Adopting assistive technologies in healthcare processes: a chatbot for patients with amyotrophic lateral sclerosis

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Abstract. The paper presents e-Health solutions for monitoring patients affected by Amyotrophic lateral sclerosis (ALS). Assistive technologies have a direct and positive impact on both the quality of life of patients and the overall management of the service. In the context of a wide project, we introduce an Ambient Assisted Living framework to investigate the adoption of telehealth and telemedicine applications in the healthcare process. First, we model the process of the hospital service where technological innovations have been applied. Second, we investigate the impact of a chatbot to improve the communications between operators and families. The chatbot obtained high adherence, compliance, and engagement of users. We provide evidence of how robust technological and organizational modelling can be successfully applied to support the staff of nutritionists staffs in ALS healthcare process. Furthermore, the solution discussed in this work provided a great impact during the COVID-19 emergency.

Keywords: Business process management, Assistive technologies, Amyotrophic lateral sclerosis, e-Health.

1 Introduction

The improvement of healthcare processes is one of the typical applications of Ambient Assisted Living (AAL), a recent multidisciplinary research area [1]. Nowadays, the impact of new technologies, integrated with AI techniques and natural language processing, is finding multiple applications in a variety of domains, such as economics [2], social media [3], management [4]. Several studies also investigate the impact of technological solutions on well-being, quality of life, and healthcare services [5,6]. The attention focuses on the adoption of technologies in e-Health systems and personal healthcare [7,8].

The applied research proposes a wide range of methodologies such as monitoring services, patients' location, and recognition of activities, data collection, and behavior detection [9]. In particular, assistive technologies focus the attention on the concepts of patient-centered care, which is actually worldwide recognized as an essential dimension for the quality of care, as well as the so-called patient empowerment. A literature review on the topic reveals how many recent works focus on the application of assistive technologies to different areas of health, as in the case of patient education or medical information management [10,11,12,13].

From an organizational perspective, several works explore the intersections between a Business Processes Management (BPM) [14] perspective and AAL in order to address healthcare managers, to better allocate the appropriate resources, to avoid bottlenecks and to improve the responsiveness of care to patients [10,15,16]. BPM and simulations are helpful to optimize the process of various healthcare service or hospital department [17], in the following directions: to reorganise existing resources in a more efficient way [18,19]; to introduce some structural changes to the process by inserting medical devices, telemedicine or digitalization of documents [20]; to evaluate the possible activities of high clinical risk [21]; finally, to verify the regulatory compliance of the whole process [22].

In this paper, we introduce a general framework exploited in "La Casa nel Parco" (CANP) project[1] for the analysis of business processes in an AAL healthcare context and the improvement of the process thanks to the introduction of some devices. In particular, this work focused on the Tertiary ALS Center (CRESLA) at "Maggiore della Carità Hospital", Novara, Italy[2]. The Center provides care - as in-patients and out-patients visits - to people with Motor Neuron Diseases (MNDs), mainly Amyotrophic Lateral Sclerosis (ALS).

Recently, also considering the COVID-19 pandemic, and the related set of problems with access in the hospital, special attention concerns how to apply technological solutions to monitor these fragile patients. In fact, the possibilities regarding these technologies in clinical practice are often marginalized by issues of access and use. However, telemedicine and technological devices are effective tools for chronic patient monitoring, allowing patients to quickly access medical evaluation, in an efficient way and without travel.

ALS patients, as an example of patients with chronic neurological disease, are extremely complex in management, not only from a neurological point of view but also from multidisciplinary care [23,24]. One of the most difficult goals with ALS patients is body weight stabilization and diet monitoring. Indeed, diet monitoring is extremely important for patients with ALS because it is well established in the literature that patients with a rapidly progressive loss of weight have a worse outcome. An increase in body mass index is associated with significantly better long-term overall survival and obesity is a strong predictor of a favorable long-term prognosis [25]. Also, it is established that nutrition supplementation promotes weight stabilisation or weight gain

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[1] See website of the project: http://casanelparco-project.it/

[2] See website of the hospital service: https://www.maggioreosp.novara.it/attivita-assistenziale/servizi-sanitari/centro-sla/

in ALS. Following these patients with frequent monitoring turned out to be a useful approach in preventing further weight loss due to both the possibility of integrating caloric needs and dietary changes.

The adoption of an assistive technology allows the dietitians to monitor their patients continuously. In particular, a *chatbot* provides the patients with a tool to register their meals through a simple and carefully designed conversational interface [26].

The remainder of this paper is structured as follows: in section 2 we describe the healthcare process perspective. Section 3 introduces the case study with a discussion of the related healthcare process, the main features of the device, and the expected improvements. The last section describes some concluding remarks and future work.

2 Methodological Framework

Process analysis in healthcare can be addressed by following a BPM perspective. Our approach can be detailed by four main steps:

- **The analysis of the context:** this step investigates the environment concerning the case study. An initial exam of existing documents, as well as data to understand the organisation. This analysis includes the main activities and actors involved in the healthcare process (e.g. duration of the activities, resources involved, analysis of stakeholders, analysis of costs, etc.).
- **The process engineering (As-Is model):** this phase investigates the functioning of the system to define a model that has to be verified and validated with system experts in order to obtain the so-called As-Is model. In our case, this model consists of a visual diagram of processes (called process map or flowchart) adopting the BPMN standard language [27].
- **The analysis and the choice of the devices:** the CANP project involves 14 enterprises that provide different types of devices (telemedicine, platforms, etc). In this phase, it is important to consider the context and the organization of the process in order to identify the better choice able to improve and optimize the tasks according to the needs of the business or to the stakeholders.
- **The re-engineering of the process for its reorganization and optimization:** in this final step there are shown scenarios to analyse and investigate the changes on the As-Is model by generating the new To-Be version. This is the purpose of the "what-if'' analysis which explores parameter sweeping and Artificial Intelligence applications by computing performance indicators in different scenarios in both medium and long term. This phase includes solutions for restructuring the process, improving the detection, and the understanding of inefficiencies, bottlenecks, constraints, and risks [28].

This framework allows investigating the performance of the business process of the CRESLA with the introduction of a technological device consisting of a *chatbot* for Diet Management.

3 The application of a technological device in healthcare

3.1 CRESLA

CRESLA represents a national and international reference Centre for the diagnosis, treatment, and clinical research of MNDs, first of all, ALS. The public service offers a multidisciplinary and interdisciplinary approach including all the facilities for diagnosis, treatment, and care. Each year more than 400 patients (roughly 200 new patients and 200 controls), coming from Italian regions and some neighboring European countries, received visits (both as out-patients' and in-patients' visits) for diagnosis and treatment.

All patients are cared for by a multidisciplinary team. Experts from different disciplines (physicians including neurologists, pneumologists, dietologists, nurses, physiotherapists, psychologists, neuropsychologists, dieticians) work in a coordinated and organized manner. Besides, the Center participates in the definition of clinical protocols for the diagnosis and management of ALS patients, with other national and international organizations. The Centre has the structure, the expertise, the facilities, and the qualified personnel needed to conduct experimental clinical trials, cooperating as coordinator or Participating Centre in many national and international multicenter therapeutic trials in ALS.

Furthermore, in recent years, the scientific interest is focusing on translational research for MNDs, in collaboration with partners with expertise in preclinical / molecular research (e.g. genetic, histology, immunology). The creation of a large Biobank, in collaboration with the University of Piemonte Orientale, is allowing great storage of patients' samples (including blood, faeces and cerebrospinal fluid).

3.2 Adoption of technologies to improve the process

This section describes the output of the modeling effort. In particular, in the following images of BPMN diagrams are shown the As-Is models of the CRESLA service. As said, the As-Is describes what is the present situation, which are both the activities and the flow before the optimization effort (To-Be model) [14].

Thus, the Figure 1 describes the initial contact with the Center (Step1) and the taking in charge of patients with the first visit (Step2). As detailed in Figure 2, all patients are initially provided with necessary treatments (Step3) and evaluated with a quarterly multidisciplinary assessment (Step4). In this phase, all the needs related to the disease are evaluated through a preferential network of consultations. A weekly Day Service is dedicated to this purpose.

The model includes the analysis of health process resources. The Center is composed of 4 specialist in-patient clinics every week, with a short waiting time (roughly 15 days, also based on the urgency and level of disability). As described above, the team takes care of more than 200 new patients every year for both new diagnosis and diagnostic confirmation. The procedures are carried out as Day Service or Day Hospital. In a small part of cases (10%) patients need to be admitted to the Department of Neurology, mainly for reasons of geographical distance from the place of residence. Patients are taken over by the multidisciplinary team through scheduled visits and a network of telephone and telematic consulting. There is a dedicated telephone number (from Monday to Friday from 9.00 to 17.30) and an email address for consultations, information, and reservations, added to a telephone number for urgent consultations.

Since September 2012 a home medical care program has been launched according to an experimental protocol for the management of patients in the terminal phases of the disease, in collaboration with the local palliative therapy units. At diagnosis, the diagnostic certification of rare disease and the therapeutic plan for regional patients are drawn up in the Regional Register of Rare Diseases.

The multidisciplinary visits provided in Step4 include the following activities:

1. neurological with physical evaluation
2. speech therapy evaluation
3. dietitian evaluation
4. spirometry and pneumological evaluation
5. psychological interview
6. neuropsychological evaluation
7. physiotherapy evaluation

If necessary, also other specialists are available (e.g. palliativist, gastroenterologist, occupational therapist, geneticist).

After each visit, the specialist draws up a report for the general practitioner containing the summary of the assessments, and the new therapeutic indications.

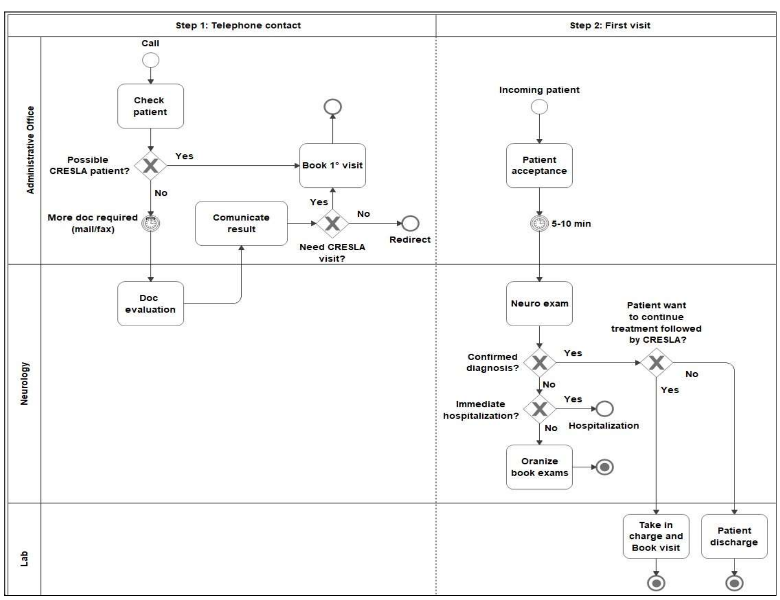

Fig. 1. The process of CRESLA. In particular, the first column concerns the initial contacts between the Center and the patient (Step1). The second column describes the activities related to the first visit, for the diagnosis and the taking in charge of the patient (Step2).

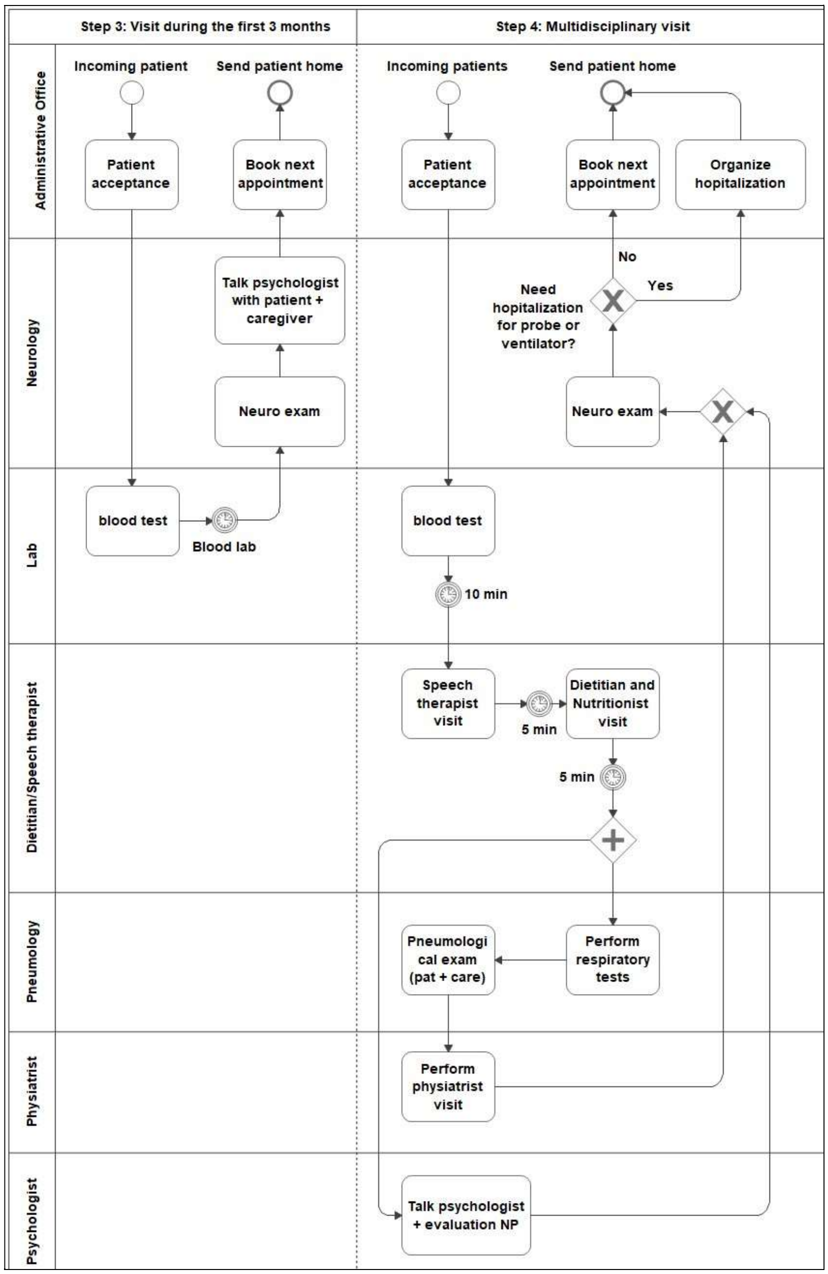

Fig. 2. The process of CRESLA from the patients point of view. In particular, the first column shows the activities related the visits in the firsts three months (Step3). The second column shown the multidisciplinary visit phase (Step4).

3.3 Chatbot for Diet Management

Diet management is one of the problems that the CRESLA team has encountered over the years while interacting with patients. Patients diagnosed with ALS undergo a first hospital visit where they are taken in charge by the staff of nutritionists. During the visit they receive written or oral indications on the most suitable diet that meets their individual needs for energy and nutrients. Once they return home, they can record how much they ate on a paper food diary which is usually completed in the period before the checkup. The next appointment with the specialist takes place 3-4 months after the previous visit. During this period various events may occur: the patient may have lost weight or his ability to swallow may have deteriorated. At that point, the nutritionist has to trace back any problem that presented during those months, possibly provide late changes to the diet, or investigate if the patient had problems following the instructions provided.

By using a digital version of the diary, patients could register their meals more frequently and the data would be communicated in real-time to the dietician. The specialist would thus be able to monitor the nutritional status of the patient even in the absence of in-person visits and could highlight any significant deviation from the planned diet, as well as any swallowing problems related to the progression of the disease. Therefore, the analysis of user requirements revealed the need for patients and caregivers to be able to take advantage of asynchronous and digital assistance, in a conversational form. Conversational interfaces - used here as synonyms of agents or chatbots - allow humans to interact with devices using "natural language", that is, the set of words and structures that are used daily to express themselves. Instead of communicating with the machine through a formal system that the computer can understand (like a programming language), the user can speak or write freely, delegating the interpretation of the message to mechanical components.

A textual chatbot allows the patient to compile their diary in an intuitive and asynchronous way. The interface does not include vocal components since the voice is a problematic element for ALS patients, being one of the abilities that vanish as the disease progresses. This decision is in line with the general design of the chatbot, which is supposed to be extremely simple to engage with. The goal was to build an interface that could be operated through the exclusive use of buttons and would not involve typing - except for one question. In this way, even in case of reduced mobility, it would still be possible for patients to successfully complete their diary.

The interface presents the patients with the compilation of their virtual food diary. There are different types of diets based on the consistency of food: regular, soft, minced, pureed, and semi-liquid. Each patient gets assigned one of the diets based on their swallowing ability (assessed by the speech therapist). For the purpose of processing the conversational interface, diets were into two large categories (solid and liquid) based on whether or not the patient needs to blend foods. A patient may then be assigned to the solid diet but may need to shift to the Liquid diet over time. It is therefore possible to change the diary interface over time.

Each diet interface contains the quantities of food required for an entire day. For each of the two diets, a schema was drawn up by the dietician with the portions of the food and the quantity of water to drink. The dietitian does not indicate the maximum quantities of food, since the purpose is to report how much food the patient has been able to consume compared to the minimum quantity expected. In fact, the clinical situation of patients often generates a situation of inappetence with a consequent decrease in body mass. The goal is to verify that users are able to consume 100% of the prescribed meal every day, and possibly even something more. By the means of this it is possible to understand if the patient has consumed a quarter, half, three quarters or the whole of the expected portion. It is always possible to indicate that it has been consumed “more than expected”.

As for the amount of water to drink, the recommended portion is 8 glasses. However, the system accepts values from 0 to 20, thus including both the cases in which the user drinks less or more than expected.

The interaction takes place as follows: the users open the interface and authenticate themselves. For privacy reasons, they log in with an "anonymous" username, that is, with credentials through which it is not possible for the chatbot provider to recognize the patients. Depending on the diet that has been set for that user, the chatbot proposes the first meal in the list (for example, breakfast, as shown in Figure 3). The user can fill in the meal in its sub-elements, or skip it. This feature is useful if the user has skipped a meal entirely, or that meal is not applicable to his case (e.g. not all patients have been prescribed supplements).

For each meal, the chatbot proposes its elements (e.g. for breakfast, biscuits/cereals, coffee/tea, etc.). The user can easily indicate the consumed fraction of the portion through the use of buttons that show the words “all”, “half”, etc. The process is repeated for each element of the various meals. Finally, the chatbot asks how many glasses of water were drunk that day. In this case, the interaction does not take place via buttons; the user must enter a number in the text field. It would have been impractical to create 21 buttons (from 0 to 20) and force the user to scroll through them all to the desired number. Once the registration phase of the actual foods has been completed, a final question is displayed every 15 days. This question is intended to periodically check for difficulties in chewing and swallowing that may arise as the disease progresses. The question, “Do you seem to have more difficulty eating?”, Requires a YES / NO answer. If the user answers YES, a free field appears in which the user can explain in her own words the difficulties she has encountered.

Once the entire list of meals in the diary has been exhausted, one last message informs the user that the compilation has been successfully completed. Users can press a button that signals a final greeting and they get automatically logged out from the interface. This behavior ensures that the diary is filled in from the beginning only after authentication. The data is saved continuously during the interaction, in order to save even partial data. If users interrupt the compilation in the middle and then forget to continue, the partial data of that day will not be lost.

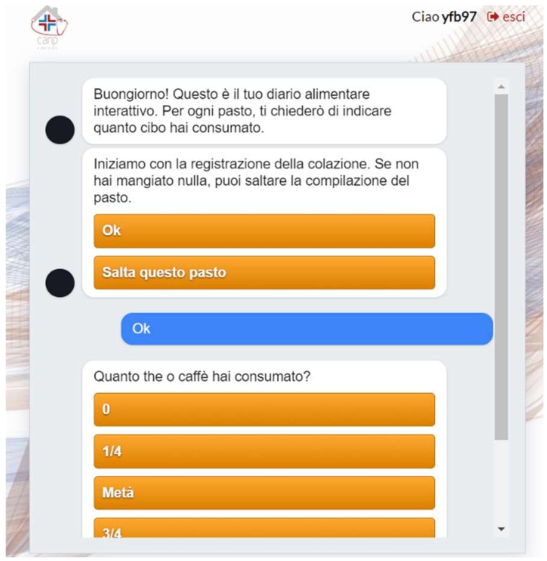

Fig. 3. An example of a chatbot dialog (in Italian). The chat starts with a welcome message and by asking the data about breakfast.

From the physician's point of view, the data extracted from each individual interaction is reported in a readable and easy-to-process format (e.g. an Excel file). The table shows a timestamp for each user, the answers provided for each meal and the answer (if any) to the last question. The dieticians can download these tables by accessing the interface through their set of credentials. The data can be used to process and monitor the patients' nutritional clinical progress and it can also be stored - being totally anonymous - and used for further studies.

In conclusion, this chatbot has been used in recent months on 22 patients. The use of this device has helped to optimize the work of doctors as it has allowed doctors to have continuous monitoring of what are the food revenues in the medium-long term, net of what may be short-term fluctuations. Moreover, the data are immediately received by the medical staff who can then intervene in a short time if the situation requires it. Finally, the compilation of a diary via app is not binding for the patient, so you can maintain good compliance even for the long term without drop-out of patients. It should also be noted that this system was very useful during the Covid-19 period as it allowed continuous monitoring without exposing fragile patients to risk infections due to visits or dietary changes in presence.

4 Conclusions

This paper introduced a general framework involving Business Process Management to investigate a healthcare process by adopting a telemonitoring device, with the aim to optimize a healthcare service. The approach considers human-centered privacy by design approach, leading to fine-grained end-user control over data collection, processing, and sharing, subsequently increasing end-user trust. The main goal is to define a robust technological and organizational model to be successfully applied in other healthcare contexts. Healthcare process modeling has been adopted to investigate the effective quality improvement of assistive technologies. In the first application on 22 patients, the chatbot obtained high adherence, compliance and engagement of users. Furthermore, we plan to improve the ALS Center process model by introducing other e-health devices for telemedicine and assistive technologies. This kind of tool demonstrated useful to support the staff of the hospital, as well as to increase the quality of life and well-being of the patients.

Furthermore, the BPMN model is an initial effort to address a process simulation, on the basis of the real parameters (arrival of patients, resources of the Center, the flow of the activities). Thanks to the collection of these data, we plan to investigate log files (event log) collected from chatbot in order to automatically detect deviations from the model, according to typical conformance checking approach, quite popular in the context of *process mining* discipline.

Moreover, this type of diet telemonitoring was also really useful during the first wave of COVID-19 period in which these fragile patients had, on one hand, the need for periodic monitoring and, on the other, forbiddance to leave the house.

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