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EXECUTIVE SUMMARY OF THE THESIS

Development and testing of a Vocal Interactive Amazon Alexa skill for Medication Adherence Support

MASTER'S DEGREE IN BIOMEDICAL ENGINEERING

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1. Introduction

The problem of medication adherence has been identified by the WHO as a global problem and represents a major challenge for the healthcare system. Studies estimate that one out of every two patients with chronic diseases does not take the medication prescribed by their doctor correctly, sometimes not starting the treatment at all, sometimes altering it or stopping it [1]. There are many causes associated with non-adherence and as a result, solutions aimed at solving this major problem are evolving along with different approaches. Among the causes are a lack of understanding of the information given by the doctor [2] and forgetfulness on the part of the subject, sometimes caused by complex therapies. With regard to the latter, various technologies have been developed and are still being developed, ranging from simple diaries to smart containers and smartphone applications. Almost all of these solutions do not provide for a direct connection of data between doctor and patient except for adherence reports that can be sent sometimes or on request to doctors or caregivers.

Among the new technologies that are interfacing with the world of healthcare in general [3], but also with the problem of non-adherence in particular, intelligent devices controlled by voice, such as Alexa developed by Amazon are rapidly emerging [4]. These devices allow third parties to develop applications, called skills, which are becoming increasingly numerous in the healthcare sector.

Specifically, in the project described in this article, a vocal interface was created on Amazon's Alexa device, capable of managing, helping and guiding the patient in the adherence planning and following his or her treatment plan. The

framework was included as a new module in the IntakeCare platform, a work-in-progress digital health solution aimed at managing the treatment plan and remote monitoring of drug adherence. The overall system offers a modular approach that includes: a dashboard through which the doctor enters, by filling in forms, the treatment plans prescribed to patients, and displays analytics about their adherence; a data layer with the function of storing records, which are organized and presented in user interfaces by means of a logical layer. Finally, a system for patients to notify and check for prescribed doses, which is developed in three alternatives: a smartwatch integrated with algorithms for gesture recognition, an AI application to recognize missing drugs from the blister pack through the mobile phone's camera, and Alexa's voice interface, capable of processing natural language, that was the focus of this work.

2. Methods

System architecture

The architecture of the platform is based on the three-tier model, with the database, the backend and the frontend, consisting of a voice interface for patients and a web application for doctors, being developed in parallel by several people in the IntakeCare team. Security, archiving and data presentation logic was also implemented [5]. The elements and frameworks used to create the architecture are shown in Figure 2.

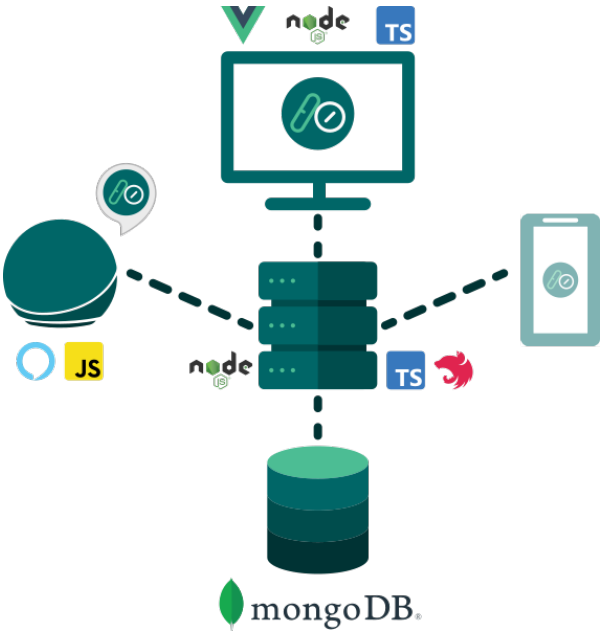

Figure 2: Three tier Architecture of Intakecare project

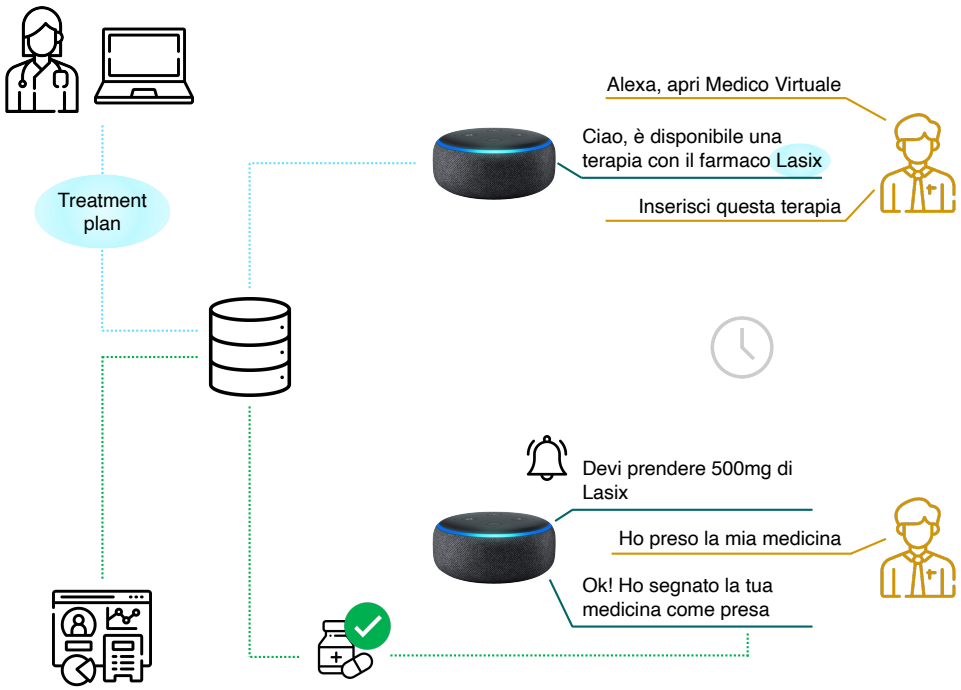

Figure 1: CareVoice interaction model

Skill development and design

CareVoice is a skill that can be used on Amazon Alexa devices. It provides an interface for patients to assist them in managing their treatment plan. Thanks to the data entered by the doctor, the skill has access to the patient's data. Identification is done securely using an OTP within a skill's intent. The user can then configure reminders on the device in accordance with prescriptions and confirm medication intake at set times. The system guarantees a second notification if confirmation is not received. The skill has been designed to respect the postulates and integrate some of the strategies of the persuasion model of Win, Khin Than et al [6]. Specifically, unobtrusiveness in everyday activities and transparency of intent were guaranteed.

The strategies of reduction, for fast and secure configuration, tunnelling, customization and self-monitoring were integrated. The construction of the functionalities took into account the approaches of praise, social role and liking, as well as the main one for the scheduling of reminders. Surface credibility and a real-world feel were also guaranteed by the presence of the doctor.

The skill allows programming of all types of therapies: daily, weekly or on specific days. The user is guided step-by-step through the configuration, which aims to program reminders in line with the therapy plan and to make the user aware while doing it.

It is possible to add, modify or delete therapies during configuration, but only if the doctor has previously requested at least one of these. Once the vocal reminder is triggered, the user only needs to confirm its intake. A notification will then be sent to the database. This allows to keep track of the intakes so that the doctor can have a global or a drug-specific view of its patients' adherence. The user can also access this information using the CareVoice features to request information on overall adherence or missed medication.

To study the usability of the skill, a one-week test was conducted, during whicha population of 7 individuals, recruited on a voluntary basis, were asked to use an Amazon Echo device with the CareVoice skill installed. Four subjects (57%) were males and three (43%) females. Only one subject was aged between 30 and 40, three between 40 and 50, none in the 50-60 bracket, two subjects between 60 and 70 and only one >70. Five subjects (71%) were already familiar or owned an Alexa device. The prerequisite was that all individuals had medication to take and sufficient digital literacy to handle the technology.

Before starting to use the skill, testers were asked to complete the Morisky Medication Adherence Scale and the IT-eHEALS, for profiling purposes. During the test, volunteers were able to explore the functionality of CareVoice and notify the Virtual Doctor (voice interface of the skill) when they took their medication. At the end of the test they were subjected to the System Usability Scale and a semi-structured interview to assess the perceived usability.

3. Results

Subject profilation

Regarding the IT-eheals, the total score of 4 subjects indicates a very good digital health literacy, while for the other 3 subjects the level is moderate. The MMAS-8, on the other hand, helps to understand the level of adherence assessed before the start of the test. The majority of participants have a low adherence propensity, only 1 subject reported medium adherence and only 1 subject reported high adherence. The table shows the numerical values for all subjects.

User	IT-eheals score (min:8; max:40)	MMAS-8 Score (min:0; max:8)	Perceived Adherence
A	40	3.5	LOW
B	20	8	HIGH
C	21	4.5	LOW
D	40	4.5	LOW
E	22	3.5	LOW
F	40	4.5	LOW
G	39	6	MEDIUM

Table 1: IT-eheals and MMAS-8 results scores

Usability of the skill

The study in terms of usability was carried out through an ad-hoc questionnaire and the validated SUS questionnaire.

In order to analyze the results of the ad-hoc questionnaire, it is possible to divide it into four macro-groups according to the theme of the questions: Setup Configuration, Skill Usage, Alexa Device, and Adherence.

In the area of setup configuration, almost all but one of the subjects found the initial access to the skill by entering the security code and the configuration of the reminders not at all complex. In the area of use of the skill, we see an overall complete satisfaction for three subjects, good for another three subjects and indifferent for only one subject. No one reported complete or partial dissatisfaction. The proposed system was considered not intrusive in personal life from 4/7, but for the other 3 there were some intrusive aspects to be considered. 2 subjects underlined the inutility of functionalities they did not use, 1 subject considered it unnecessary to repeat the dosage every notification, while 1 subject considered the notifications too repetitive. Positive aspects were the automated reminder setting, the possibility to communicate by voice, and the ability to use the skill also from the Alexa App. The repetition of the notification 25 minutes after the first one was an appreciated feature in 5 out of 7 patients, but in 3 out 7 the interval of time (that ranges from 1 hour before to 1 hour after the programmed time of the intakes) to take the medication was judged not enough. 5 out of 7 subjects found some difficulty in communicating with the skill, in most cases due to the complexity of the utterance that has to be used.

Use of the skill

As regards the use of the Alexa device in general, both users that were already using the device and those that did not use it before will be interested in using it to monitor adherence, and also for other purposes.

In terms of perception of adherence, before the start of the trial, it varied widely between subjects, ranging from Low to Very High. In spite of this variety, surprisingly 4/7 of subjects reported that their adherence improved during the testing phase, while in the other 3/7 it remained the same.
In Table 2, the SUS score for each subject is reported:

User A	User B	User C	User D	User E	User F	User G
80	77,5	97,5	75	92,5	92,5	75

Table 2: SUS scores results

As a score above 68 is considered good, and the lowest reported score is instead 75, it can be highlighted that for all subjects the results in terms of usability were very good, up to a maximum of 97.5 for subject C and median (25^{th} percentile, 75^{th} percentile) equal to 80 (76.25; 92.5) with interquartile range equal to 16,25.
In answers 1,2,4,6,8,9 and 10 the median coincides with the ideal value of this answer. Answers 3,5,7 concern issues such as ease of use, immediacy in learning the technology, and the presence of well-integrated features. Also in these, a very good result can be seen, as the median deviates in all

three cases by only one point from the optimum value.

Among the results of the study, in addition to the semi-structured ad-hoc interview and the SUS questionnaire, we kept track of the various logs that allow us to assess how much and which functionalities were used during the testing phase. Also in this case results can be subdivided in two macro-areas: configuration and confirmation functions of the therapies, and additional functions concerning the request of missed intakes or data on adherence.

Regarding the configuration and confirmation phase, values were adequate to expectation, and the logs confirmed that there was constant participation throughout the test period for all participants. There was concordance between the logs of the functionalities linked to the confirmation of the intakes with the actual intentions of the subjects.
On the other hand, very low values were found for the use of additional functionalities. This may be due to a short period of time of use of the system which was therefore not sufficient to arouse the user's interest in additional information.

4. Discussion

The findings can be interpreted from two perspectives, that of adherence and that of usability. It should be emphasized that the duration of the test is relatively short to draw any conclusions about the trend in adherence, which nevertheless appeared to be very positive. It is essential to recognize that each tester used CareVoice's features to test its usability. From the semi-structured interview, it can be concluded that almost all users were fairly or completely satisfied with the technology used in the test. Most of the users liked almost all aspects of the skill, however, some expressed doubts about specific features or functionality that in some cases could be modified or implemented. One issue raised by several individuals was that the activation phrases were considered too long and difficult to remember. In some cases it should be noted that there are implementation limitations imposed by Alexa that have prevented them from proceeding with solutions other than those taken, an example being constraints on the wording of utterances requiring the fixed activation phrase that may be less natural. The phrase to use the skill must sequentially contain the invocation 'Alexa', the request 'ask the skill to...' and the specific function within the created skill that is to be triggered. In the specific case of this test, the sentence translated from Italian takes the form: 'Alexa, ask the virtual doctor to note that I have taken my medicine'. A possible future analysis could focus on what would be the perfect combination to build an effective, streamlined and syntactically correct utterance.
Another feature questioned was the time period in which it is allowed to confirm that the medicine has been taken, which was considered too narrow. This is an example of specifications that in future development could be configured by the doctor who, at his discretion, could set latency ceilings for taking medication. With regard to the latter, it should be noted that in the specific case of this test no doctor was involved and that the configuration was standardized for all subjects.

5. Conclusions

The objective of this work was to create and update components of the structure of the IntakeCare platform described in the introduction. The system is presented as a modular solution aimed at tracking, assisting and facilitating the prescription and intake of medication. One of the most fundamental aspects is the connectivity between the elements of this platform, in particular between doctors and their patients. The developed framework comprises several IT solutions, which are used to fulfill the main tasks related to communication and adherence monitoring. While the doctor can remotely enter the patients' medication and view their progress and

compliance, the patients are supported by a system that notifies and records their intakes.
One of the fundamental aspects that makes this project innovative is the creation of a direct and automated link between the platform used by the doctor to insert the patient's treatment plan and the Alexa device used by the patient. This step is of considerable importance as the misunderstanding of drug labels and prescriptions provided by doctors is one of the major problems contributing to adverse drug events.

The key points covered by this and a companion work [5] were: the direct entry by the doctor of prescriptions on a web platform; the storage of all prescribed treatment instructions in a database; a voice reproduction through Alexa in compliance with the instructions entered by the doctor; an appropriate voice-mediated notification system; the tracking of intakes via the voice interface; the saving of intakes in the database; the monitoring and representation of adherence; the feedback to the patients and their scores displayed on the doctor's control dashboard; persuasive solutions implemented in the workflow.

Compared to many existing state-of-the-art solutions, where the user is in charge of self-administration, IntakeCare's platform has a significant advantage: scheduling and confirming intake are clearly assigned to the doctor and the patient, respectively. It means that users are not overloaded with tasks in managing their treatment pathway. The platform guarantees greater seriousness in the scheduling of the treatment plan, as it is the doctor's responsibility. Moreover, control is promoted, thanks to the patients' feedback on their intakes.

6. References

[1] Bosworth HB, Granger BB, Mendys P, Brindis R, Burkholder R, Czajkowski SM, Daniel JG, Ekman I, Ho M, Johnson M, Kimmel SE, Liu LZ, Musaus J, Shrank WH, Whalley Buono E, Weiss K, Granger CB. Medication adherence: a call for action. Am Heart J. 2011 Sep;162(3):412-24. doi: 10.1016/j.ahj.2011.06.007. PMID: 21884856; PMCID: PMC3947508.

[2] Patel MJ, Khan MS, Ali F, Kazmi Z, Riaz T, Awan S, Sorathia AL. Patients' insight of interpreting prescriptions and drug labels--a cross-sectional study. PLoS One. 2013 Jun 3;8(6):e65019. DOI: 10.1371/journal.pone.0065019. PMID: 23755168; PMCID: PMC3670850

[3] Ilievski, Andrej & Dojchinovski, Dimitri & Gusev, Marjan. (2019). Interactive Voice Assisted Home Healthcare Systems. BCI'19: Proceedings of the 9th Balkan Conference on Informatics. 1-5. 10.1145/3351556.3351572.

[4] Corbett CF, Combs EM, Chandarana PS, Stringfellow I, Worthy K, Nguyen T, Wright PJ, O'Kane JM. Medication Adherence Reminder System for Virtual Home Assistants: Mixed Methods Evaluation Study. JMIR Form Res. 2021 Jul 13;5(7):e27327. doi: 10.2196/27327. Erratum in: JMIR Form Res. 2022 Jan 27;6(1):e36381. PMID: 34255669; PMCID: PMC8317037.

[5] F.Cancelliere. Development and Testing of a Web Interface and an Application Framework for a Physician Driven Adherence Support Platform. Master's thesis, Politecnico di Milano, Piazza Leonardo Da Vinci 32, 2020.

[6] Win, Khin Than et al. "Persuasive system features in computer-mediated lifestyle modification interventions for physical activity." Informatics for health & social care vol. 44,4 (2019): 376-404. doi:10.1080/17538157.2018.1511565