

Article

# An Open Data-Based Omnichannel Approach for Personalized Healthcare

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**Abstract:** Currently, telemedicine and telehealth have grown, prompting healthcare institutions to seek innovative ways to incorporate them into their services. Challenges such as resource allocation, system integration, and data compatibility persist in healthcare. Utilizing an open data approach in a versatile mobile platform holds great promise for addressing these challenges. This research focuses on adopting such an approach for a mobile platform catering to personalized care services. It aims to bridge identified gaps in healthcare, including fragmented communication channels and limited real-time data access, through an open data approach. This study builds upon previous research in omnichannel healthcare using prototyping to design a mobile companion for personalized care. By combining an omnichannel mobile companion with open data principles, this research successfully tackles key healthcare gaps, enhancing patient-centered care and improving data accessibility and integration. The strategy proves effective despite encountering challenges, although additional issues in personalized care services warrant further exploration and consideration.

**Keywords:** mobile companion; omnichannel adoption; healthcare services; personalized care services; openEHR specification; remote patient follow-up; ambulatory surgery contact



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## 1. Introduction

Many innovations and technological advances have been happening in healthcare, especially around how patients and health professionals interact. The COVID-19 pandemic reinforced the need to use digital technologies in patient care services [1]. Several solutions were designed and improved during the pandemic, including telemedicine, digital health, telehealth, and others, many of which focused on patients and the service quality-of-care [1–3]. Healthcare facilities are striving to adopt and implement new omnichannel solutions to increase the quality of the care delivered to their patients. The omnichannel strategy has gained relevance in the healthcare industry, as it enables the integration of numerous communication channels and information exchange between healthcare providers and patients [4,5]. In addition, using mobile companions in healthcare takes advantage of the omnichannel strategy, an area that has seen significant growth and expansion in the healthcare domain [5,6]. Ensuring personalized and continuous care service remains a challenge in many care services provided to patients. Patients often face difficulties accessing relevant and valuable information and guidance, while health professionals face many challenges in interacting with patients across different interaction channels [7].

The present study is more theoretical, aiming to present a conceptual architecture of omnichannel interaction based on an open data approach. It focuses on addressing problems in the healthcare domain regarding personalized care services as well as on delineating notable contributions and improvements achieved by employing omnichannel interactions, referring to the use of multiple channels to communicate with patients so as to provide them with seamless and smooth care services. To achieve this, an illustrative

instantiation of an omnichannel mobile companion has been meticulously designed and aligned with the proposed architecture to effectively address the identified challenges. A use case focusing explicitly on patient contact in the context of ambulatory surgery has been strategically chosen in order to exemplify how the outlined architecture addresses and overcomes the problems and gaps prevalent in personalized care services.

The healthcare domain still faces many issues at different levels and with varying levels of complexity. The main recurring gaps and challenges identified are [8–12]:

- **G1:** Fragmented communication channels necessitate seamless communication among healthcare providers and systems. When information is not effectively shared between various entities, this can lead to misunderstandings, delays, and potentially compromised patient care.
- **G2:** Incoherent patient data presentation in different channels leads to inconsistencies in how patient data are presented across various channels, which can cause misunderstandings among health professionals and make it challenging to obtain a comprehensive and accurate view of the patient's health condition.
- **G3:** Lack of systems integration and interoperability means that healthcare providers must often use different systems and technologies that may not easily communicate with each other. System integration and data interoperability are required to ensure seamless patient data exchange without causing inefficiencies in care services.
- **G4:** Real-time data access is needed for timely decision-making and to ensure timely access to accurate and up-to-date patient data. Emphasizing the critical need for improved information flow and accessibility is crucial for making informed decisions in the healthcare domain, as delays or challenges in real-time access to pertinent information may impede healthcare professionals' ability to make timely and informed decisions.
- **G5:** Overloaded health professionals, including doctors, nurses, and other staff, may experience heavy workloads due to high patient volumes, administrative tasks, and inefficient processes. This may lead to burnout, increasing the risk of errors and raising further challenges in providing quality care to patients.

In order to address these challenges and issues, we have outlined the following research question (RQ):

- **RQ:** To what extent can a mobile companion use an omnichannel approach based on open data to make personalized care services more effective?

To answer this research question, we explore the capabilities of current mobile technology in enabling personalized care services to patients in an omnichannel environment within the ambulatory surgery context while ensuring continuous interaction across multiple channels. The following set of objectives and guidelines were identified:

- Explore the technology and propose an omnichannel architecture for healthcare services that leverages the open data approach.
- Demonstrate the implementation of mobile companions based on the proposed omnichannel architecture.
- Identify the main contributions and gains of adopting mobile companions in an omnichannel environment based on an open data approach for personalized patient care services.

The central concept of this study revolves around leveraging an omnichannel approach, mainly using a mobile companion based on open data, to enhance personalized care services in the healthcare domain. This study addresses identified challenges in healthcare services such as fragmented communication channels, incoherent patient data presentation, lack of systems integration, poor real-time data access, and overloaded health professionals. Thus, its focus is on improving interactions between healthcare providers and patients by seamlessly integrating various communication channels to ensure consistent and accessible patient data and alleviate the workload of healthcare professionals.

Based on the identified objectives and the central concept of this study outlined to answer the main research question, we formulated the following hypothesis:

- Implementing an omnichannel mobile companion based on an open data approach will significantly enhance the effectiveness of personalized care services in the healthcare domain. This enhancement will be evidenced by improved communication among healthcare providers, coherent presentation of patient data across multiple channels, enhanced system integration and interoperability, timely access to real-time patient data, and a reduced workload on the part of health professionals, ultimately contributing to higher quality of care for patients.

This hypothesis suggests that the proposed omnichannel mobile companion aligning with the outlined architecture has the potential to address the identified gaps and challenges in the healthcare domain, leading to more efficient and personalized delivery of healthcare services. This study aims to explore how a mobile companion driven by an open data approach can bring about positive changes in personalized care services, particularly within an ambulatory surgery context.

The ensuing subsections provide a concise background delving into personalized care services, omnichannel interactions facilitated by mobile companions, and open data. These specific domains collectively serve as the conceptual foundation for this research.

## 2. Background

### 2.1. Personalized Care Service

The search for personalized care tailored to each patient's unique needs and journey is vital in healthcare services. Healthcare providers must address care services to all patients and recognize their distinct characteristics and preferences in order to provide personalized care services for each patient based on their needs and requirements [13,14]. Personalized care service has several factors, but this research presented only the characteristics related to care services provided to patients. Thus, the main characteristics of personalized care service are understanding the patient's medical history and personal traits and individualized care plans that address specific concerns focused on a patient-centered approach [9]. Another characteristic is actively involving patients in decision-making, considering their preferences, values, and goals when designing treatment plans. In addition, patients experience customized treatments and preventive measures that optimize outcomes and promote overall well-being, strengthening the doctor–patient relationship as individuals become more involved in their health journey [15,16]. Personalized healthcare often involves continuous monitoring of patient's health status and treatment responses. Regular feedback allows healthcare providers to make necessary adjustments to treatment plans based on real-time data. Lastly, personalized care services also present privacy and security concerns [17,18].

There are many challenges and issues regarding personalized care services and healthcare services provided to patients. Traditional healthcare systems frequently encounter problems arising from fragmented communication channels and incoherent patient information, resulting in inefficiencies and the possibility of care service gaps [8]. Identified gaps include the lack of a seamless and personalized communication channels that hinders effective patient engagement and medical follow-up, lack of systems integration, data interoperability, poor data access preventing timely real-time decision-making, and work overload on health professionals. In order to overcome these challenges, it is crucial to establish a comprehensive solution capable of integrating diverse communication channels, ensuring system interoperability, and standardizing data exchange [7,19].

### 2.2. Mobile Companions in Healthcare Service

Mobile companions such as smartphone applications and wearable devices have emerged as transformative tools in delivering modern healthcare to patients. These digital companions provide patients access to essential health information, remote monitoring capabilities, and real-time communication with health professionals [3,11]. Thus, mobile

companions enable patients to stay connected with healthcare professionals in order to receive timely reminders for preoperative and postoperative contacts, medical appointments, medication schedules, and recovery milestones. In addition, patients can log their symptoms, record vital signs, and track their progress, empowering them to actively participate in their recovery process. Moreover, mobile companions facilitate continuous data collection, allowing health professionals to monitor patients' progress remotely and intervene proactively when necessary [13,20–22].

### 2.3. *The Omnichannel Approach in Healthcare Service Delivery*

Omnichannel interaction in healthcare is an approach that aims to provide patients and care providers with an integrated and seamless user experience across multiple communication and service delivery channels. This ensures that regardless of whether patients choose to interact through web apps, mobile apps, in-person visits, telehealth consultations, or phone calls, their experience is consistent, efficient, and focused on their needs (patient-centric) [23]. The omnichannel strategy in healthcare services refers to using multiple channels to provide seamless and personalized patient experiences [6,23]. This approach integrates data from various channels to create a unified and continuous environment that promotes communication between patients and health professionals [23,24]. The omnichannel approach has grown in importance in the healthcare domain, since it enables the integration of several communication channels and information exchange between health professionals and patients [25]. In addition, it optimizes patient engagement and experience. Patients can access healthcare information, communicate with health professionals, and receive personalized guidance through their preferred communication channel. Omnichannel mobile companions become a centralized platform aggregating data from various sources, including openEHR-compliant systems, wearables, and other health devices. This integrated approach enhances the ability to deliver personalized care recommendations, leading to more informed decision-making and improved patient outcomes [26].

### 2.4. *Open Data—openEHR Specification*

The Open Electronic Health Records (openEHR) specification is an open standard specification in health informatics that describes the management and storage, retrieval, and exchange of health data in Electronic Health Records (EHRs) [27]. The openEHR Specification Program develops, manages, and maintains specifications and their computable expressions in support of the openEHR goal of enabling the development and deployment of open, interoperable, and computable patient-centric health information systems [27]. The openEHR specification is a widely adopted standard for interoperability in healthcare, providing a common framework for the representation and exchange of EHRs [28]. The notion of leveraging open data in healthcare has grown significantly in recent years, as it offers enormous promise for how healthcare information is shared, accessed, and used. The openEHR specification is one of the most successful projects in the field, employing internationally accepted healthcare standards to represent and exchange EHRs. OpenEHR is an open standard for the representation and exchange of health-related information. The openEHR approach uses archetypes, templates, and reusable clinical content models that describe specific data elements and their relationships [28,29]. It separates the information from domain knowledge, allowing clinical expertise to define how to capture reality without redefining a stable information model [30]. It represents information through a Reference Model (RM), which enables the development of EHR systems that communicate with different systems without loss of meaning, thereby achieving semantic interoperability. Moreover, it defines a structured and standardized way for capturing clinical data, ensuring interoperability between various healthcare systems and applications [31].

#### 2.4.1. *Benefits of Open Data Using openEHR*

Benefits of adhering to the openEHR approach include the ability of healthcare organizations to achieve seamless interoperability between diverse EHR systems and healthcare

applications, thereby promoting efficient data exchange and continuity of care service [32]. The openEHR approach enables the aggregation of clinical data from multiple sources, including wearables and health-related devices, offering a comprehensive view of patients' health for personalized care services through the mobile companion [29,33]. Using archetypes and templates provides flexibility in capturing varied clinical data [32]. Moreover, open data principles in openEHR guarantee long-term accessibility to healthcare data, supporting research, epidemiological studies, and retrospective patient outcome analysis regardless of technological changes or which EHR systems are used [34–36].

#### 2.4.2. Challenges and Considerations

While the openEHR approach presents several advantages, its implementation also brings specific challenges and considerations that must be overseen. First, data security and privacy demand the utmost attention, necessitating robust measures to safeguard patient clinical information, adhere to data protection regulations, and prevent unauthorized access [33]. Second, establishing defined data governance models is crucial to managing ownership, access rights, and responsibilities within the openEHR ecosystem. Collaborative efforts between healthcare providers, policymakers, and technology experts are imperative for effective data governance [28,37]. Lastly, integrating open EHR systems and applications can be intricate and time consuming, requiring meticulous planning and stakeholder cooperation necessary to ensure seamless integration and data sharing across different EHR systems [37,38]. Addressing these challenges can enhance the overall success and impact of the openEHR initiative.

This section has presented a brief contextual background to the critical topics related to this study by providing an understanding of ambulatory surgery and emphasizing personalized care service and mobile companions in healthcare services. Additionally, exploring the omnichannel approach in healthcare service delivery and open data sets the groundwork for designing and implementing an omnichannel mobile companion for personalized healthcare service. This research aims to explore a robust and innovative approach that addresses the unique needs of an omnichannel mobile companion and implements a demonstration with a proof-of-concept in ambulatory surgery, enhancing patient contact and monitoring and improving patient outcomes.

This research aims to demonstrate the viability of using an open-data approach in an omnichannel environment to provide personalized care services to patients. Thus, it showcases the possibility of health professionals using this approach to reduce their workload regarding manual remote patient follow-up.

### 3. Materials and Methods

This research article adopts a prototyping of a use case method as a way to explore the implementation of the proposed conceptual architecture in the context of ambulatory surgery. It builds upon the previous case study on the maturity model for the omnichannel strategy in healthcare services in [39].

The prototyping method employed in this paper aims to design a prototype of an omnichannel mobile companion by leveraging an open data approach such as the openEHR specification. This prototype is designed and employed in a specific context, i.e., patient contact in ambulatory surgery.

In addition to the prototyping method, a qualitative research method was used through interviews and a focus group. Both the interviews and focus group involved health professionals in order to understand and explore their experiences with the current healthcare system, the challenges they faced, and their expectations for the proposed omnichannel mobile companion while allowing them to share their views on the challenges and potential benefits of the omnichannel interaction strategy. Additionally, this study includes a practical implementation of an omnichannel mobile companion that takes advantage of the proposed omnichannel interaction architecture. By combining these methods, this research



extends the findings of the previous study [39], providing a more robust understanding of the impact of the omnichannel mobile companion on personalized healthcare services.

#### 4. Results

This section delineates the principal outcomes achieved through the implementation of the Omnichannel Interaction Architecture Proposal (OIAP) within the context of patient interaction in ambulatory surgery. An illustration of the manual process can be found in Appendix A. The section begins by identifying existing gaps in healthcare and demonstrating how the OIAP addresses these deficiencies. Subsequently, it discusses the characteristics of personalized care services and how the OIAP enhances these attributes.

Table 1 provides a gap analysis, contrasting previously identified gaps with the proposed solutions offered by omnichannel mobile companions within the OIAP architecture. This table evaluates the extent to which the OIAP addresses each identified gap.

**Table 1.** Gaps: Omnichannel Mobile Companions vs. OIAP.

| Gaps | OIAP  |
|------|---|
| G1   | The OIAP unifies information across all communication channels, ensuring seamless interactions between patients and health professionals.   |
| G2   | The OIAP creates a centralized data management layer based on the openEHR specification, ensuring consistent and coherent patient data display across all communication channels. |
| G3   | The OIAP integrates existing healthcare systems to foster interoperability, facilitating seamless data exchange and providing a comprehensive view of patient information.        |
| G4   | The OIAP provides health professionals with real-time patient data across all channels, enabling timely decision-making and rapid response to patient needs and emergencies.      |
| G5   | The OIAP incorporates intelligent automation features for task monitoring, efficiently distributing tasks and reducing the burden on health professionals.                        |

The OIAP addresses fragmented communication, incoherent data presentation, system integration issues, real-time data access, and the burden on health professionals through unification of channels, standardization of data presentation, integration of systems, provision of real-time data access, and implementation of automation. The integration of the openEHR specification within the proposed architecture enhances the overall healthcare experience from both a systemic and user perspective. Following this, the characteristics of personalized care services are introduced and the OIAP's approach to addressing these characteristics is presented.

Table 2 presents a comparative analysis of personalized care service characteristics and how mobile companions can address these characteristics in an omnichannel environment. The study focuses on data-driven decision-making, a patient-centered approach, and continuous follow-up and monitoring, providing insights into how the OIAP leverages data integration, patient engagement, and remote monitoring to enhance personalized care delivery.

The OIAP enhances data-driven decision-making, patient-centered care, and continuous follow-up and monitoring by leveraging data integration, patient engagement, and remote monitoring capabilities, thereby improving personalized care delivery and patient satisfaction.

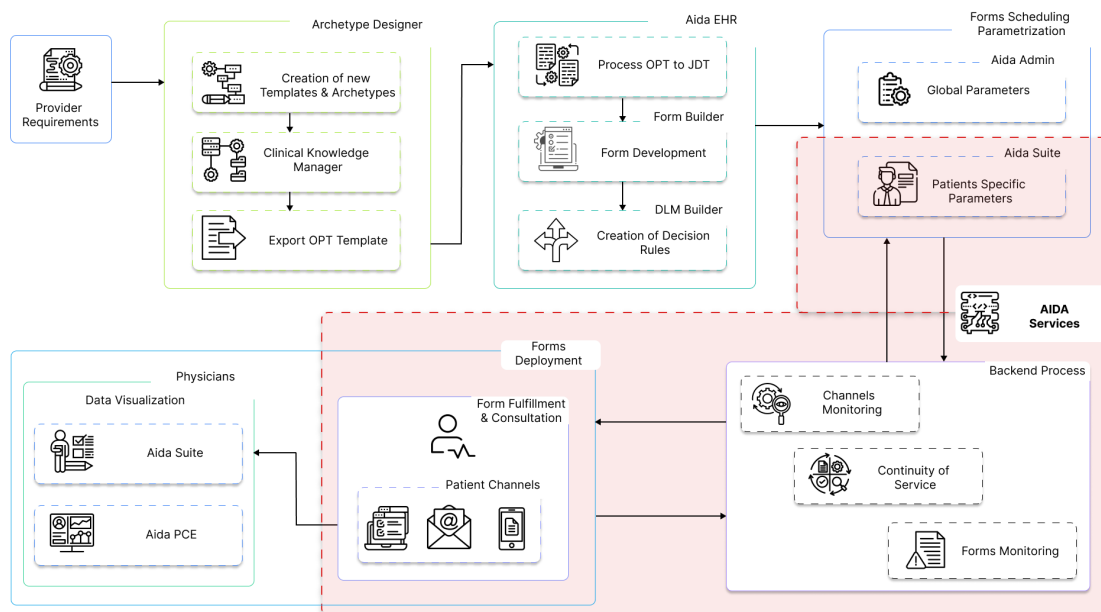
##### 4.1. Architecture Overview

A generic architecture for an omnichannel mobile companion based on an open data approach was designed, incorporating concepts from prior studies on omnichannel strategies in healthcare services [23,40]. This architecture focuses primarily on the coordination tier of omnichannel interaction services in healthcare [40].

**Table 2.** Characteristics of PCS vs. OIAP.

| Characteristics of PCS              | OIAP   |
|-------------------------------------|--|
| Data-driven decision making         | The OIAP centralizes all patient clinical data according to the openEHR specification, providing health professionals with real-time access to patient information for timely and informed decision-making. This access to treatment history and progress allows for more personalized care decisions, optimizing patient outcomes.  |
| Patient-centered approach           | By enabling patients to actively participate in their care and work together with care professionals, the OIAP promotes a patient-centered approach, improving the patient-centric care experience. This is achieved through convenient access to health data, personalized recommendations, and interactive communication channels. |
| Continuous follow-up and monitoring | The OIAP enables continuous follow-up through automated alerts, reminders, and remote monitoring capabilities across preferred interaction channels. This ensures timely updates and interventions, supporting adherence to care plans and early detection of health deviations, resulting in improved patient outcomes.             |

Figure 1 illustrates the OIAP, emphasizing the backend processes and communication channels available to patients and health professionals. These channels are realized through mobile companions for facilitating continuous care services. This implementation will be integrated into the Agency for Integration, Diffusion, and Archive of Medical Information (AIDA) platform [41–43].



**Figure 1.** Proposed architecture.

The architecture includes several components: the Archetype Designer, AIDA EHR, and AIDA ADMIN and SUITE. The Archetype Designer allows clinical professionals to create templates and archetypes based on clinical specifications. These are exported as Operational Template (OPT) files, converted to JSON Data Templates (JDT), and used to create forms within AIDA EHR. Decision rules are then defined using the Decision Logic Module (DLM) builder and forms are published for utilization.

AIDA ADMIN and AIDA SUITE handle form scheduling configurations, alert settings, and global and specific parameterizations. Backend processes monitor form availability and ensure continuity of service across multiple channels. Patients can access forms through various channels, with a mobile app being the primary channel for this context. This approach eliminates the need to develop new applications from scratch by leveraging openEHR specifications for dynamic and adaptable form creation.

## 4.2. Use Case Implementation

This subsection outlines the application of the OIAP in the specific use case of patient interaction during ambulatory surgery. The process begins with a brief overview of ambulatory surgery followed by the design and implementation of the use case.

### 4.2.1. Overview of Ambulatory Surgery

The ambulatory surgery procedure aims to give the patient the advantages of efficiency and convenience, facilitating their return home as quickly as possible from the day of the surgical procedure [44]. Employing diminutive incisions with specialized instruments and the wonders of video imaging, these techniques orchestrate meticulous interventions that leave minimal tissue damage in their wake and usher in swifter recuperation periods. However, it is essential to exercise caution when selecting patients, undertake comprehensive preoperative assessments, and ensure a robust support system, all of which guarantee the safety and accomplishment of ambulatory surgery [45,46].

It is essential to settle patients' readiness and clinical appropriateness before their ambulatory surgery. Thus, a questionnaire is issued to patients 24 h before their ambulatory surgical procedure. This preoperative evaluation questionnaire acquires information regarding the patient's medical history and potential dangers and verifies the surgical intervention's safety and efficacy along with the patient's preparation for the surgery [44,45].

Equally important is the postoperative follow-up with patients, which aims to monitor their recovery progress and promptly address any concerns. By issuing a postoperative questionnaire within 24 h following the surgical procedure, health professionals can gather critical clinical data concerning the immediate outcomes and promptly identify any complications or adverse effects that may arise [45]. This diligent approach enhances patient care and facilitates early detection and management of potential issues. Additionally, a follow-up questionnaire 30 days after surgery provides insights into the long-term recovery progress and allows health professionals to evaluate the overall success of the procedure [46,47].

While these measures are undoubtedly essential, the current manual process of nurses conducting these questionnaires through telephone contact poses several challenges [48]. First, the growing number of patients waiting to undergo ambulatory surgical procedures has significantly strained nursing staff. They are already tasked with numerous responsibilities, and adding these time-consuming patient contacts to their workload to assess their readiness for surgery through telephone contact is becoming increasingly challenging to manage effectively. Second, the financial implications of this manual process should be noted. Allocating human resources solely to conducting patient telephone contacts strains the nursing staff and incurs considerable costs for the institution [48]. As healthcare institutions strive to optimize their resources and streamline processes, they must seek alternatives in order to mitigate these challenges.

### 4.2.2. Structured Approach

Six meetings and collaborative brainstorming sessions were held with nurses and health information systems professionals over four months. By including professionals from different backgrounds, we aimed to ensure a comprehensive understanding of the challenges faced in patient questionnaire completion for the subsequent formulation of an effective strategy.

These meetings yielded valuable information regarding the primary limitations and challenges experienced by nurses in executing this activity. Furthermore, these collaborative brainstorming sessions helped formulate a strategy to address the existing limitations and challenges. This strategy primarily centers around implementing an omnichannel interaction approach within healthcare services encompassing five crucial dimensions: strategy, processes, systems, data, and people.

Using the collective expertise of participants from different professional backgrounds, a strategy for handling these problems and limitations was established after the brainstorming sessions, where issues, limitations, and challenges were identified. Subsequently,



the necessary processes for implementing the proposed solution were put in place and it was determined which procedures should be automated to enhance efficiency. Moreover, attention was paid to identifying suitable systems for deployment and creating an integration plan to incorporate these new systems seamlessly with existing legacy systems within the hospital setting. The data specification to be utilized in this approach was defined, as was how the data would be presented to patients. Lastly, the proposed solution’s target audience and intended users were identified.

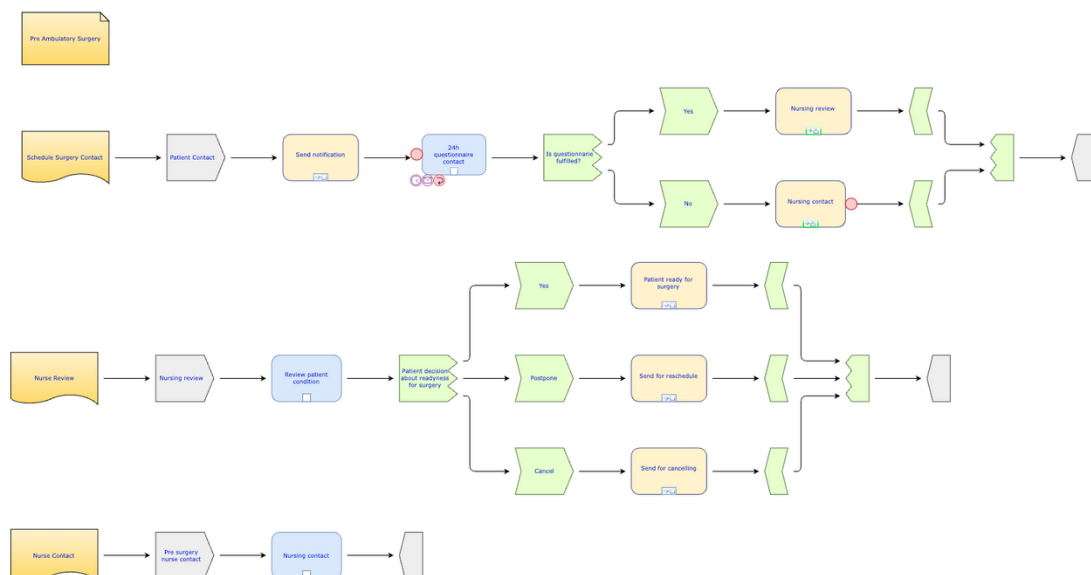
Valuable insights were gained through these iterative meetings and brainstorming sessions, leading to a structured strategy encompassing multiple dimensions crucial to successfully implementing the selected case study. The collaborative efforts of healthcare professionals in defining this strategy helped to pave the way for addressing the limitations and challenges faced in the current patient questionnaire process within the ambulatory surgery context. As mentioned previously, the OIAP is focused on strategy, processes, systems, data, and people, dimensions that promise to revolutionize the patient communication approach and enhance the overall efficiency of healthcare services in this context.

### 4.2.3. Demonstration

The demonstration involved the implementation of the OIAP in ambulatory surgery patient contact. The process began with case study selection, definition, and modeling of the use case in Archetype Designer. The OPT modeling structure is exported and converted into a JDT structure in AIDA EHR, followed by form creation, parameterization, and presentation to patients.

### Modeling Process Requirement

After defining the process requirement, the archetype designer conducted the modeling process alongside health professionals. Below is an illustration of the modeling process of this case study carried out in the Archetype Designer platform. Figure 2 contains the work plan for this specific use case and all of the task plans. For each task plan, a set of tasks and decision nodes were modeled based on the current context of the patient’s journey.



**Figure 2.** Archetype Designer modeling.

For this specific use case, the process begins with patient notification (through a mobile app-only channel used for demonstration purposes) to fill out a new ambulatory surgery questionnaire 24 h before the procedure. This questionnaire will be available to patients at a specific interval. Supposing that the patient fills out the questionnaire within this period,

an alert is sent to the nurse to validate the patient's completed questionnaire and ensure the patient's readiness for surgery. Otherwise, if the patient does not return the questionnaire within the indicated period, an alert is sent to the nurse notifying them that the patient did not satisfy the questionnaire requirements and that manual contact with the patient is required in order to ask about the surgery readiness procedure.

This case study includes a modeling process for 24 h and 30 days after the medical discharge from the surgical procedure. These processes are very similar to the ones presented previously, except with crucial differences in when they are made available to patients.

### Form Creation

The form can be created after uploading the OPT modeling structure into AIDA EHR and converting it into a JDT structure. Here, it parameterizes all UI-related definitions such as form colors, field size, letter size, input type, field visibility, and many others. After this parameterization, the form is created; when the creation process is completed, the form must be validated and published before being made available to patients.

### Form Parameterization in AIDA SUITE

With the form creation completed and published on the AIDA SUITE platform, the nurses can set a list of parameters regarding the questionnaire to be made available to patients (Figure 3). First, they must select the form, define the event name, and choose the number of occurrences and frequency of these occurrences. In addition, they can add a brief description to this form parameterization.

The screenshot displays the 'Configuração do Formulário' (Form Configuration) screen in the AIDA SUITE platform. At the top left is the 'Portal Colaborad.r' logo, and at the top right are navigation icons. The main content area is titled 'Configuração do Formulário' and contains several sections:

- Utente:** Name: ANTONIO JOSE DA SILVA; Data Nascimento: 02-01-1958; Episódio: 41568140.
- Procedimento Cirurgico:** Data e Hora Intervenção: 11-07-2024 - 10:30; Especialidade: CE CIRURGIA AMBULAT PRE-OP/CICA; Sala: SALA CINZA 2 CICA; Unidade: CICA.
- Formulário:**
  - Deseja aplicar o protocolo para diferentes formulários?
  - Formulário:** Transplante C6mes (selected in a dropdown menu).
  - Evento:** Teste contacto (text input field).
- Detalhes da parametrização:**
  - Valor do Delta:** 5 (text input field).
  - Frequência do Delta:** Dias (dropdown menu).
  - Valor da Repetição:** 2 (text input field).
  - Frequência de Repetição:** Dias (dropdown menu).
  - Tipo:** Preencher formulário (text input field).
  - Repetição Máximo:** 10 (text input field).
  - Horas de Validade:** 8 (text input field).
  - Descrição:** A large empty text area for adding a description.
- Deseja notificar o utente sobre a disponibilização do formulário do inquérito?

At the bottom of the screen, there is a version number '©DEV202407.2.4.1' and logos for 'CIAMPE 2020', '2020', and 'EUROPEAN UNION'.

**Figure 3.** AIDA SUITE form parametrization.

After the form parameterization, a set of backend processes monitors the parameterization and makes it available to the patient prior to the procedure based on the previously defined frequency. These backend processes are also responsible for ensuring the continuity of interaction between multiple channels of interaction, sending form alerts, and monitoring the channels available to patients for interacting with health professionals.

## Mobile App

Currently, the Centro Hospitalar Universitário de Santo António (CHUdSA) already has a mobile application for its patients. Thus, it was unnecessary to design a new application from scratch. Instead, we integrated the new module to present the forms to patients (Figure 4). This new module introduces the form to the patient based on the process modeling and context. Below is an example of a questionnaire form given to patients in the context of ambulatory surgery modeled in Archetype Designer and processed in AIDA EHR.

This integration allows patients to interact with health professionals without significant constraints or limitations.

When a patient requires a new questionnaire, it can be modeled in Archetype Designer, processed, published into AIDA EHR, parameterized in AIDA SUITE, and made available to the patient across multiple interaction channels. This approach removes the necessity of developing a new feature to accommodate new forms or questionnaires for patients. Thus, this module is dynamic and adaptable based on the process requirements and data modeling.

**Figure 4.** CHUdSA mobile app dynamic form module.

The approach used in the present case study brought about considerable innovation regarding how data and channels were managed. Information about the interaction channels available to and used by patients and health professionals was integrated into the

modeling process. This allowed the information about the interaction channels to be saved following openEHR data structure and specifications. Thus, all information about which interaction channel was used is stored in the form’s composition.

The implementation of the OIAP in ambulatory surgery patient interaction showcases the potential of omnichannel strategies in healthcare. By addressing existing gaps and enhancing personalized care, the OIAP demonstrates its effectiveness in improving healthcare delivery and patient outcomes. The structured approach and continuous follow-up provided by the OIAP offer a sustainable and scalable solution for modern healthcare challenges.

## 5. Discussion

### 5.1. Principal Findings

Several outcomes have been uncovered based on the proposed OIAP through implementing and demonstrating the omnichannel mobile companion in the healthcare domain. By analyzing the implementation results, it is possible to conclude that the proposed OIAP can indeed fill the gaps identified in health services. The application of an omnichannel mobile companion grounded in openEHR specifications yields substantial gains in various dimensions. These include integrated and unified health records data, enhanced patient engagement through dynamic interfaces, efficient resource allocation based on open data-driven solutions, flexible and adaptable care service delivery with real-time updates, smooth communication and collaboration among healthcare stakeholders, personalized patient education resources and alerts, proactive and preventive health monitoring, interoperability and data integration, efficient data analytics with standardized data, increased accessibility to personalized medicine services through mobile companions, and improved privacy and security measures. The findings emphasize the comprehensive impact of the OIAP, underscoring its potential to revolutionize patient care and enhance healthcare outcomes through a data-driven and patient-centric approach. Upon more thorough analysis, several additional contributions and gains can be outlined. Table 3 contains a list of gains and contributions found based on the design, implementation, and demonstration of the omnichannel mobile companion, accompanied by an explanation of each gain.

**Table 3.** Gains of mobile companion adoption in personalized care service based on open data approach.

| Characteristics of PCS                               | OIAP  |
|--|---|
| Integrated and unified health records data           | OpenEHR specifications promote the standardized representation of electronic health records, ensuring that information from multiple channels is integrated smoothly and seamlessly.  |
| Enhanced patient engagement through mobile companion | Mobile companions with built-in openEHR specifications provide dynamic and user-friendly interfaces and personalized features, enhancing patient engagement across multiple channels.   |
| Efficient resource allocation                        | Through the adoption of open data-driven solutions, healthcare institutions can allocate their resource more efficiently by understanding patients’ needs, and health trends, while healthcare institutions can better optimize their human resource allocation, equipment, and services. |
| Flexible and adaptable care service delivery         | The dynamic data modeling capabilities of openEHR support flexible and adaptive care delivery complemented by accessibility and real-time updates across all channels.  |
| Smooth and seamless communication and collaboration  | The use of mobile companions in an omnichannel environment promotes seamless communication and collaboration among healthcare providers, patients, and caregivers.  |
| Personalized patient education resources and alerts  | The delivery of personalized educational resources and alerts to patients based on their healthcare conditions and preferences allows for better understanding and promotion of patient adherence to personalized care plans.   |

Table 3. Cont.

| Characteristics of PCS   | OIAP  |
|--|---|
| Proactive and preventive health monitoring                     | Integration of multiple sources of data and the availability of real-time data from these sources promotes continuous monitoring, early detection of health changes, and personalized interventions, contributing to preventive and predictive care strategies.   |
| Interoperability & data integration                            | The adoption of standards such as openEHR enhances interoperability among healthcare systems, ensuring that patient data can be seamlessly shared and accessed across different healthcare providers and facilities. Patient clinical data can be integrated from various sources, including wearables, EHRs, and patient input, providing a comprehensive view of the patient's health. This can aid in more accurate diagnoses and treatment plans. |
| More efficient data analytics and real-time insights           | The use of standardized data based on openEHR across all channels makes it easier and more efficient to analyze patient data from different channels, as these data are collected in a standardized format.   |
| Increased accessibility and convenience with mobile companions | The use of mobile companions in an omnichannel environment enhances the accessibility of personalized medicine services by allowing patients to engage with their healthcare provider conveniently from their devices.  |
| Increase privacy and security issues                           | Implementation of security measures help to ensure privacy and data security in omnichannel environments across multiple channels of interaction.   |

This approach may enhance patients' reliability regarding self-collected information by making them more involved in their care process. It incorporates technological aids such as mobile applications or devices (digital companions) to guide them and enable more accurate data input. The success of patient self-collection ultimately depends on factors such as patient education, user-friendly interfaces, and integration of this information into the more extensive healthcare system. Thus, this approach can contribute to unique healthcare services, as patients and health professionals can contribute to collecting patient clinical data and synergize the manual approach (nurse phone contact) with the new approach through the omnichannel environment to achieve a comprehensive and more reliable patient interaction with a healthcare provider. Furthermore, an appendix is provided with a mapping between the identified gaps and how they were addressed, the characteristics of personalized care services, and the contributions found from the design and implementation of the omnichannel mobile companion (Appendix A).

After analyzing the gains gathered through the designed approach in the chosen use case, the following conclusions emerged regarding the initially identified research question. It is indeed viable to improve and enhance the provision of care services through a mobile companion in an omnichannel environment, particularly in the selected use case of patient contact. This approach diminishes the workload of health professionals in manual patient contact, lowers the costs associated with network operators, and fosters greater patient engagement by enabling interaction with health professionals through the mobile companion.

Ensuring the privacy and security of patient data is one of the main requirements of the proposed architecture. Furthermore, a prior study [49] identified privacy and security concerns that apply equally to this study. To this end, all channels made available to patients will have authentication and validation mechanisms. All interactions between the different channels are encrypted, as are the personal and clinical data of patients. Despite using the open data structure, all shared information is duly encrypted. Moreover, the proposed architecture must comply with General Data Protection Regulation (GDPR) and Health Insurance Portability and Accountability Act (HIPAA) regulations, ensuring that patient clinical information is treated with the highest standards of confidentiality and security. Thus, these measures collectively increase the reliability of our platform and protect against potential data breaches.



### 5.2. Limitations

Several limitations were encountered during this research project, mainly from a technological perspective. There was enormous difficulty in implementing the proposed approach due to the limited number of data types available for modeling on the Archetype Designer platform, mainly because the openEHR specification is much more focused on electronic health records than on devices and interaction channels. To overcome this issue, we searched in the Clinical Knowledge Manager (CKM) repository for a template with built-in data types that allow for the storage and association of patient devices and interaction channels. With this template, the modeling process stores the patient EHR information and the information about the device and channel used in the openEHR data format (compositions). This solution adds value to the presented approach and represents a contribution to future work.

Another of this study's shortcomings is the problem of technology adoption in healthcare, which still presents significant obstacles. To address this issue, training sessions with healthcare professionals are planned, along with an emphasis on intuitive and user-friendly interface designs to guarantee ease of use for both patients and healthcare providers. Furthermore, ongoing technical support will be provided to resolve any issues that may arise during implementation. In addition, we intend to adopt a phased implementation approach, which will allow healthcare professionals and patients to gradually integrate the proposed architecture into their interactions. This approach should minimize disruptions to existing workflows and encourage a smoother transition, ultimately increasing the likelihood of successful adoption and sustained use of this new approach.

Because this study is theoretical and conceptual, the identified impacts and benefits are significant. The conceptual model indicates possible cost savings from fewer physical consultations. However, it is crucial to support these claims with real-world data. Therefore, future research will need to rigorously validate the financial impacts of the proposed system. This will involve collecting data from patient interactions and from various metrics of the system. Additionally, insights can be gathered from patient satisfaction surveys and healthcare providers. This approach aims to not only confirm theoretical assumptions but also to offer solid evidence supporting the cost savings advantages of adopting an omnichannel approach in healthcare.

### 5.3. Comparison with Prior Work

Amid the initial surge of the COVID-19 pandemic, CHUdSA employed an innovative strategy that enabled remote patient monitoring within the context of home-based care [50]. This pioneering intervention was grounded in the adoption of openEHR specifications and the integration of two interaction modalities. It significantly influenced the provision of care services for patients in home-based care during that period, yielding numerous advantages for both patients and healthcare providers [50]. Analogous to the approach expounded in the current research study, both interventions aimed to leverage the capabilities afforded by the openEHR specification.

While the approach implemented in the first wave of the pandemic garnered a positive reception from patients and health professionals, it encountered certain limitations. These included challenges related to the seamless continuity of interaction across different channels and the integration of interaction channel records within the openEHR specification [50]. Recognizing these constraints, the presented approach evolved from the initial one introduced during the first wave of the COVID-19 pandemic. Consequently, the OAIP represents a noteworthy advancement over the strategy employed in the initial phase of the pandemic. Both approaches strive to enhance the quality of patient services by integrating novel information technology.

Lastly, upon searching the background literature, it was not possible to find any previous work that could be directly related to this work.

## 6. Conclusions

This theoretical study aims to present a conceptual architecture of omnichannel interaction based on an open data approach. It is focused on addressing the identified gaps in the healthcare domain regarding personalized care service by applying this approach in a specific context (ambulatory surgery—patient contact). Moreover, it revolves around proposing a conceptual architecture that leverages the open data paradigm and adheres to the openEHR specification to enable continuous patient follow-up and monitoring across multiple interaction channels. Furthermore, based on the contributions outlined in implementing an omnichannel mobile companion in ambulatory surgery, patient contact shows the potential of this approach to transform patient care by prioritizing individual needs and preferences. In addition, the openEHR specification empowers healthcare providers with data-driven decision-making tools, improving healthcare outcomes and resource allocation. This research highlights the gains that can be provided by mobile companions in omnichannel interaction environments based on an open data approach. OpenEHR adoption ensures standardized data structures, promoting interoperability and efficient data exchange. Integrating mobile companions in ambulatory surgery patient contact enhances efficiency, reducing the need for physical follow-ups and enabling remote monitoring for cost savings and patient satisfaction. While challenges such as privacy and technology adoption exist, the benefits include improved care, engagement, and streamlined processes. Personalized follow-up tailored to patients' needs enhances well-being, reduces complications, and improves healthcare outcomes.

The approach presented in this paper holds promising benefits for healthcare institutions compared to the previous manual processes. These advantages include streamlining and automating patient contact in ambulatory surgery settings, lowering the costs associated with network operators, decreasing nurses' manual workload in patient communication, and more. Omnichannel interaction in healthcare services further enhances the characteristics of personalized care services. The findings gathered in this research indicate that the well-planned adoption of the omnichannel strategy has enormous potential, and could drive healthcare institutions to higher maturity on several levels. As previously mentioned, this article intends to present a conceptual architecture in order to explore and implement the previously developed case study while addressing the initially identified gaps.

Moreover, this study presents a step forward in the evolution of the omnichannel strategy's maturity level. It achieves this by designing, implementing, and leveraging the omnichannel strategy from previous studies to effectively tackle recognized gaps in the healthcare domain concerning the provision of personalized care services to patients.

In order to build upon the theoretical foundation presented in this study, it is planned to undertake empirical validation of the proposed omnichannel architecture based on an open data approach. The next phase involves real-world testing to assess the practical efficacy of the omnichannel mobile companion in enhancing personalized care services. Quantitative and qualitative data will be collected, including details regarding patient interactions across various channels, medical records and health monitoring data, feedback from healthcare providers, patient satisfaction surveys, and system performance metrics. The methodology will combine a mixed-methods approach, incorporating pilot implementation, structured surveys, focus groups, and comparative studies. The theoretical framework presented here is aimed at demonstrating the practical viability of the conceptual architecture, identifying potential challenges and limitations, refining the model based on empirical findings, and providing robust evidence supporting the adoption of omnichannel strategies in healthcare. This future work will not only validate the proposed architecture but also offer actionable insights and guidelines for its broader implementation, thereby contributing to the advancement of personalized care services.

Currently, this is an ongoing project at CHUdSA that is in the implementation phase. Additional extensive and in-depth experiments will be performed to address gaps and characteristics of personalized care services that could not be identified in the selected case study in order to assess the extent to which this approach can address such gaps and can have a more

significant impact on care services provided to patients based on the presented architecture. Despite the present study focusing on patient contact in ambulatory surgery, the omnichannel architecture can be applied in other healthcare service domains as well. Thus, collaboration between a multidisciplinary team must be emphasized, as it allows for the implementation of the proposed approach. Working closely with health professionals from different backgrounds helped to provide an insightful contribution to the concretization of this study.

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## Appendix A

1. Manual Patient Contact
2. Mapping Table PCS, MC, OIAP, and OpenEHR

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