing the effects of different sets of interventions. This was because its draft design was obstructing the main functionality and cluttering the User Interface. There is currently preliminary work on alternative designs, that will be evaluated for inclusion in the second version that could enhance user experience and not suffer from those drawbacks.

Other New Features:
The design of the ASCAPE Dashboard and the ASCAPE Visualizations Library will continue in the upcoming months. The aim will be to identify useful additional features, integrate them into the current design while avoiding complicating the design for no apparent benefit to most doctors.

3 ASCAPE Doctor User Interfaces in the Pilots

The ASCAPE Dashboard and the ASCAPE Visualizations Library can help bring ASCAPE functionality to doctors in a wide variety of sites, with different IT infrastructures and different degrees of control over that infrastructure. This section aims to shows how this is achieved in the four ASCAPE pilots, demonstrating why both the ASCAPE Dashboard and the ASCAPE Visualizations Library are valuable outputs of the project that can not only support its four pilots, but could, in the future, support a wide range of other clinical and non-clinical environments.

3.1 ASCAPE Visualizations in the Context of the Four ASCAPE Pilots

This section presents the overall context of the use of ASCAPE by doctors in the four ASCAPE pilots. It discusses information systems used, provides a glimpse of the wider user experience, and provides enough information to evaluate the benefits of ASCAPE's architectural approach.

3.1.1 Orebro/Uppsala Pilot

In Sweden, fully implemented Electronic Medical Records (EMR) solutions in hospitals and primary care centres are used since the late 2000s. Due to the different EMR solutions across the country, the National Patient Summary (NPÖ) was initiated in 2009 to allow healthcare providers to access patients' records stored at another provider if certain legal requirements are fulfilled. EMRs are accessible for patients as well [3]. However, as the Orebro and Uppsala Hospitals do not have direct access to the code and the data of the EMR solution used, integration with a research project's platform either at the level of data or at the level of UI would be unrealistic.

The electronic system that will be used for prospective data collection and integration to ASCAPE in Orebro/Uppsala pilot is the electronic data capture platform SMART-TRIAL. This platform is commonly used as data capture system in clinical trials at both Orebro and Uppsala, so most doctors are familiar with it. The main advantage of SMART-TRIAL in relation to EMRs is that SMART-TRIAL can be designed to fit the purpose and specific needs of each clinical trial, on this case the ASCAPE Orebro/Uppsala pilot. One initial concern with regards to using SMART-TRIAL was the ability to export its data and make them available to ASCAPE. This was resolved by means of an export function provided for the Orebro and Uppsala deployments of SMART-TRIAL, allowing the corresponding SMART-TRIAL – ASCAPE data bridges to transfer data into the corresponding Orebro and Uppsala Edge Nodes so that they can, eventually, be made available to via the Dashboard installations for each of the two hospitals.

In clinical trial setups such as this, there is a degree of duplication of effort in keeping both the Hospital EMR system and the clinical trial system (SMART-TRIAL) up to date, but in the context of research-oriented hospitals this is not unusual. Besides, the bulk

of data in ASCAPE are collected from patients themselves, with the help of SMART-TRIAL. The duplication of effort arising from the use of SMART-TRIAL primarily concerns providing the initial data about the patient when registering him/her in the clinical trial.

The use of the ASCAPE Dashboard will be, as far as doctors at the two hospitals are concerned, a novelty of the ASCAPE trial. After doctors provide information about previous follow-up interventions, they will be able to examine the course of their patient's QoL and QoL issues using the ASCAPE visualizations in the Dashboard, see which interventions ASCAPE proposes, experiment with different interventions and see ASCAPE's predicted effect of these interventions on both the overall QoL of the patient, as well as on specific QoL issues. Once they have decided on which interventions they will suggest to their patient, they will finalise them (having first discussed them with their patient, possibly using ASCAPE's results and visualizations in the conversation, where applicable). In the second version of the Dashboard, doctors will also be able to obtain additional explanatory results though ASCAPE explainable AI visualizations as well as use additional functionality added in that version. After finalising the interventions on the Dashboard, they will also need to update the hospital's EMR system.

3.1.2 Barcelona Pilot

The Hospital Clinic of Barcelona (HCB) have been using different Electronic Health Record (EHR) systems since 1998 and became a paperless hospital around 2003-2005 with the implementation of SAP ISH Med. In general, the capacities of commercial systems to store clinical information derived of clinical practice is limited and clinical information is usually stored and managed by physicians with precarious tools, such as spreadsheets. For this reason, the Medical Informatics unit of the HCB developed OntoCR, a semantically interoperable clinical repository based on ontologies [4] and conforming to the CEN/ISO 13606 standard [5].

OntoCR is being used regularly in different projects of the HCB for more than ten years and is becoming more and more integrated with the rest of clinical information systems in use, both in hospital care (at HCB) and in primary care, specifically at Primary Care Centres (PCCs) in the wider Barcelona Region.

The patients eligible to be included in the Barcelona pilot are patients that belong to a pre-existing cohort of breast cancer patients. These patients are in a program of shared care in the HCB and in Primary Care Centres in the wider Barcelona region supported by OntoCR. Physicians, both in HCB and Primary Care Centres, access clinical data in OntoCR through their respective EHR systems.

Data collection for the Barcelona pilot will be entirely electronic using OntoCR, which has been specifically adapted to integrate ASCAPE and the data collection tools needed for this pilot. Thus, OntoCR is the centralised platform where clinical data will

be stored and where questionnaires will be completed. It is also the platform which ASCAPE will enhance upon full integration, producing predictions and intervention suggestions which will be made available to doctors though the ASCAPE Visualizations Library.

3.1.3 Athens Pilot

Data collection for the NKUA pilot will be entirely electronic using an NKUA-developed Prostate Cancer Electronic Health Record (EHR) information system. A fully ASCAPE-integrated version of the system will support the NKUA ASCAPE trials at the Urology Department of Sismanoglio Hospital, while an earlier version is already in use, collecting data from patients recruited into the NKUA ASCAPE study, but not yet offering ASCAPE functionality to doctors.

In addition to managing information about patients and follow-ups, the NKUA system allows questionnaires to be filled electronically (directly by patients or with the help of the clinic's staff) and makes those questionnaires (with their scores) available to doctors at the clinic. ASCAPE visualizations are expected to help doctors provide better interventions advice based on information displayed and ASCAPE AI-predictions and intervention recommendations but also include ASCAPE's proactive monitoring capabilities.

3.1.4 CareAcross Pilot

CareAcross is a UK-based SME providing free information and guidance to people suffering from cancer or dealing with Quality-of-Life issues after treatment. Users of the service register online, are asked to fill in short questionnaires, and receive material automatically from the CareAcross system by email shortly after they do so. CareAcross makes it a point to clarify to users that it does not provide medical advice and ultimately aims to improve the patients' relation with their doctor, not pose as an alternative venue for obtaining medical advice. The content selection and advice sent to CareAcross users is currently determined on a rules-based approach and is fully automatic.

Yet in the context of the ASCAPE trial runs, CareAcross will fully respect the fact that ASCAPE is designed to inform a doctor's suggestions to a patient rather than act autonomously in providing the patient with intervention suggestions. Patients who want to participate in the CareAcross ASCAPE study for a twelve-month period (same as in other pilots) will not receive advice from CareAcross's rules-based system. Instead, patients will receive intervention suggestions by a doctor with expertise in cancer who will have available ASCAPE's predictions and intervention suggestions through the ASCAPE Dashboard. These suggestions will be accompanied by relevant text that will guide the patient to discuss them with their treating physician, who is the one responsible for providing them with medical advice.

The data used by ASCAPE will be the data submitted by the patient through the

CareAcross platform, including medically relevant data obtained during registration and answers to CareAcross's pilot's questionnaires.

3.2 Lessons from the Four Pilots

Looking at the pilot systems as case studies for how ASCAPE can be integrated with existing system clearly shows the advantage of offering both the ASCAPE Dashboard and the ASCAPE Visualizations Library as options:

- The ASCAPE Dashboard was the natural option for the Orebro/Uppsala pilot, where the code of neither SMART-TRIAL, nor the hospital's EHR system was available for modification, but also in the CareAcross pilot where there was no system for doctors to begin with.

- The ASCAPE Visualizations Library nearly trivialises integration at the UI-level in cases where this is both possible due to control over the system's source code and highly desirable (if not necessary) for usability reasons as was the case in the Athens and the Barcelona pilot, especially with the latter involving a large number of doctors in Primary Care Centres in the Barcelona region who have no direct contact with the ASCAPE project and expect to be able to do their job in an easy manner without having to use an additional new information system.

By offering both solutions the ASCAPE Consortium not only to accommodate the four pilots, but also make a step towards addressing the needs of different clinics and hospitals, or bodies overseeing healthcare on a regional or national level.

Table 2 Doctor's access to ASCAPE functionality

Pilot	Access to ASCAPE Functionality
CareAcross & Orebro/Uppsala	Via the ASCAPE Dashboard
Athens & Barcelona	Via own HIS enhanced with ASCAPE functionality using the ASCAPE Visualizations Library

4 Conclusions

This deliverable marks an important milestone in the evolution of the ASCAPE Platform, as it presents the core ASCAPE User Interface, namely:

- the visualization for a patient's Overall Quality of Life (together with the time-period selection control) accompanied by interventions visualization
- the intelligently prioritised individual Quality of Life Issues visualizations (each accompanied by an interventions visualization)
- the QoL issues radar chart (together with its textual companion listing the most important QoL issues)
- the interventions selection control allowing doctors to both experiment with the effect of different interventions and inform ASCAPE of the interventions they have selected for the patient

The interface design for the patient overview page has avoided cluttering the doctor's view with a multitude of options that would potentially confuse or distract; it has separated the doctor's view in clearly distinguishable areas (Figure 14) each with a clear purpose (see Section 2.2), and enriched the individual visualizations foreseen in D1.3 wireframe diagrams. The new content-rich timeline visualizations (Figure 9 and Figure 10) allow possible causal correlations between interventions and an observed change in one or more QoL issue graphs and the overall QoL graph to be identified visually by the doctor. Finally, the proactive monitoring list (Figure 4) offers potentially very useful functionality to doctors allowing them to intervene when a patient is identified by ASCAPE as having serious current or predicted QoL issues, as well as when, though intervention, there are predicted to be opportunities for significant improvements.

All targets for the first (M18) version of both the ASCAPE Dashboard and the ASCAPE Visualizations Library have been met, and T4.1 work is underway for producing the second (M24) version (Section 2.4). Specifically, it will include:

- Exploration of designs for visualising auxiliary data sources, specifically weather data and wearable device data
- Exploration of designs for explaining ASCAPE AI predictions and suggestions
- Explorations of designs for more involved interaction with the ASCAPE UI for doctors (e.g., comparing the effect of different sets of interventions)

As the ASCAPE Consortium aims to see ASCAPE widely used, Task 4.1 has focused also on making the visualizations available in the context of different existing (or new) Healthcare Information Systems. This lead to the packaging of the core functionality of the ASCAPE Dashboard inside a reusable, open-source visualizations library which can be used in web-based Healthcare Information Systems to provide ASCAPE functionality to doctors using them (Sections 1.3 and 2.3). Providing both the ASCAPE

Dashboard and the ASCAPE Visualizations Library as alternative pathways towards offering ASCAPE functionality to doctors does not only serve future exploitation scenarios. Viewing the four ASCAPE pilots as integration case studies, clearly reveals the benefits of being able to offer both alternatives (Section 3.2).

5 Annex I. Source Code

The implementation of the ASCAPE Dashboard and the ASCAPE Visualizations Library is currently on a private repository and access can be given upon request.

Both the ASCAPE Dashboard and the ASCAPE Visualizations Library will be released as open-source and will be made available on a publicly accessible repository.

6 References

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