Home Assistive Robot for Alzheimer's Patients

Antónia Nóbrega [1], Camila Hayashida[1], Mariana Portela[1], Sofia Tavares[1], Pedro Guimarães[1,2], Frederico Jacob[1,2] and Arcelina Marques[1,2] [0000-0002-5528-9898]

[1] Physics Department, ISEP – P.Porto, Portugal
[2] CIETI, ISEP – P.Porto, Portugal
fljb@isep.ipp.pt

Abstract. With the increase in the senior population, especially patients with dementia and Alzheimer's, healthcare professionals are increasingly overwhelmed. Existing assistive technologies to improve these patients' quality of life and their caregivers are scarce given the daily challenges they face. To tackle this issue, a domestic assistive robot was developed for Alzheimer's patients – AlzheimerAlly - which encompasses the functionalities of a service robot, and a companion robot. AlzheimerAlly's functionalities involve tracking continuous monitoring of the patient's anatomical points to detect the type of movement and medication intake. The movement of the robot follows the movement of the patient. Additionally, the graphical interface allows cognitive and stimulation tests to be carried out. The medication dispenser, implemented, contains compartments, each with a LED. Finally, there is a website, which allows you to enter and access relevant data about the medication dispenser and cognitive tests. The functionalities described were thoroughly tested, demonstrating effective implementation. However, the prototype still remains subject to improvements. Although AlzheimerAlly requires improvements, it is already a significant and functional contribution to the area of care for Alzheimer's patients. This robot represents innovation and improvement in the quality of life of patients, their caregivers and healthcare professionals.

Keywords: Alzheimer's, Dementia, Service Robots, Companion Robots, Assistive Technology.

1 Introduction

The notable increase in average life expectancy that has been felt in recent years, represents the greatest achievement of the century, and is only possible through improvements in living conditions and technological advances in the area of health (Bravo & Ayuso, 2020). In Portugal alone, the longevity index, responsible for measuring the aging of the population, was 33.6% in 1960 and rose to 47.9% in 2011 (AJSepúlveda, nd). Although the increase in average life expectancy and the number of elderly people is a social benefit, on the other hand, associated with the risks and fragility related to aging, long-term problems have emerged that depend on expensive and complex interventions. Among these problems, there are mainly strokes, diabetes and dementia, caused in most cases by Alzheimer's (Jaul & Barron, 2017). It is possi-

ble to define Alzheimer's as being “the main cause of dementia, and is quickly becoming one of the most lethal, costly and challenging diseases of this century” (Scheltens et al., 2021). Currently, the number of individuals affected by Alzheimer's globally reaches values close to 50 million, representing 60 to 80% of dementia cases. Portugal reaches an average of 19.9 cases per thousand inhabitants, making it the 4th country with the highest incidence globally (Oliveira da Silva et al., 2019). The brain has immense nerve cells that connect and communicate with each other through chemical reactions. Each of these cells has the ability to receive stimuli, process and store information and, finally, transmit it to produce an electrical action (Quillfeldt, n.d.). Despite the misinformation about the event that leads to the origin of this disease, scientists point to the sudden failure of these units to function, which translates into irreversible changes in the brain. The first phase is characterized by symptoms such as forgetting recent information, difficulty in carrying out tasks in your professional and personal life, organizational problems and lack of interest (Zvěřová, 2019) (MD dos Santos & Borges, 2015). When the disease reaches the moderate stage, the symptoms become more pronounced and evident, manifesting themselves in behaviors such as confusion in speech, unexpected attitudes, hallucinations, difficulty remembering to perform daily tasks, mood changes and temporal disorientation. During this period, the individual is still able to participate in their daily activities, although they require assistance (Zvěřová, 2019) (MD dos Santos & Borges, 2015). Finally, the disease reaches its most advanced stage, where the symptoms are more severe, such as the loss of responsiveness, the emergence of involuntary movements and even their loss, decline in cognitive abilities and change in the patient's personality. At this stage, the person requires continuous 24-hour assistance, resulting from the loss of basic skills such as walking, sitting and swallowing accompanied by the weakening of their immune system (Zvěřová, 2019) (MD dos Santos & Borges, 2015). Although there is currently no cure for Alzheimer's, there are medications that can temporarily slow the worsening of symptoms. As this disease affects each person differently, treatment is highly individualized. Additionally, there are a series of medications and therapies associated with controlling the patient's behavior and environmental management measures that help to alleviate symptoms (Massoud et al., 2011). Following everything mentioned above, a significant problem arises: caring for a person with Alzheimer's. This aid presents enormous costs, not only on an economic level, but also on an emotional and psychological level. The patient's family member, friend or person close to them needs to quickly take action to provide daily assistance. This help has implications such as adjusting schedules, location and a complete change in the personal lives of the two individuals in question. When the situation reaches the point where it is necessary to hire a professional caregiver, which presents a vast expense to family members and companions, they have an enormous responsibility in controlling not only their patient and their basic needs, but also the social environment. In both cases, the loss of the person responsible personal time is inevitable, as well as an increase in stress, a feeling of overload and a decrease in their emotional and physical well-being (Contreras et al., 2022). In this context, the combination between technology and medical assistance becomes essential, with the emergence of technology and assistive robots. Assistive technology is understood as the area of knowledge that

encompasses products, resources, methodologies, strategies, practices and services with the aim of providing greater independence and quality of life to people with disabilities (Pereira de Lima, nd).

2 State -of-Art

Assistive robots have become crucial in healthcare, particularly in two main areas: assistive service robots and assistive companion robots. Furthermore, socially assistive robots (SARs) have been developed to address the growing demand for caregivers in areas such as the healthcare of patients with Alzheimer's disease and dementia. These robotic devices not only provide cognitive, physical and social stimuli, but also perform tasks to alleviate the burden on caregivers (Jorge S. Gonçalves, nd) (Badr & Dankar, 2022). The rise of the Internet of Things (IoT) has revolutionized connectivity, with the Internet of Medical Things (IoMT) enabling the collection and storage of vast health data for monitoring. This data can be used to implement Artificial Intelligence (AI) systems, facilitating remote diagnoses and treatments. IoT-driven interconnectivity, as well as assistive robots, are fundamentally changing the way healthcare is monitored and managed, offering innovative opportunities to improve care and efficiency in the medical sector (Stavropoulos et al., 2020) (Kakhi et al., 2022). Table 1 provides a comparative analysis between the various technological and assistive devices for the healthcare sector, with a focus on dementia.

In summary, assistive technologies are vital for improving the quality of life for Alzheimer's patients and alleviating caregiver burden, making them essential in today's healthcare landscape (Carmo et al., 2015).].

Table 1. Comparative analysis between technological and assistive devices

TECNOLOGIA / ROBÔ	APLICAÇÃO NA SAÚDE	TIPO	REFERÊNCIA
Clara	Problemas cardíacos, AVC	Robô assistivo de serviço	(Kang et al., n.d.)
Babyloid	Demência	Robô assistivo de companhia	(Salichs et al., 2016)
Vector	COVID-19	Robô assistivo de companhia	(Odekerken-Schröder et al., 2020)
PARO	Demência	SAR	(Rashid et al., 2023)
NAO	Demência, TEA	SAR	(Martín et al., 2013)
Hector	Demência	SAR	(Robots and Androids, n.d.)
COACH	Demência	SAR	(Koutentakis et al., 2020)
Smart Glasses	Demência, Pré-Depressão	IoMT	(Salehi et al., 2022)
Smart assistive glasses	Demência	IoMT	(Gacem et al., 2019)

3 Materials and Methods

In this section, the functional requirements of the robot will first be presented, and its characteristics and applied logic will be described. Subsequently, the Hardware will be outlined, covering all its physical components and connections between them.

3.1 Functional Requirements

The robot that is intended to be implemented, called “AlzheimerAlly”, is made up of five major components, these being the medication dispenser, cognitive tests, the Website, computer vision and pose detection, as well as the movement of the prototype. Fig. 1 illustrates the overall architecture of AlzheimerAlly.

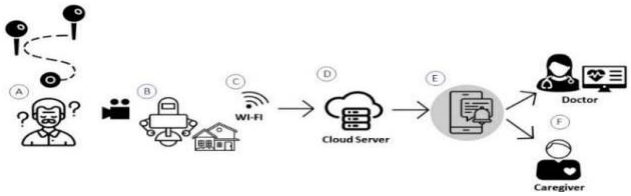

Fig. 1. General architecture of AlzheimerAlly

The medication dispenser retrieves information from the Database regarding medication schedules and the associated compartment. It compares the time in real time with the time provided by the health professional and, when they match, the dispenser opens the tray and activates the LED in the respective compartment. It was implemented using Arduino language, with the Arduino IDE software and specific modules (RGB LEDs, Button touch, RTC Module, Relays, connecting wires and a CD Player system). The cognitive and stimulation tests were implemented in Python using the Tkinter library to assess immediate, recent, and remote memory, visual recognition, and executive functions through questions with three possible answers, including images. Tests inspired by existing cognitive tests such as Montreal Cognitive Assessment (MoCA), Mini Mental State Examination (MMSE), AddenBrooke Cognitive Assessment - Revised Version (ACE-R) and also manuals 1 and 2, “Illness Alzheimer’s – Stimulation Exercises”, must be performed three times a week. In order to be able to carry out the tests at the times scheduled on the Website, it was necessary to develop an algorithm that not only made time available, but also managed it autonomously. Thus, the implemented code allows that, once run, there is an automatic update every minute. Whenever the current time coincides with one of the programmed times, the test is executed, displaying its corresponding window. The score for each test is sent to the Database, as it is a strong indication of the disease's evolution, together with information on the respective times. The test response time also appears as an ally to the perception of the progress of the pathology. The codes for computational visualization and pose detection, through anatomical points, are also implemented in Python. This functionality is divided into two parts, one of which is responsible for detecting the type of movements performed by the patient, and the second appears as a complement to the medication dispenser, checking whether or not medication has been taken. In the first code, gait is identified through the positions and angles of the points, checking whether the individual is “walking forward”, “turning to the left”, “turning to the right” or “standing still”. Subsequently, this information is sent to the Arduino, which recognizes the signal and moves the robot, always imitating the patient's movement. The second code consists of detecting medica-

tion intake, checking whether the individual carries out the movement of bringing their hand to their mouth, through the distance between these two points and, additionally, the angle formed by the arm. This code has the ability to autonomously and automatically compare, minute by minute, the current time with the scheduled medication taking times. If there is a match, pose detection is performed to check whether or not the medication has been taken. Subsequently, the corresponding results and times are sent to the Database. Following the previous functionality, the movement of the robot appears, whose programming was developed in Arduino language. In this segment, the signal sent by the preceding code is recognized and, depending on the byte, one of four movements is carried out. These movements are executed and prepared through the activation/deactivation of the prototype's constituent engines.

In turn, the Website, developed in the Visual Studio Code editor, uses the languages HTML, CSS (along with the Bootstrap framework), JavaScript and PHP. The Database is created using MySQL, with the help of Xampp. Caregivers/health professionals, must validate their identity with a username and password to access the Webite. They can then input medication details, including name, intake time, and dispenser compartment, as well as cognitive test schedules. All data is stored in the Database, which also logs and provides access to the history of medication intake and cognitive test results.

3.2 Hardware

To complement all functional requirements, there are associated physical components that make the robot functional and lead to its practical application. Fig. 2 shows the prototype open and properly labeled, for a full understanding of the concepts covered and materials used in this section.

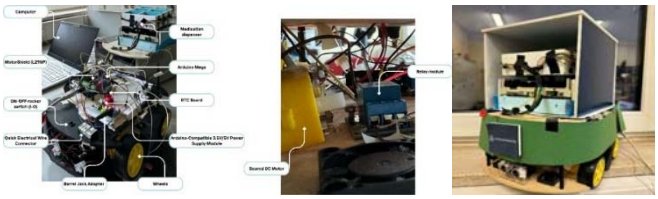

Fig. 2. Prototype and its components.

All codes developed are executed on a computer that has not only a camera, used to detect anatomical points that enable the identification of movement, but also the touch screen for carrying out cognitive tests. Additionally, and since one of the codes aims to imitate the patient's movement by the robot, the prototype has a base made up of four DC motors, associated with four wheels and coupled to a wooden chassis. The chassis contains the Arduino Mega integrated, along with the motorshield L298P, and a breadboard powered by a power module associated with an adapter barrel jack. All components are powered by a power supply, which supplies the circuit with 12 V, and which is regulated by means of a rocker switch (OI). The Arduino, present in the base, is then connected to the computer, through a serial port, to send information

from the code to the board. Furthermore, the dispenser consists of a spongy cardboard tray with 6 compartments, each designed for a specific type of medication. Each division has an associated RGB LED, colored red, whose power supply and circuit are in a breadboard located at the base of the chassis. In turn, the implementation was also done on the Arduino Mega, which receives information from the Database. Thus, the same Arduino can acquire data from different codes (Movement and Medicine Dispenser), present in the computer.

4 Results and Discussion

The results to be presented below will reflect the effectiveness and practical viability of "AlzheimerAlly" as an innovative assistive robot for the management and support of individuals with Alzheimer's disease. The results described are observations that come from various tests carried out throughout the development of the features. With regard to the medication dispenser, the results demonstrate an effective operation, efficiently meeting the stipulated objectives. After the health professional enters data relating to medications on the Website, such as the medication to be taken, the associated compartment and the time taken, a code developed in Python fetches the information from the Database and sends it correctly to the Arduino Serial Port. Using this sequence of data, the dispenser correctly compares the medication intake time entered with the current time, opening the tray and illuminating the compartment containing the desired medication, as can be seen in Fig. 3.

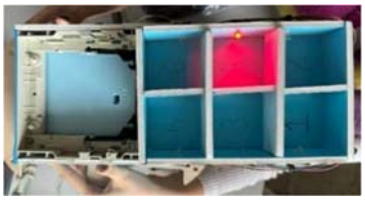

Fig. 3. Opening the tray and lighting the LED corresponding to the desired compartment.

To close the dispenser, the patient must press the ButtonTouch implemented, a practice that showed good results. However, closure is only allowed after the LED turns off, which occurs within one minute. Given the presumed duration of the patient's administration, this aspect did not prove to be inconvenient, since, after closing the dispenser, it only opens again when the medicine is next taken. Regarding the code relating to cognitive tests, the results indicate good functioning, efficiently fulfilling the proposed objectives. The tests methodically provide 10 questions, with feedback on the answers, presented through visual animations, such as a green background and the comment “Very good!” or a red “X”. Some important and relevant information is also printed on the console, through a performance history, such as the final score, total time test execution and the time at which it starts. The code additionally compares, accurately and minute by minute, the current time with the times programmed on the Website. If both are the same, the tests are accessed automatically, and the

interface appears. One of the problems associated with this code is that, when the time comes to perform the test, several interfaces appear, each corresponding to a test that was not performed, due to the incompatibility of the time. Even so, data relating to the score obtained and the time of execution are sent to the Database.
For example, for the question "What is the name of the place where we buy clothes?" with possible answers being "Bakery", "Marketplace", and "Store". The console displays the list of possible test schedules and the current time. A message indicates when it is not yet time to perform the cognitive test, and another message indicates when it is time to perform it. Once it is completed, a message is printed indicating the time the test finished and the performance history, which includes the score obtained, the duration of the test and the time the test was performed.

Regarding the movement type detection code, the results allow us to conclude that, although it is functional, it has substantial flaws. The exclusive dependence on the coordinates of the body segments, combined with the fact that there is only one camera and no support from other sensors, makes the detection and identification of movement difficult. Functions like “is_standing”, “is_turning_left” and "is_turning_right”, reveal relatively good results, however, there are occasions where the movement is wrongly identified. The function “is_walking_forward” presents greater problems since it is based only on hip coordinates, obtaining more false results. The connection between the results and the Arduino is functional, and data is sent efficiently. In Fig. 4, an image of the identified anatomical points of interest and the messages printed on the console during one of the tests carried out are present.

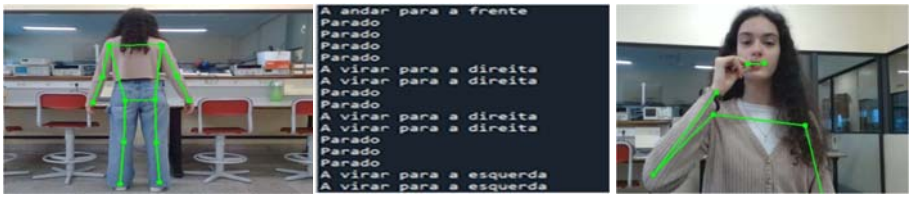

Fig. 4. Anatomical points of interest detected (left). Messages printed on the console during execution of the device detection code type of movements (middle). Anatomical points of interest for taking medications (right).

The right image in Fig. 4 indicates movement and position of the patient. There, the results indicate that the patient was walking in front ("A andar para a frente") then stopped ("Parado"). Here, the patient turned right ("A virar para a direita"), then stopped again ("Parado"). This movement was repeated, and finally the patient turned left ("A virar para a esquerda").

Regarding the medication intake detection code, it is possible to state that it produces reliable results, as it accurately identifies the typical movement. The code compares, effectively and minute by minute, the current time with the times programmed on the Website. Detection is therefore carried out exclusively when there is a correspondence between times. This algorithm, once run, lasts 10 seconds, with information about the results and times sent to the Database. In Fig. 4 (right), an image of the

camera is represented where it is possible to visualize the anatomical points of interest for the movement of taking medications. Console messages in this case are possible schedules for taking medication, the current time, a message indicating that it is not yet time to take the medicine or “it is time to take the medicine”. Here, a message indicates that the patient “took the medicine” and provides the result - the time the medication was taken and a message indicating that the data is being sent to the database.

About the movement of the robot and its structure, the results indicate that the prototype has functional motors and wheels, with the switch (OI) providing power to the circuit when desired, demonstrating good functioning of the electronics associated with the robot. As previously mentioned, the connection between the robot's Arduino and the movement detection code (tracking) works correctly, allowing the robot to execute functions such as 'andarParaFrente()', 'virarDireita()', 'virarEsquerda()' and 'parar()'. However, the robot is not able to move due to its weight, which requires future adjustment. As for the Website, the associated results are notable, allowing it to operate smoothly and organized. The simplistic architecture invokes quick and efficient use of this page, allowing for an intuitive browsing experience. User validation, which checks the session state (started/ended) in the browser, provides a layer of security for the data collected. The Website allows both the efficient insertion of data into the Database and the visualization of information from it. It is also important to mention the correct correspondence between introduced elements and the historical results, this connection being made over hours. Regarding the Database, it is operational and showing good results, correctly receiving data from the Website, test codes and medication intake. Furthermore, it is structured in an appropriate way so that the medicine dispenser can access information regarding the compartment and time for taking medicines. Likewise, the Website can access the data received from the tests, making it possible to view the histories. Therefore, the connection between codes, Database and Website is efficient, without presenting any errors in logic or execution.

5 Conclusions

The implementation of the AlzheimerAlly project marked a significant advance in creating personalized solutions to improve the quality of life for Alzheimer's patients and their caregivers. The proposed robot, AlzheimerAlly, features crucial elements, such as tracking and a camera, to ensure patient safety by continuously monitoring them and identifying anomalous behaviors, as it mimics the patient's movements. On the other hand, cognitive and stimulation testing provides a dynamic way to assess the disease's progression while stimulating the patient's memory, problem-solving, and functional abilities. The medication dispenser is a major advancement, ensuring precise and timely medication administration according to scheduled doses. The Website serves as the bridge between all elements of this system, enabling caregivers and healthcare professionals to input and access data related to the dispenser and cognitive tests, facilitating remote monitoring and reducing the burden of care. Thus, the inclusion of the Database and Website allows an intuitive and real-time view of the pa-

tient's activities, thus centralizing all important information. Both the language Python, such as the Arduino Mega device, proved to be fundamental for the implementation and realization of the entire project. The Python – Database – Arduino connection is a strong point of this robot, allowing efficient integration between data processing, centralized control and actions performed by the hardware. Despite the limitations present in the initial phase of the project, it is important to highlight that they offer opportunities for improving the robot. A notable challenge lies in the continuous need to increase the accuracy and sensitivity of the tracking, so that there is better monitoring of the patient's activities, particularly through the integration of other sensors. Furthermore, in the future, existing functions should be improved and further developed in order to detect situations where the patient is lying, sitting, or falling. Additionally, the cognitive testing graphical interface can be expanded to cover a wider range of cognitive abilities. The code for these features is subject to some improvements. The medication dispenser, while effective, can be refined to incorporate additional verification systems and ensure even safer and more personalized administration. In the future, it is intended that the compartments will be printed in 3D, in order to gain stability and robustness. It is also important to mention that it is essential to combine all these functionalities in a processing unit, such as the Raspberry Pi. Finally, despite the desired future improvements, it is crucial to highlight that the developed prototype already represents a significant and functional contribution to the area of care for Alzheimer's patients. AlzheimerAlly not only meets the practical needs of managing the disease, but also provides additional support for the patient and their caregiver. This prototype represents a technological advancement and a mechanism that can truly make a difference in the lives of those affected by Alzheimer's, offering an innovative approach to home care.

References

1. A.J.Sepúlveda. (n.d.). LONGEVIDADE: IMPLICAÇÕES SOCIAIS. Retrieved November 2, 2023, from https://www.culturgest.pt/media/filer_public/17/f9/17f9417b-bd3e-48ac-a345-2ad518be45b3/culturgest_fidelidade2020_folhadesala_implicacoesociais.pdf
1. Badr, N. G., & Dankar, M. (2022). Assistive Healthcare Robotics – Challenges in Nursing Service Innovation: Critical Review. ITM Web of Conferences, 41,02002. https://doi.org/10.1051/itmconf/20224102002
2. Bravo, J. M., & Ayuso, M. (2020). Mortality and life expectancy forecasts using bayesian model combinations: An application to the portuguese population. RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao, 2020(E40), 128–144. https://doi.org/10.17013/risti.40.128-145
3. Carmo, E. G., Zazzeta, M. S., Fuzaro Junior, G., Micali, P. N., Moraes, P. F., & Costa, J. L. R. (2015). A utilização de tecnologias assistivas por idosos com Doença de Alzheimer. Revista Kairós Gerontologia, 18(4), 311–336. https://doi.org/10.23925/2176-901X.2015v18i4p311-336
4. Contreras, M., Mioshi, E., & Kishita, N. (2022). What are the educational and support needs of family carers looking after someone in the early stages of Alzheimer’s disease? A

qualitative retrospective approach. Health and Social Care in the Community, 30(5), 1726–1734. https://doi.org/10.1111/hsc.13552

5. Jaul, E., & Barron, J. (2017). Age-Related Diseases and Clinical and Public Health Implications for the 85 Years Old and Over Population. In Frontiers in Public Health (Vol. 5). Frontiers Media S.A. https://doi.org/10.3389/fpubh.2017.00335
6. Jorge S. Gonçalves, P. (n.d.). Robótica, uma visão para o futuro. Retrieved November 2, 2023, from https://repositorio.ipcb.pt/bitstream/10400.11/3075/1/R_IPCB2_2.pdf
7. Kakhi, K., Alizadehsani, R., Kabir, H. M. D., Khosravi, A., Nahavandi, S., & Acharya, U. R. (2022). The internet of medical things and artificial intelligence: trends, challenges, and opportunities. In Biocybernetics and Biomedical Engineering (Vol. 42, Issue 3, pp. 749–771). Elsevier B.V. https://doi.org/10.1016/j.bbe.2022.05.008
8. Massoud, F., Gabriel, ;, & Léger, C. (2011). Pharmacological Treatment of Alzheimer Disease. In The Canadian Journal of Psychiatry (Vol. 56, Issue 10). doi: 10.1177/070674371105601003.
9. Oliveira da Silva, M. S. G., Octávio de Sá, L., Marques, G. F. S., & Morada, M. S. (2019). Impacto do Transtorno Neurocognitivo na Família: Scoping Review The Impact of Neurocognitive Disorder in the Family: A Scoping Review PESQUISA Autora Correspondente. https://doi.org/10.33159/25959484
10. Pereira de Lima, M. M. L. (2011). A importância das tecnologias assistivas para a inclusão de alunos com deficiência visual. Retrieved November 2, 2023, from https://bdm.unb.br/bitstream/10483/2433/1/2011_ManoelaMariaLiomiziaPereiradeLima.pdf
11. Quillfeldt, J. A. (n.d.). ORIGEM DOS POTENCIAIS ELÉTRICOS DAS CÉLULAS NERVOSAS. Retrieved November 2, 2023, from https://www.ufrgs.br/mnemoforos/arquivos/potenciais2005.pdf
12. Santos, M. D. dos, & Borges, S. de M. (2015). Percepção da funcionalidade nas fases leve e moderada da doença de Alzheimer: visão do paciente e seu cuidador. Revista Brasileira de Geriatria e Gerontologia, 18(2), 339–349. https://doi.org/10.1590/1809-9823.2015.14154
13. Scheltens, P., De Strooper, B., Kivipelto, M., Holstege, H., Chételat, G., Teunissen, C. E., Cummings, J., & van der Flier, W. M. (2021). Alzheimer's disease. In The Lancet (Vol. 397, Issue 10284, pp. 1577–1590). Elsevier B.V. https://doi.org/10.1016/S0140-6736(20)32205-4
14. Stavropoulos, T. G., Papastergiou, A., Mpaltadoros, L., Nikolopoulos, S., & Kompatsiaris, I. (2020). Iot wearable sensors and devices in elderly care: A literature review. In Sensors (Switzerland) (Vol. 20, Issue 10). MDPI AG. https://doi.org/10.3390/s20102826
15. Zvěřová, M. (2019). Clinical aspects of Alzheimer's disease. In Clinical Biochemistry (Vol. 72, pp. 3–6). Elsevier Inc. https://doi.org/10.1016/j.clinbiochem.2019.04.015