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The ProACT project has received funding from the *European Union's Horizon 2020 research and innovation*

Release History

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V0.1	03/10/2016	D	Initial Draft (M10). Updates to this document will be available in M22 and M39.	Shane Gavin
V0.2	13/10/2016	D	Internal proof-read	Suzanne Smith
V0.3	23/10/2016	D	Revised based on Internal Reviews by Salvatore Tedesco and Nuwani Edirisinghe	Shane Gavin
V0.4	27/10/2016	D	Proof and review before submission	Caoimhe Hannigan / John Dinsmore
V1.0	28/10/2016	C	Deliverable for submission	Shane Gavin

*Status of deliverables is indicated by abbreviations/terms as follows:

Draft (D): The deliverable is partially complete or complete but under review/revision before release.

Complete (C): The final deliverable document is 100% completed, reviewed and authorised for release by the partner responsible for the deliverable or the WP leader.

Revised (R): The final released document has been modified/updated with new content.

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Acronyms and Abbreviations

API	Application Programming Interface
CABIE	Context-aware Brokering and Inference Engine
ICT-AT	Information Communication Technology – Assistive Technology
PoC	Proof of Concept (Trial)
PwM(s)	Person(s) with Multimorbidity
RTT(s)	Round-trip Time(s)
SIMS	Subject Information Management System

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Executive Summary

The **overall aim of ProACT** is to develop an open web application programming interface (API) ecosystem to integrate a wide variety of new and existing technologies to pull, aggregate and analyse data for the purposes of higher order inference, and to improve and advance integrated care for multimorbidity (including associated comorbidities). The ecosystem will connect four key care and support models central to understanding and implementing effective, continued and coordinated patient centric care (including self-management). These models are: 1) homecare (including informal care) 2) hospital care 3) community and social care and 4) social support networks.

This document presents initial evaluations of areas in which the ProACT ecosystem's performance can be measured at a macro level, producing outputs relevant to project researchers and technical teams. **Section 1** serves as an introduction to the document scope. **Section 2** describes categorisations for analytics in the ProACT ecosystem, and identifies the areas in which analytics to measure ecosystem performance will operate. **Section 3** presents an initial list of 15 areas for measuring ProACT ecosystem performance. **Section 4** lists the data requirements for the area of analysis presented in section three. Finally, **section 5** identifies those analytics which are planned for integration in time for ProACT's friendly trial.

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1 Introduction

The ProACT technology platform incorporates a wide range of hardware sensing devices, and both user-facing and infrastructural software components which intercommunicate and data-share through application programming interfaces (APIs). A core function of this technology platform is the collection and dissemination of volume data relating to individuals engaged with ProACT systems, inclusive of persons with multimorbidity (PwMs), formal and informal carers, health care professionals, and other actors providing supports for improved self-management by those living with multiple chronic health conditions. These data sets are used, and added to, by a core set of person-centric analytics which operate on available data for individual stakeholders in the ProACT ecosystem (CareAnalytics). While these analytic methods underpin the functionality and goals of the ProACT platform, their direct outputs do not facilitate inspection of the technology ecosystem at a higher level, nor are they positioned to inspect or evaluate aspects of the platform's technical performance on an on-going basis.

The analytic methods presented in this document augment these person-centric methods and can be broadly described as "aggregate", "technical", or "meta" analytics—i.e. analytics which are designed to inspect the ProACT ecosystem at a macro level, covering areas such as technical performance and availability; aggregation and comparison of person-centric analytics per trial site; and system usage and engagement levels at trial site and global levels.

While person-centric analytic methods and those described in this document may exhibit areas of conceptual overlap, the two categories are ultimately differentiated by the intended audiences for their outputs. Person-centric analytics produce outputs relevant to *users* of the ProACT ecosystem (PwMs, support actors, etc.). The analytics detailed here--those which measure ecosystem performance--by contrast, produce outputs relevant to entities involved in the *development* or *evaluation* of the ProACT system. This distinction is examined in further detail in section 2 of this document.

Analytics which measure ecosystem performance will operate on data available from, or generated by, three of the ProACT technology platform's core systems. These are:

- **CareApps:** Interactive dashboards which provide tailored interfaces and bidirectional feedback mechanisms for multiple ProACT ecosystem stakeholders. These are used to deliver scheduled surveys and behaviour change training and support to PwMs; to connect care network stakeholders; and to assist in everyday condition management tasks.

- **CABIE**: A novel data collection and aggregation system which connects to a wide range of device manufacturer data stores, through a mixture of both open and proprietary gateways and APIs. Employed for local data aggregation. Includes the SIMS (Subject Information Management System) module which, among other functions, manages PwM information, and access rights for CABIE data and CareApps.

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- **InterACT:** A cloud-based platform for secure and scalable federated storage, mining, and analysis of de-identified PwM data. Employed for global data aggregation, and the central location for person-centric analytic data.

For a full overview of the ProACT technology platform, readers are referred to D2.5 (*ProACT Platform, 1st Release*) which details all components and their interactions.

2 Categorisations of Ecosystem Performance Analytics

Analysis of ProACT ecosystem performance will be undertaken in a variety of conceptual categories targeting a number of output consumers. This section provides an overview of all analytics which will operate on ProACT data, presents general categorisations for the analytics presented in this document, and identifies target consumers for outputs from same. In addition to the initial set of categories presented below, feedback from system stakeholders will be examined throughout the course of the project to identify additional areas of desirability for ecosystem analysis. Updated categorisations for analyses will be available in future versions to this deliverable (due M22 and M39). For brevity, analytics which measure elements of ProACT ecosystem performance will, hereafter, be referred to as *Ecosystem Analytics*.

2.1 Resolution of ProACT Analytic Types

Analytics within the ProACT ecosystem will operate on a variety of data sets and in a variety of locations. At a high level, analytic methods will have access to data stored in either, or both, of the project's local or global data stores. Here, the term *local store* refers to raw PwM data stored in CABIE aggregators. The term *global store* refers to the InterACT cloud which stores de-identified PwM data from all trial sites in a centralised location. For the purposes of this document, the datasets and PwM groupings on which analytics operate are referred to as an analytics' *resolution*. Figure 1, below, illustrates the 4 primary resolutions available within the ProACT ecosystem, and the remainder of this section details each of these, identifying the resolutions at which ecosystem analytics will operate.

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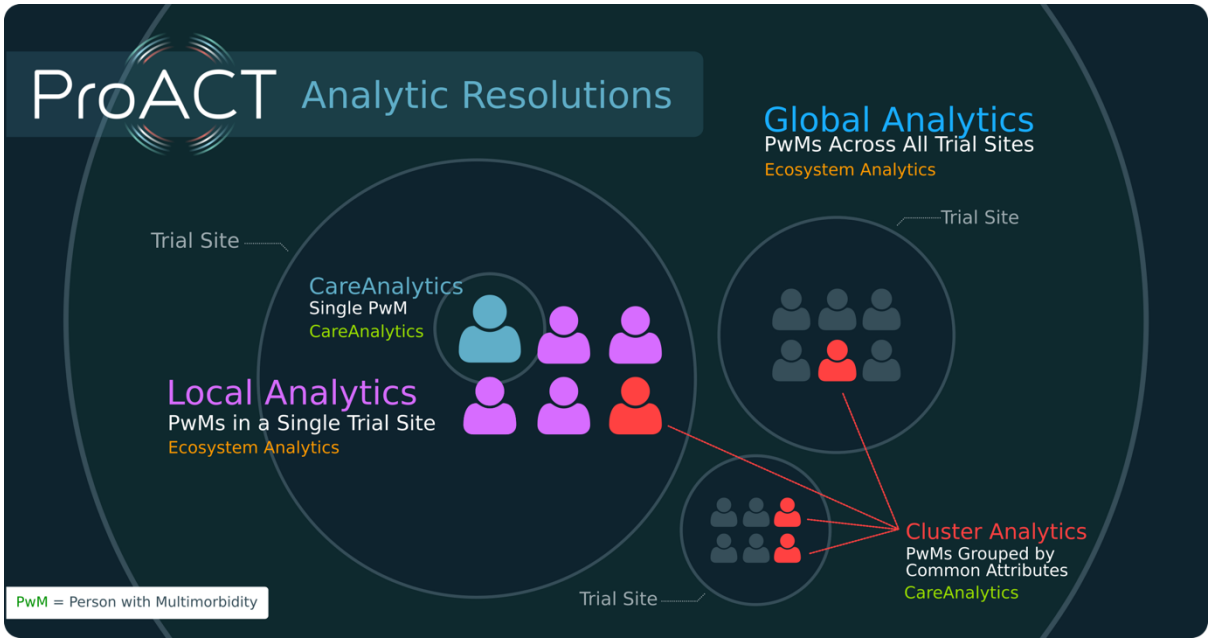

Figure 1: Categories of ProACT Analytic Resolution

2.1.1 PwM (CareAnalytics)

Person-centric analytics within the ProACT ecosystem, referred to as CareAnalytics, are contextually-aware procedures or algorithms which can detect and react to current or historic data in the ProACT system. These are used to track and monitor clinical and non-clinical parameters for multimorbidities, condition management and condition status; and to inform learning, guidance, and care pathways for PwMs. CareAnalytics, as a general rule, operate on individual PwM data to produce output relevant to individual PwMs, or other stakeholders in their care networks. With the exception of one special case which crosses resolution boundaries for technical reasons (see Section 3, Table 1, Analysis Area 14), Ecosystem analytics within ProACT do not operate at this level, but will make use of outputs from analytics which do. Descriptions of ProACT CareAnalytics can be found in D3.1 (*A Machine-processable Representation of the Individual and the Analytic Models*), D3.2 (*A Set of Person-centred Analytical Methods for Risk and Outcomes*), and D3.5 (*A Machine-processable Catalogue of CareApps*).

2.1.2 PwM Clusters (CareAnalytics)

PwM Clusters are special-case groupings of CareAnalytics which examine PwMs who share attributes such as age, gender, or commonalities in outputs from other analytic methods. Ecosystem analytics do not operate at this level, and as a general rule will not make use of output from analytics which do. Descriptions of PwM clustering can be found in D3.2 (*A Set of Person-centred Analytical Methods for Risk and Outcomes*) and D3.5 (*A Machine-processable Catalogue of CareApps*).

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2.1.3 Local Ecosystem (Ecosystem Analytics)

Local Ecosystem Analytics in ProACT operate on PwM and technical data available at the individual trial site level. These analytics examine aspects of each trial site in isolation, to produce output relevant to research and technical teams directly involved with the site's operation and evaluation. These analytics aggregate data at the local level (via CABIE), however, they may also leverage data from the project's global store (InterACT) which directly relates to PwMs within a given trial site (e.g. the output from PwM CareAnalytics). While these analytics operate at the trial site level, their outputs will be available at a global level to allow for comparisons between trial sites.

2.1.4 Global Ecosystem (Ecosystem Analytics)

Global Ecosystem Analytics in ProACT operate on PwM data available in the project's global store (InterACT), and on aggregated outputs from Local Ecosystem Analytics. These analytics examine aspects of the overall ecosystem and produce output relevant to research and technical teams across all trial sites. These analytics aggregate data at the global level (InterACT) and will operate on a mixture of de-identified global PwM data, and the outputs from Local Ecosystem Analytics which have been made available to the global store by local aggregators (CABIE). Outputs from these analytics will most commonly take the form of comparisons between trial sites.

2.2 Conceptual Categorisation of Ecosystem Analytics

This section defines three conceptual categories for Ecosystem Analytics which group individual analytics by intended output usage. It should be noted here that any single analytic may intersect more than one of the following categories.

2.2.1 Technical Analytics

Technical analytics examine elements of performance and reliability with regard to ecosystem technology components, specifically targeting the identification of issues which might affect availability or responsiveness of ProACT systems to end-users (PwMs and support stakeholders). As example, technical analytics might perform real-time (or more accurately, close-to-real-time) evaluations of the load being exerted on ProACT servers. Outputs from this type of analytic can be utilised to generate alerts for technical teams indicating a need to intervene during short-term periods of performance degradation, or may be utilised in historical context to identify recurring data processing bottlenecks. As a general rule, technical analytics will operate at local resolution.

2.2.2 Comparative Analytics

The comparative analytic category covers those analytics which compare two or more like elements of the ProACT ecosystem at either local or global resolution. This is a broad category which could, as example, include analytics which compare PwM or other stakeholder

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engagement levels between different CareApps, different types or makes of devices, or compare these values between trial sites. Comparative analytics can also be employed to examine the differences between PwMs in each trial site by gathering local averages of CareAnalytic outputs. As example, a comparative analytic might calculate the average "wellness" score for each trial site, locally, then evaluate the differences in average wellness between trial sites, globally. As a general rule, comparative analytics will operate on outputs from other Ecosystem and CareAnalytic methods.

2.2.3 Engagement and Retention Analytics

Engagement and retention analytics measure PwM and support stakeholder engagement with technology elements of the ProACT ecosystem, and by extension with the ecosystem itself. The purpose of this category of analytics is not to make determinations on the success of stakeholder engagement or retention, or on the overall acceptance of ProACT technologies, but is, instead, to provide objective data to assist in evaluation of these areas. For example, analytics in this category will measure *who* (i.e. which stakeholder type(s)) is engaged with the system through use of provided CareApps, *how* frequently these parties engage with the system, and *how* these engagement levels change over time (as a measure of retention). As a general rule, engagement and retention analytics will operate at local resolution, but their outputs will become the subject of a comparative analytic for a global comparison between trail sites.

2.3 Target Consumers for Ecosystem Analytics

The outputs from CareAnalytics within the ProACT ecosystem are targeted at PwMs and other stakeholders in their support groups. Ecosystem analytics, by contrast, are targeted at various actors involved in the provision of the project, or beyond the life of the project, in the deployment of ProACT systems. This section identifies and describes three primary consumers for the outputs of Ecosystem Analytics.

2.3.1 The ProACT Research Team

Here, the ProACT Research Team refers to all project consortium members. This group will be a prime target for outputs from comparative analytics and engagement and retention analytics. It is hoped that these outputs will be valuable for periodic evaluations of the ProACT ecosystem, in providing objective data on system usage for reporting, and in better understanding patterns of system usage by all relevant stakeholders. This group does not have a comparable (non-research) substitute beyond the life of the project, but does overlap the Trial Site Teams grouping.

2.3.2 Trial Site Teams and Administrators

Here, Trial Site Teams and Administrators refers to those individuals directly involved in the day-to-day running of trial sites, and coordination of trial site logistics. This group will be a prime target for outputs from engagement and retention analytics, and to some extent outputs from comparative analytics. It is hoped these outputs will help this audience better understand

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usage within their trial site, and provide objective data for improving trial site experiences. For the life of the ProACT project this group will be comprised of a subset of ProACT research team, but beyond the project timeframe this role could, conceivably, be filled by administrative staff, or researchers, who are users of the ProACT system, but not directly involved in its development. In this scenario, these individuals would make-up the Trial Site Teams and Administrators grouping.

2.3.3 ProACT Technical Teams

Here, ProACT Technical Teams refers to those project consortium members directly contributing, and maintaining, technology components to the ProACT technology platform. This group will be the primary target for outputs of technical analytics, and will use these to refine system performance, and to debug data collection and component intercommunication issues. During the project time frame, the role of trial site system administrators will be filled by the same entities developing and maintaining core ProACT services. Beyond the life of the project, this role could, conceivably, be filled by *users* of the ProACT system not directly involved in its development. In this scenario, it may be appropriate to include third-party system administrators in the ProACT Technical Teams grouping.

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3 Areas of Ecosystem Analysis

The table below presents an initial list of fifteen target areas for analysis of ProACT ecosystem performance. The table entry for each area provides a high-level overview of requirements and potential methods of generating required outputs. The following points should be considered when examining the table:

- Each area for analysis has been categorised as being a *Technical* analytic, a *Comparative* analytic, or an *Engagement* analytic in line with section 2 definitions. Areas for analysis may overlap multiple categories.

- The resolution to which each area of analysis will be performed has been identified as one of *Local*, *Global*, or in the special case of Area 14 (*Daily Identification of Missing Inputs per PwM*) as *PwM*.

- For each area of analysis, an appropriate data source is suggested, as is a frequency for computing or updating outputs.

- For each area of analysis, primary consumers for outputs have been identified. Where a group has *not* been identified as a primary consumer, this does not imply that the group has no interest in area outputs, simply that they are not the direct target audience of the analytic.

This list should not be, at this stage, considered exhaustive and will be updated to reflect additional needs in future revisions of this deliverable (due M22 and M39).

<table>
<tr><th colspan="5">Area 1: Daily Identification of Data Provision and / or Collection Issues</th></tr>
<tr><td>Requirement(s):</td><td colspan="4">Trial site administrators must monitor a wide array of input devices for a large number of PwMs, to ensure each device is gathering or generating data as expected. Manual management of this process on a daily basis would be overly burdensome on trial site teams, and would be prone to human error or oversights.

An analytic method is required which can detect devices which are not working as expected, and when such defects are found, generate alerts in a timely manner.</td></tr>
<tr><td rowspan="2">Analytics Type(s):</td><td>Technical</td><td>Comparative</td><td>Engagement</td><td>Resolution</td></tr>
<tr><td>✓</td><td>×</td><td>×</td><td>Local</td></tr>
<tr><td rowspan="4">Potential Method(s):</td><td colspan="4">Comparison of expected data providers for all PwMs in a given trial site in any daily period, and of the data sources for inputs received for the same PwMs on that day. Identifies expected providers which have not generated input across the trial site.</td></tr>
<tr><td colspan="2">Data Source</td><td colspan="2">Generated / Updated</td></tr>
<tr><td colspan="2">CABIE</td><td colspan="2">Daily</td></tr>
<tr><td>Research Team</td><td>Trial Site Admins</td><td colspan="2">Technical Team</td></tr>
</table>

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<table>
<tr><td>Targets Consumer(s):</td><td>✗</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="4">**Area 2:** Live Identification of Overloaded Local Aggregators</td></tr>
<tr><td>Requirement(s):</td><td colspan="3">Local data aggregators process high volumes of data on-demand, both in input (collection) and output (dissemination) streams. While the amount of data processed daily is relatively low when measured across a full 24-hour period, high volume bursts of data have the potential to affect overall system performance.

An analytic method is required which can detect degraded system performance, generate alerts when such occurrences are identified, and to provide technical teams with the knowledge needed to better balance rates of data processing.</td></tr>
<tr><td>Analytics Type(s):</td><td>Technical
✓</td><td>Comparative
✗</td><td>Engagement
✗</td><td>Resolution
Local</td></tr>
<tr><td>Potential Method(s):</td><td colspan="3">Comparison of the times taken to process all API requests to the system against baseline optimal response times. This method can be employed at response-time resolution to generate alerts for severely degraded performance, and at desired time resolutions (e.g. every hour) to discover recurring periods of sub-optimal performance.

Use of stand-alone process monitors (e.g. the open-source monit utility for UNIX-like systems) to generate alerts on the detection of high server CPU-load or RAM usage.

Data Source: CABIE
Generated / Updated: On-demand</td></tr>
<tr><td>Targets Consumer(s):</td><td>Research Team
✗</td><td>Trial Site Admins
✗</td><td>Technical Team
✓</td></tr>
<tr><td colspan="4">**Area 3**: Measurement of PwM Engagement with Core CareApps</td></tr>
<tr><td>Requirement(s):</td><td colspan="3">PwMs will be expected to engage with their primary CareApp on a regular basis (e.g. daily) to answer questionnaires, view trends in their personal data, and to view training materials relevant to their conditions. It is important, however, to understand how PwMs engage with their primary CareApp in practice. Is the app being opened daily? Are questionnaires being completed on time? Which functionalities of the app are being used regularly, and which are not, by PwMs in a given trial site. These questions should also be answered for other PwM-focused CareApps integrated into the core of the ProACT ecosystem. It is also important here to understand how this usage changes over time.</td></tr>
<tr><td>Analytics Type(s):</td><td>Technical
✗</td><td>Comparative
✗</td><td>Engagement
✓</td><td>Resolution
Local</td></tr>
<tr><td>Potential Method(s):</td><td colspan="3">All data requests into the system are logged, and their point of origin tracked. Each request is accompanied by a token which will be unique to its point of origin—i.e. a specific type of CareApps for a specific PwM or support stakeholder. Access data of this type can be used to track basic interactions with CareApps (how often they are being used / which sections are being used / which CareApps are being used most frequently, etc.)</td></tr>
</table>

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<table>
<tr><td></td><td>As the core set of CareApps to be deployed within ProACT are web-based applications, third-party analytic applications (e.g. Google Analytics) can be employed for more detailed analysis of user interactions within each CareApp.
<table><tr><th>Data Source</th><th>Generated / Updated</th></tr><tr><td>SIMS</td><td>Daily</td></tr></table></td></tr>
<tr><td>Targets Consumer(s):</td><td><table><tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr><tr><td>✓</td><td>✓</td><td>×</td></tr></table></td></tr>
<tr><td colspan="2">Area 4: Measurement of PwM Engagement with Input Devices</td></tr>
<tr><td>Requirement(s):</td><td>Non-ambient sensing devices to be employed in ProACT require active engagement by PwMs (e.g. daily). It is important to understand how these devices are being interacted with in practice. Are they being used as scheduled, or are they being used less frequently? This should be tracked by device type, rather than specific devices. As example, the need here is to understand how PwMs have accepted daily use of a blood pressure monitor, rather than understanding their acceptance of a given make of blood pressure monitor. It is also important here to understand how this usage changes over time.</td></tr>
<tr><td>Analytics Type(s):</td><td><table><tr><th>Technical</th><th>Comparative</th><th>Engagement</th><th>Resolution</th></tr><tr><td>×</td><td>×</td><td>✓</td><td>Local</td></tr></table></td></tr>
<tr><td>Potential Method(s):</td><td>For each data type collected by the system, which requires active engagement (e.g. blood pressure, weight, etc.), compare expected daily input types for each PwM against those actually received by the system to discover rates of adherence to schedules by type, across the entirety of a trial site.
<table><tr><th>Data Source</th><th>Generated / Updated</th></tr><tr><td>CABIE</td><td>Daily</td></tr></table></td></tr>
<tr><td>Targets Consumer(s):</td><td><table><tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr><tr><td>✓</td><td>✓</td><td>×</td></tr></table></td></tr>
<tr><td colspan="2">Area 5: Comparison of PwM CareApp Engagement by Trial Site</td></tr>
<tr><td>Requirement(s):</td><td>Global aggregation of Area 3 results (Measurement of PwM Engagement with Core Care Apps) to allow for comparisons between trial sites. Are certain CareApp types more or less used in different trial sites?</td></tr>
<tr><td>Analytics Type(s):</td><td><table><tr><th>Technical</th><th>Comparative</th><th>Engagement</th><th>Resolution</th></tr><tr><td>×</td><td>✓</td><td>✓</td><td>Global</td></tr></table></td></tr>
<tr><td>Potential Method(s):</td><td>Simple aggregation of existing data.
<table><tr><th>Data Source</th><th>Generated / Updated</th></tr><tr><td>InterACT</td><td>Daily</td></tr></table></td></tr>
<tr><td>Targets Consumer(s):</td><td><table><tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr><tr><td>✓</td><td>✓</td><td>×</td></tr></table></td></tr>
<tr><td colspan="2">Area 6: Comparison of PwM Device Engagement by Trial Site</td></tr>
<tr><td>Requirement(s):</td><td>Global aggregation of Area 4 results (Measurement of PwM engagement with Input Devices) to allow for comparisons between trial</td></tr>
</table>

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<table>
<tr><td></td><td colspan="4">sites. Are certain device types more or less used, as scheduled, in different trial sites?</td></tr>
<tr><td>Analytics Type(s):</td><td>Technical</td><td>Comparative</td><td>Engagement</td><td>Resolution</td></tr>
<tr><td></td><td>×</td><td>✓</td><td>✓</td><td>Global</td></tr>
<tr><td>Potential Method(s):</td><td colspan="4">Simple aggregation of existing data.</td></tr>
<tr><td></td><td colspan="2">Data Source</td><td colspan="2">Generated / Updated</td></tr>
<tr><td></td><td colspan="2">InterACT</td><td colspan="2">Daily</td></tr>
<tr><td>Targets Consumer(s):</td><td>Research Team</td><td>Trial Site Admins</td><td colspan="2">Technical Team</td></tr>
<tr><td></td><td>✓</td><td>✓</td><td colspan="2">×</td></tr>
<tr><td colspan="5">Area 7: Comparison of PwM Device Engagement by Device Make</td></tr>
<tr><td>Requirement(s):</td><td colspan="4">While it is important to understand how PwMs engage with device types, it is equally important to understand how they engage with specific devices from different manufacturers. While this will not necessarily identify specific usability issues with, or reasons for resistance to, specific devices, it may help research teams identify common patterns in devices with differing usage rates. As example, this may show more or less adherence to usage schedules when connected devices are used over manual input devices.</td></tr>
<tr><td>Analytics Type(s):</td><td>Technical</td><td>Comparative</td><td>Engagement</td><td>Resolution</td></tr>
<tr><td></td><td>×</td><td>✓</td><td>✓</td><td>Local</td></tr>
<tr><td>Potential Method(s):</td><td colspan="4">ProACT’s data aggregator, CABIE, distinguishes incoming data by manufacturer (provider)—it cannot distinguish between 2 devices of the same type from the same manufacturer. As such, analytics around this topic can only be employed to compare engagement by device makes. This method would closely resemble that described in Area 4 (Measurement of PwM Engagement with Input Devices), but with input device lists filtered by manufacturer.</td></tr>
<tr><td></td><td colspan="2">Data Source</td><td colspan="2">Generated / Updated</td></tr>
<tr><td></td><td colspan="2">CABIE</td><td colspan="2">Daily</td></tr>
<tr><td>Targets Consumer(s):</td><td>Research Team</td><td>Trial Site Admins</td><td colspan="2">Technical Team</td></tr>
<tr><td></td><td>✓</td><td>✓</td><td colspan="2">×</td></tr>
<tr><td colspan="5">Area 8: Measurement of Support Stakeholder Engagement with ProACT</td></tr>
<tr><td>Requirement(s):</td><td colspan="4">Measurement of engagement with the ecosystem by PwM support stakeholders, inclusive of informal carers, formal carers, and the full range of healthcare professionals. This should include identification of the different types of support actors engaged at the trial site level, and measurement of their engagement levels with provided CareApps. Where support actors are expected to complete questionnaires, levels of engagement with these should also be measured. It is important to understand how this usage changes over time.</td></tr>
<tr><td>Analytics Type(s):</td><td>Technical</td><td>Comparative</td><td>Engagement</td><td>Resolution</td></tr>
<tr><td></td><td>×</td><td>✓</td><td>✓</td><td>Local</td></tr>
<tr><td>Potential Method(s):</td><td colspan="4">In a similar manner to that employed for Area 3 (Measurement of PwM Engagement with Core CareApps), centralised access tokens which are tagged by stakeholder type can be employed here to discover</td></tr>
</table>

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<table>
<tr><td></td><td>which stakeholder types are engaging with provided CareApps, and how frequently they access each app. This data can be augmented by server access logs to gain a more granular view of used functionality.

As the core set of CareApps to be deployed within ProACT are web-based applications, third-party analytic applications (e.g. Google Analytics) can be employed for more detailed analysis of user interactions within each CareApp.

<table>
<tr><th>Data Source</th><th>Generated / Updated</th></tr>
<tr><td>SIMS, Other</td><td>Daily</td></tr>
</table>
</td></tr>
<tr><td>Targets Consumer(s):</td><td>
<table>
<tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr>
<tr><td>✓</td><td>✓</td><td>×</td></tr>
</table>
</td></tr>
<tr><td colspan="2">Area 9: Comparison of Support Stakeholder Engagement by Trial Site</td></tr>
<tr><td>Requirement(s):</td><td>Global aggregation of Area 8 results (Measurement of Support Stakeholder Engagement with ProACT) to allow for comparisons between trial sites. Are certain stakeholders more or less engaged in different trial sites?</td></tr>
<tr><td>Analytics Type(s):</td><td>
<table>
<tr><th>Technical</th><th>Comparative</th><th>Engagement</th><th>Resolution</th></tr>
<tr><td>×</td><td>✓</td><td>✓</td><td>Global</td></tr>
</table>
</td></tr>
<tr><td>Potential Method(s):</td><td>Simple aggregation of existing data.

<table>
<tr><th>Data Source</th><th>Generated / Updated</th></tr>
<tr><td>InterACT</td><td>Daily</td></tr>
</table>
</td></tr>
<tr><td>Targets Consumer(s):</td><td>
<table>
<tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr>
<tr><td>✓</td><td>✓</td><td>×</td></tr>
</table>
</td></tr>
<tr><td colspan="2">Area 10: Generalised Aggregation of Person-centric Analytics per Trial Site</td></tr>
<tr><td>Requirement(s):</td><td>A wide array of person-centric analytics will be applied to all PwMs in the ProACT ecosystem, examining data at the individual level to, for example, calculate overall wellbeing scores, successfulness of behaviour change interventions, and more. It will be useful for research teams to be able to view site-level aggregations of these metrics, and to be able to compare those aggregations by trial site.

This analytic should take the form of a generalised implementation which can be applied to a wide array of person-centric analytic outputs, and which can adapt to new, future outputs.</td></tr>
<tr><td>Analytics Type(s):</td><td>
<table>
<tr><th>Technical</th><th>Comparative</th><th>Engagement</th><th>Resolution</th></tr>
<tr><td>×</td><td>✓</td><td>×</td><td>Local & Global</td></tr>
</table>
</td></tr>
<tr><td>Potential Method(s):</td><td>Simple aggregation of existing data with allowances for multiple data types.

<table>
<tr><th>Data Source</th><th>Generated / Updated</th></tr>
<tr><td>InterACT</td><td>Daily</td></tr>
</table>
</td></tr>
<tr><td>Targets Consumer(s):</td><td>
<table>
<tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr>
<tr><td>✓</td><td>×</td><td>×</td></tr>
</table>
</td></tr>
</table>

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<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Area 11: Measurement of PwM Goal Achievement</td></tr>
<tr><td>Requirement(s):</td><td colspan="3">As part of their behaviour change intervention, PwMs may be set specific, regular goals to engage with the system. For example, PwMs may be set a target number of system logins with reported self-management or goal progress over a given time period. An analytic method is required to determine how successful PwMs are in meeting these goals across trial sites. This data may be beneficial in measuring the appropriateness of goal levels, and may be useful in identifying goals which are not being met by a large number of PwMs. This in turn may be helpful in identifying goals which are inherently unachievable.</td></tr>
<tr><td rowspan="2">Analytics Type(s):</td><td>Technical</td><td>Comparative</td><td>Engagement</td><td>Resolution</td></tr>
<tr><td>✗</td><td>✗</td><td>✓</td><td>Local</td></tr>
<tr><td rowspan="3">Potential Method(s):</td><td colspan="3">Comparing local, up-to-date data on goal metrics to goals set by other analytic methods. These analytics can make use of InterACT or CABIE data to measure goal targets against success rates. Outputs should also be used by the technical team for refinement of analytics which programmatically generate goals.</td></tr>
<tr><td colspan="2">Data Source</td><td colspan="2">Generated / Updated</td></tr>
<tr><td colspan="2">InterACT</td><td colspan="2">Daily</td></tr>
<tr><td rowspan="2">Targets Consumer(s):</td><td>Research Team</td><td>Trial Site Admins</td><td>Technical Team</td></tr>
<tr><td>✓</td><td>✗</td><td>✓</td></tr>
<tr><td colspan="4">Area 12: Comparison of PwM Goal Achievement by Trial Site</td></tr>
<tr><td>Requirement(s):</td><td colspan="3">Global aggregation of Area 11 results (Measurement of Goal Achievement) to allow for comparisons between trial sites. Are there differences in the rates of goal achievement in specific areas across trial sites?</td></tr>
<tr><td rowspan="2">Analytics Type(s):</td><td>Technical</td><td>Comparative</td><td>Engagement</td><td>Resolution</td></tr>
<tr><td>✗</td><td>✗</td><td>✓</td><td>Global</td></tr>
<tr><td rowspan="3">Potential Method(s):</td><td colspan="3">Simple aggregation of existing data.</td></tr>
<tr><td colspan="2">Data Source</td><td colspan="2">Generated / Updated</td></tr>
<tr><td colspan="2">InterACT</td><td colspan="2">Daily</td></tr>
<tr><td rowspan="2">Targets Consumer(s):</td><td>Research Team</td><td>Trial Site Admins</td><td>Technical Team</td></tr>
<tr><td>✓</td><td>✗</td><td>✗</td></tr>
<tr><td colspan="4">Area 13: Measurement of Accuracy of CareAnalytic Alerts</td></tr>
<tr><td>Requirement(s):</td><td colspan="3">A number of person-centric analytics in ProACT will generate alerts when suspected issues are found in PwM data, such as when a suspected fall in the home is detected. A method is required to determine the accuracy of these alerts. This should track the number of alerts which identified genuine issues against those alerts which were false positives.</td></tr>
<tr><td rowspan="2">Analytics Type(s):</td><td>Technical</td><td>Comparative</td><td>Engagement</td><td>Resolution</td></tr>
<tr><td>✓</td><td>✗</td><td>✗</td><td>Global</td></tr>
</table>

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<table>
<tr><td>Potential Method(s):</td><td colspan="4">Implementation of this analytic will require feedback from alert recipients to report on outcomes. Recipients should be polled on each alert received to discover if the alert required intervention, or not. This may require the provision of a dedicated interface for alert recipients, and should take non-reporting into account when comparing alerts to required interventions.

<table>
<tr><th>Data Source</th><th>Generated / Updated</th></tr>
<tr><td>InterACT</td><td>Daily</td></tr>
</table></td></tr>
<tr><td>Targets Consumer(s):</td><td colspan="4"><table>
<tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr>
<tr><td>✓</td><td>×</td><td>✓</td></tr>
</table></td></tr>
<tr><td colspan="5">Area 14: Daily Identification of Missing Inputs per PwM</td></tr>
<tr><td>Requirement(s):</td><td colspan="4">Trial site administrators, technical teams, and PwM support actors need to be alerted when expected inputs have not been collected for a given PwM in a given day. For example, an alert should be generated at the end of each day if a PwM who is scheduled to take daily blood pressure readings has not done so. This is better categorised as a person-centric analytic (a CareAnalytic), but technical requirements place it with the other technical analytics in this section.</td></tr>
<tr><td>Analytics Type(s):</td><td colspan="4"><table>
<tr><th>Technical</th><th>Comparative</th><th>Engagement</th><th>Resolution</th></tr>
<tr><td>✓</td><td>×</td><td>×</td><td>PwM</td></tr>
</table></td></tr>
<tr><td>Potential Method(s):</td><td colspan="4">Similar method to Area 1 (Daily Identification of Data Provision and / or Collection Issues), but with a focus on data types (e.g. blood pressure, weight, etc.) rather than data sources. Additionally, this analytic will operate on individual PwM data, and generate alerts relevant to individual PwMs, rather than generating alerts relevant to the wider trial site.

<table>
<tr><th>Data Source</th><th>Generated / Updated</th></tr>
<tr><td>CABIE</td><td>Daily</td></tr>
</table></td></tr>
<tr><td>Targets Consumer(s):</td><td colspan="4"><table>
<tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr>
<tr><td>×</td><td>✓</td><td>✓</td></tr>
</table></td></tr>
<tr><td></td><td colspan="4"></td></tr>
<tr><td colspan="5">Area 15: System Uptime Monitoring</td></tr>
<tr><td>Requirement(s):</td><td colspan="4">General monitor of availability of all server-based components.</td></tr>
<tr><td>Analytics Type(s):</td><td colspan="4"><table>
<tr><th>Technical</th><th>Comparative</th><th>Engagement</th><th>Resolution</th></tr>
<tr><td>✓</td><td>×</td><td>×</td><td>N/a</td></tr>
</table></td></tr>
<tr><td>Potential Method(s):</td><td colspan="4">A future update to this document will identify a reliable method for determining average uptime ratios for all core ProACT infrastructural components.

<table>
<tr><th>Data Source</th><th>Generated / Updated</th></tr>
<tr><td>Misc.</td><td>Daily</td></tr>
</table></td></tr>
<tr><td>Targets Consumer(s):</td><td colspan="4"><table>
<tr><th>Research Team</th><th>Trial Site Admins</th><th>Technical Team</th></tr>
<tr><td>×</td><td>×</td><td>✓</td></tr>
</table></td></tr>
</table>

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Table 1: **Overview of Areas for Analysis of Ecosystem Performance**

4 Required Data Points

Building on the areas for analysis and requirements identified in section three of this document, the table below lists the data points required for analysis of ProACT ecosystem performance and the areas of analysis to which each data point is relevant. The following should be considered when examining this table:

- The term "list" does not necessarily refer to a persistently stored dataset, but may instead refer to datasets which are generated "on-the-fly" from other system data as needed.

- Where need for a manually-defined baseline value is listed, these baselines have not yet been identified and will be itemised per relevant system in later revisions to this deliverable (M22 and M39).

As per the analysis areas listed in section 3, the list of required data points below should not, at this stage, be considered exhaustive or complete.

Data Point 1: List of Expected Providers for Each PwM			
Description:	For each PwM, a list of the providers (data sources) which are expected to generate input each day, collected from PwM records.	Required for:	Area 1 Area 7
Data Point 2: Record of Providers Actively Providing per Day			
Description:	A record of the providers which have generated data in each day.	Required for:	Area 1 Area 7
Data Point 3: System-wide API Response Times from Controlled End-points			
Description:	Round-trip response time (RTTs) from controlled end-points (core CareApps) when requesting data from ProACT backend systems.	Required for:	Area 2
Data Point 4: System-wide API Internal Processing Times			
Description:	Internal processing times for API requests in all ProACT back-end systems (as per data point 3, without taking transfer times into account).	Required for:	Area 2
Data Point 5: List of Baseline Acceptable API Response Times			
Description:	Manually-defined baselines for maximum acceptable API response times which do not affect human perception of responsiveness. Jakob Nielsen (1993), citing earlier references, presents 3 response time thresholds which should be considered when designing applications. Of these, the "reacting instantaneously" threshold is of most relevance to this section and sets a maximum target threshold of 100 milliseconds (0.1 seconds)	Required for:	Area 2

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	for responsiveness to give the illusion of reaction without delay.		
Data Point 6: Baseline Alert Thresholds for Detection of High CPU Usage			
Description:	Manually-defined baselines for CPU load averages on backend systems above which technical teams may wish to manually intervene or monitor. On Linux-based server systems, CPU load averages are available through system tools, and are measured in 1, 5, and 15 minute intervals. Load averages are calculated relative to the number of available cores in a server (as example: a load average of 1.0 on a single-core machine would indicate 100% CPU utilization average over the inspection period, as would an average of 2.0 on a dual-core machine) (Gunther, 2007). A load average of 0.7 per core is generally considered high, but stable. Load averages of 1.0 per core indicate issues which need to be addressed urgently (but likely are not yet affecting performance) while load averages above 1.0 per core indicate sustained performance degradation.	Required for:	Area 2
Data Point 7: Baseline Alert Thresholds for Detection of High Memory Usage			
Description:	Manually-defined baselines for memory (RAM) usage levels on backend systems above which technical teams may wish to manually intervene or monitor. Memory monitoring on Linux-based server systems is available through system tools. These systems will generally utilise all available memory to optimise system performance (memory unused by applications will be used for disk caching). Consequently, it is important to monitor memory usage minus disk caches. Memory usage exceeding 85% of available system resources over sustained periods (15 minutes) generally indicates issues which may need attention.	Required for:	Area 2
Data Point 8: Timestamped Records of All Stakeholder Types who Access CareApps			
Description:	Records of all data access requests which identify stakeholder of origin, stakeholder categorisation (PwM, Informal Carer, etc.), and time of request.	Required for:	Area 3 Area 8
Data Point 9: Definitions of Custom Variables for Third-party Analytics Suites			
Description:	Definition of custom variables for integrated third-party analytics suites (e.g. Google Analytics) which can be used to view analytics by ProACT categories (stakeholder group, etc.)	Required for:	Area 3 Area 8
Data Point 10: List of Expected Data Types for Each PwM (Daily)			

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Description:	A list, per PwM, of the types of data which are *expected* to be collected in each day (blood pressure, weight, SpO2, etc.).	Required for:	Area 4 Area 14
Data Point 11: List of Received / Collected Data Types for Each PwM (Daily)			
Description:	A list, per PwM of the types of data which *have* been collected in each day (blood pressure, weight, Spo2, etc.).	Required for:	Area 4 Area 14
Data Point 12: Person-centric Analytics Output			
Description:	Individual PwM outputs from person centric analytics across all categories, available through analytics collections in InterACT. e.g. use of calculated wellness scores for each PwM to generate average wellness per trial site.	Required for:	Area 10
Data Point 13: Record of Defined Goals in All Categories per PwM			
Description:	Record of all behaviour change goals set for each PwM within a trial site.	Required for:	Area 10 Area 11
Data Point 14: Record of Percentages of Goals Achieved in All Categories per PwM			
Description:	Record of percentages of behaviour change goals achieved on time / completed to compare to goals originally set.	Required for:	Area 11
Data Point 15: Record of System-generated Alerts			
Description:	Record of all alerts generated from CareAnalytics, categorised by alert type or generating analytic.	Required for:	Area 13
Data Point 16: Feedback from Alert Recipients			
Description:	Feedback from recipients of alerts generated from CareAnalytics, to measure the rate of false positives.	Required for:	Area 13
Data Point 17: Outputs from Areas 3, 4, 8, and 11			
Description:	Outputs from other ecosystem performance analytics for global comparison between trial sites. For example, are PwMs in one trial site more engaged with a certain CareApp than those in another.	Required for:	Area 5 Area 6 Area 9 Area 12

Table 2: Overview of Data Requirements for Ecosystem Performance Analysis

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5 Friendly Trial Availability

The first release of the ProACT technology platform will be evaluated in a friendly trial setting. ProACT defines a friendly trial as a trial to test the robustness of a technology ecosystem prior to its deployment to real end-users. For the purposes of this trial, ProACT research staff will take on the roles of multiple ecosystem stakeholders to evaluate technology components. As part of this process a subset of the analytics described in this document will be deployed and evaluated by research and technical teams. These are:

- **Daily Identification of Data Provision and / or Collection Issues**
  Data sets to support a version of this analytic already exists in core ProACT systems. Additional works required to support this analytic include: creation and scheduling of scripts to examine available data, and to generate email alerts on discovery of data collection issues at the end of each day.

- **Measurement of PwM Engagement with Core CareApps**
  An early, proof-of-concept, implementation of this analytic will be tested against manually reported usage patterns. Data sets to support this analytic already exist in ProACT systems, but are not yet in a convenient format for regular programmatic inspection. Additional works required to support this analytic include: liberation of required data from dense usage logs into indexed collections.

- **Measurement of Support Stakeholder Engagement with ProACT**
  An early, proof-of-concept, implementation of this analytic will be tested against manually reported usage patterns. Partial data sets to support this analytic already exist in ProACT systems, but are not yet in a convenient format for regular programmatic inspection. Additional works required to support this analytic include: liberation of required data from dense usage logs into indexed collections, and the ability to categorise user tokens by stakeholder type.

- **Daily Identification of Missing Inputs per PwM**
  Data sets to support a version of this analytic already exists in core ProACT systems. Additional works required to support this analytic include: creation and scheduling of scripts to examine available data, and to generate email alerts on discovery of missing data.

- **Live Identification of Overloaded Local Aggregators**
  A partial implementation of this analytic will be available for the friendly trial process, and additional data required for a full implementation will be collected (but only examined manually). Specifically, higher-level examination of server loads will be available, and will generate alerts. Local API response processing times will be logged, but will not be programmatically measured at this stage.

Beyond the timeframe of the friendly trial, in advance of ProACT's main PoC trial, works will continue to provision required datasets, define required baseline values, and complete deployment of the remaining Ecosystem Analytics.

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6 References

Gunther, N.J. (2007) 'Understanding load averages and stretch factors', LINUX-Magazine (October), pp. 62–70.

Nielsen, J. (1993) Usability engineering - Jakob Nielsen. 2nd edn. Boston: AP Professional.

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