Smart Pill Dispenser for Children – An EPS@ISEP 2024 Project

Lena Ehrenhofer[1], Łukasz Borowski[1], Noé Oliveira[1], Stijn Steyaert[1], Tamara Kronshagen[1], Tibo Clauwaert[1], Abel J. Duarte[1,2,3], Benedita Malheiro[1,4], Cristina Ribeiro[1,5], Jorge Justo[1], Manuel F. Silva[1,4], Paulo Ferreira[1], and Pedro Guedes[1,4]

[1] ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
[2] REQUIMTE/LAQV, ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
[3] CIETI, ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
[4] INESC TEC, Campus of Faculdade de Engenharia da Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
[5] INEB, Rua Alfredo Allen, 208, 4200-135 Porto, Portugal
epsatisep@gmail.com
https://www.eps2024-wiki2.dee.isep.ipp.pt/

Abstract. People around the globe struggle with health issues requiring regular medication. Children, in particular, suffer more and more from chronic illnesses. In 2024, a team of six EPS@ISEP students chose to design a solution for this problem, followed by the assembly and testing of the corresponding proof-of-concept prototype. The aim was to design a solution for children to take the right medication, at the right time and in the right dose, in a pleasant and engaging way, based on technical, ethical, sustainability and market analyses. Focusing on children between the ages of 8 and 12, the team decided to incorporate a motivational system based on rewards to ensure that they take their medication correctly. The outcome is billy, a pill dispenser controlled via an app which allows carers to plan doses and release rewards, and children to autonomously take their medication. The system dispenses up to 21 doses of medication to the child through fingerprint authentication, and photographs the child taking the medication to reassure carers.

Keywords: Engineering education · European Project Semester · Pill dispenser for children · Smart device.

1 Introduction

This report describes the work carried out by a group of six students from different universities and countries who took part in the European Project Semester (EPS) [3] at Instituto Superior de Engenharia do Porto (ISEP). The aim of EPS@ISEP is to offer projects that address real and topical problems in order

to develop a number of skills, such as teamwork, communication, ethics and sustainability driven problem solving [4].

Technology has become unavoidable and of unquestionable importance in everyday life [14]. A main reason is that it offers devices that complement and free the user from tasks that can be fully or partially automated, thus adding value to their lives. Health devices that help users maintain routines, such as exercising, measuring physiological parameters or taking medication, are one such example.

Children increasingly suffer from chronic illnesses [8], such as allergies, and need to take medication on a daily basis. They start taking medicines in tablet form at the age of eight [2] and often need to be reminded, encouraged and helped to overcome swallowing difficulties. In addition, families with working parents are only together at the beginning and end of the day, which makes it difficult to be present when children of this age need to take medication during the day. Motivated by this challenge, a team decided to work together on a solution for children and their caretakers.

Since many health solutions available on the market are aimed at adults or elderly, there is a clear market opportunity to tailor solutions to children. The proposed solution, named billy, aims to help parents and children with taking medication. billy not only notifies when to take, dispenses the correct pills and photographs who takes the medication, but also motivates the child by releasing rewards set by the carers.

This document outlines the various stages and elements involved in the making of this project. Section 2 presents products and solutions that already exist on the market, the state of the art, as well as ethics, sustainability and marketing. In Section 3 a proposal for a possible solution is introduced and Section 4 details the prototype development. Finally, Section 5 presents the main conclusions.

2 Preliminary Studies

2.1 Related Work

Although the market offers a significant number of medicine dispensers with complementary apps for user notification and interaction (see Figure 1), there is a gap when it comes to meeting the needs of children. The cheapest models, such as GoGooda and LiveFine (only has an alarm), have few or no intelligent features. The more complex models have multiple functions, such as authentication via facial recognition or fingerprint, high pill storage capacity and carer notification whenever the patient needs to take medication. With the exception of basic pill dispensers, which are colourful and therefore may appeal to children, most smart dispensers are for adults. The team therefore sought to innovate by designing a solution for children.

The goal became the creation of a medication dispenser with a more playful and colourful design, facilitating direct interaction through the integration of elements of gamification. This novel approach allows children to engage in a

(a) GoGooda [6] (b) LiveFine [10] (c) Karie [9]

(d) Hero [7] (e) MedaCube [11]

Fig. 1. Different types of medication boxes and pill dispensers.

game with the goal of receiving a reward upon taking medication, achieving the purpose of enabling children to take medication without supervision, a feature not found in existing products. Thus, billy integrates a number of easy-to-use features, is attractive and fun for children and has a reasonable price.

2.2 Ethics

When developing a product, ethical and deontological concerns must always be considered. The goal of billy is to only request the personal information it requires to operate. The aim is to make the product valuable for children as well as the caretaker, by following all ethical and deontological guidelines.

To build a product that has the least environmental impact as possible, one should start with components that are environmentally friendly. The team is committed to follow sustainable practices throughout the entire value chain, from sourcing materials to manufacturing, packaging, and distribution. Moreover, it will be possible to: (*i*) lease the product for a period; and (*ii*) return a broken product, even outside the warranty period, for recycling and reusable parts.

Since ethics and deontology are subjective issues, it is important to comply with European Union guidelines. In the event of non-compliance, not only ethical problems arise, but also potential legal liabilities, such as violation of privacy laws, discrimination laws or consumer protection laws, among others. The team is therefore committed to working conscientiously to develop an ethical product.

2.3 Marketing

The team defined the value proposition, market segmentation and positioning, marketing mix and marketing programme for billy. The value proposition states: "*For* children *who* have to take medication *the* billy solution *is a* pill dispenser *that* secures and monitors pill intake; *unlike* other pill dispensers *our* product makes pill intake fun and safe."

Market segmentation is a practice companies use to divide their target market into smaller, more manageable groups of people. They do so by identifying the common features of the target group to optimise their marketing, advertising, and sales efforts [13]. Ultimately, it allows for a more efficient use of resources and provides a better customer experience, making the company grow [1]. The team chose to focus on children aged between 8 and 12 living in Europe and who need to take pills. Considering product smartification, adjustability, ergonomics and design, billy is well positioned in relation to its competitors (Figure 1), being the most innovative and comparatively cheaper.

While the idea of a pill dispenser is not innovative, the team believes that billy makes a difference by focusing on children. Many children have problems taking medication, particularly pills. For that reason, there is an opportunity to design a product for children. The main aim is to make taking pills more fun as well as remind (when to take), protect (against overdoses) and reward (after taking) children. The team firmly believes that this product can add value to children who need to take pills and, by extension, to the family. Thus, billy can help children take their medication in a playful and safe way.

The product promotion will explore methods like social media campaigns and dissemination of communication materials. Specifically, the team contemplates creating campaigns on social media platforms such as Facebook [5], Instagram and Google Ads, targeting parents of young children, as well as distribute flyers and leaflets at healthcare facilities. Marketing research will help to define the profile of the parents as well as of the healthcare facilities.

2.4 Sustainability

Over the last few decades, sustainability has gained increased importance. The pursuit of sustainability attempts to prevent the depletion of natural resources, climate change and the reduction of biodiversity over time [12]. Such an holistic concept covers much more than just having low carbon emissions or making products from recycled materials. This means that it is mandatory to assess the impact that each new product will have on the environment, society and the economy, from design to recycling.

To minimise billy's ecological footprint, the team chose to work with polylactic aciad (PLA). This is a durable plastic suitable for 3D printing. The packaging and filling is also recyclable and biodegradable. The simple technical composition allows billy to be produced locally, avoiding that unnecessary transportation. Considering the society, billy is expected to have a positive impact on the lives

of the children and their families. Economically, the solution devised, when compared with existing ones, is a promising basis for creating a company around a successful new product. Last but not least, billy contributes to Sustainability Development Goal 3 – "Good Heath and well-being"[1] – of the United Nations.

3 Proposed Solution

The designed solution implements a new smart pill dispenser for children concept that comprises a device and a complementary Web application.

3.1 Concept

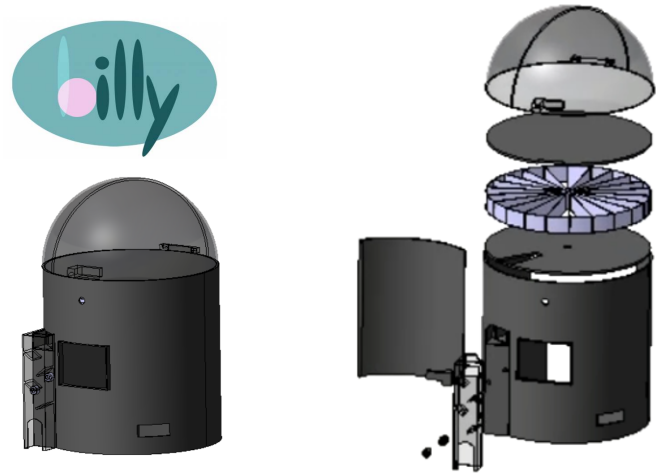
The team started this project by brainstorming on how to create an automatic pill dispenser for children. Since the market offers multiple types of pill dispensers for the elderly, but none for children, the decision was to create a more fun and less stressful solution by introducing a motivational reward system.

The proposed solution, called billy, comprises an automatic pill dispenser and complementary app, and dispenses up to 21 doses of medication. The caregiver fills the dispenser with the medication and sets the date and time of each dose via the app. When it is time to take the medication, the system alerts the child with an audible alarm and a flashing light-emitting diode (LED). The child accesses the medication through fingerprint recognition. At the same time, the system photographs the child to reassure caregivers, which can remotely release a reward. The pill dispenser shows information, such as the time of the next dose, in a touch screen and allows caregivers to place in the top dome any reward that fits, like charades, games, tickets or sweets. Caregivers can access the historical record of photographs, medication and rewards collected through the app. billy has a power consumption less than 9 W and an estimated selling price of 250 €.

3.2 Design

Structure With safety in mind, the structure adopts a cylindrical shape with as few sharp edges as possible to prevent injuries. The top contains a transparent dome for storing and displaying rewards. The cylindrical body has a transparent front slide to watch the medicine fall, similar to a toy vending machine that children love. To prevent over-medication, it has a notched lock, operated by a servomotor, which slides and locks the pill door. This lock only opens when the carer's fingerprint is recognised. The lock on the reward dome works on the same principle. The dispenser delivers 21 doses of medication, corresponding to one dose per day for three weeks. To meet this technical requirement, the pill container has 22 different slots, 21 for pills plus a closed slot. The dispensing mechanism has a fixed part with a hole and a rotating pill container. The medication slide mechanism relies on gravity to drop the pills and, in addition, provides structural support. The product was 3D-modelled using the computer-aided design program Catia. Figure 2 shows the design of billy.

[1] https://sdgs.un.org/goals/goal3



(a) Logo and side view (b) Exploded view

Fig. 2. billy design.

Smart Control The brain of the dispenser is an ESP32-CAM which connects directly to a touch screen display, fingerprint sensor, motors, buzzer and LED. billy uses two servomotors to operate the pill door and dome locks, a stepper motor to rotate the pill container and dispense the pills, and a buzzer and LED to alert the child when to take medication. The fingerprint sensor unlocks: (*i*) the pill dispenser with the child's fingerprint at the time of medication; and (*ii*) the pill container and reward dome with the carer's fingerprint at any time. The integrated camera photographs the child taking the medication. The reward dome can also be opened remotely by the carer via the app.

Web Application The designed web application allows caretakers to control and configure billy. Through the app, the caretaker plans the doses and schedules the intake times, as well as accesses the historical records of photos, medication and rewards. The caretaker can also create and manage different profiles (names, roles and fingerprints). Figure 3 shows the interface of the Web application.

4 Prototype Development

This section presents the development and testing of the proof-of-concept prototype – device and Web application.

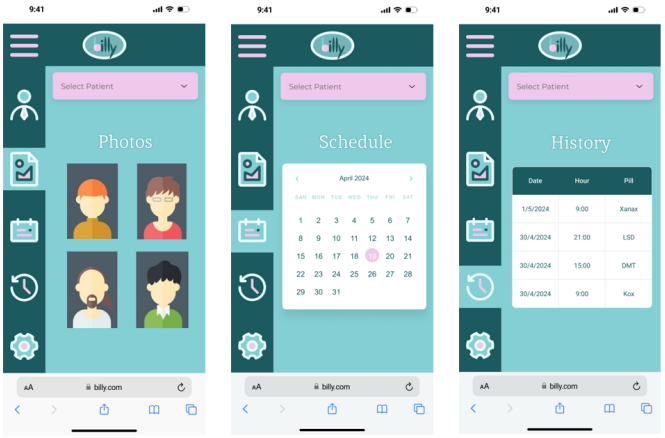


Fig. 3. Web application interface.

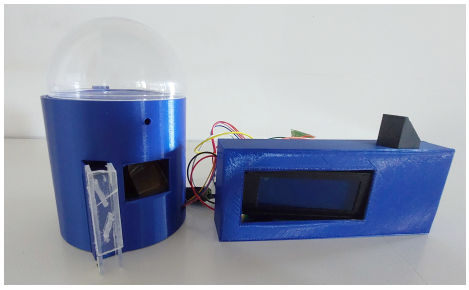
4.1 Assembly

Structure The proof-of-concept prototype is an half-size version of the designed structure. The team chose to 3D-print the prototype, using cost-effective and sustainable PLA plastic, which is lightweight, strong, and 100 % bio-based and biodegradable. The only exceptions were the reward dome (bought), and the slide (made from plexiglass). Due to the reduction in size, the screen and the fingerprint reader have been housed in a separate box. The 3D-printing process required some structural changes: (*i*) reinforcing parts to prevent deformation during printing; (*ii*) adding chamfers in specific places of the body to support printing; and (*iii*) increasing the thickness of the slot walls of the pill container to prevent breakage. Lastly, the reward dome is made from a purchased transparent plastic Christmas ball.

Figure 4 displays the assembled prototype (Figure 4a), the pill container (Figure 4b), and the testing set-up (Figure 4c).

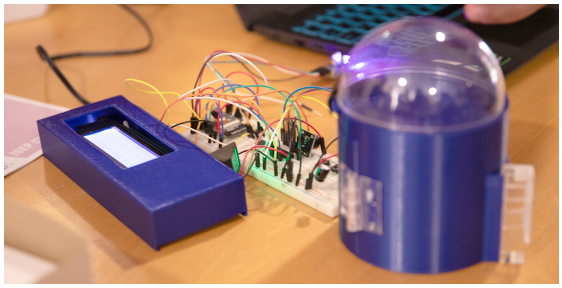
Smart Control To comply with the allocated budget of 100 €, the team decided to prioritise crucial functions such as security, keeping the fingerprint reader despite its higher cost, while choosing lower-cost, lower-performance options for the display and motors. The control system communicates via Wi-Fi with the remote app database.

Web Application The Web app facilitates the interaction of caretakers with billy. Through the control panel, users can review the history of dispenses, children photos during intake, access information about the device status and many more. Additionally, caretakers schedule dispensations and remotely open the reward dome via the website. These features are accessible after authentication with the correct credentials.



(a) Front view

(b) Pill container



(c) Testing

Fig. 4. billy prototype

4.2 Tests & Results

The tests applied check whether the structure, control system and application function correctly. The structural stress analysis, carried out using SolidWorks software, is designed to assess the behaviour of the structure (materials and their characteristics) in extreme situations of use. The control system test assesses if the electronic components implement the main functions of billy. Finally, the tests carried out on the application characterise and verify whether its performance, in terms of latency and data volume, is adequate.

Structure The stress simulation uses the finite element method, which consists of dividing the 3D model into several small interconnected sections to see the reaction of each element. The stress analysis considers the case where a child stands on top of the reward dome to obtain the reward by force. The simulation test applied a force of 824.04 N, representing two times the average weight of a 12-year-old child (42 kg according to the World Health Organisation). The results are very satisfactory. The maximum Von Mises stress of 5.136 MPa is well below the yield limit of the used Plexiglas (70 MPa). Deformations are minimal, at just 0.279 mm. Lastly, the safety factor analysis revealed that the minimum safety coefficient for the dome is 15, exceeding the requirements. These results indicate

that the dome will effectively resist to the predefined force and that the choice of plexiglass was appropriate.

Smart Control The tests carried out to verify the correct functioning of the control system focused on evaluating the different functionalities. Table 1 lists the functionalities tested and the results.

Table 1: Control tests

Function	**Result**
Dispense a dose of medicine when the buzzer vibrates and the child authenticates via fingerprint	Pass
Open the doors when the carer selects parent mode and authenticates via fingerprint	Pass
Photograph the child while taking the medicine	Pass
Display on the screen when the next dose will be available	Pass

These results indicate the prototype successfully implements the main functions.

Web Application These tests, which were repeated 10 times, verify the operation and performance of the app. They determine the data exchanged and the average (μ) and standard deviation (σ) latency regarding the implemented functionalities. The results are displayed in Table 2.

Table 2: App tests

Function	**Endpoint**	**Method**	**Result**	**Data** (B)	**Latency** (ms)	
					μ	σ
User registration	`/api/user/register`	POST	OK	377	221	189
User authentication	`/api/user/login`	POST	OK	1046	290	125
Dose scheduling	`/api/schedule/`	PATCH	OK	469	173	76
Photo history	`/api/gallery`	GET	OK	668	234	98

These results confirm that the Web application implements the main functions with success, and presents data exchange and latency values compatible with this type of application.

5 Conclusion

Considering the project outcomes, the team is proud of the final achievement. The designed automatic pill dispenser helps children to take their medication independently, by creating a safe, enjoyable and stress-free experience. After extensive research and brainstorming, the team proposed billy, a solution that meets the needs of children from 8 to 12 years of age and respects ethical, deontological and ecological principles. It alerts children when to take their medicine,

authenticates their identity via fingerprint recognition, offers motivational rewards and takes a photo to reassure carers. This helps prevent over-medication and ensures that the correct medication is taken at the right time, even when the child is at home alone. billy is paired with a Web application for carers to set up child medication intake, verify that it has been taken through the photo gallery and release rewards. The rewards are chosen, placed and released by carers to encourage the child to take the medication. The team has also successfully developed a proof-of-concept prototype that implements billy's main functions.

Overall, EPS@ISEP provided a rich learning environment, intercultural experiences, and professional and personal skill development. Specifically, team members report that participation in the EPS has contributed to:

Skills Development – All the students mentioned improvement in various skills namely teamwork, project management, communication (especially English), and even in specific areas like design or web development.

Adaptability and Intercultural Learning – The programme challenged students to adapt to a new environment and collaborate with peers from different backgrounds, fostering intercultural understanding and broadening perspectives.

Personal Growth – The participants reported personal growth, gaining confidence, and stepping outside their comfort zones.

Teamwork and Diversity – The multicultural team brought new approaches and problem-solving methods, leading to a richer learning experience.

Language Proficiency – All the students mentioned significant improvement in their English proficiency due to the program's emphasis on using English for communication and project management.

Although the project has achieved its goals, there is always room for improvement. billy's screen only displays information about the time of the next dose. Games and virtual rewards could be accessible from the screen to make it more engaging for children. Currently, billy prevents the dose from being administered outside of the scheduled time, creating a problem when the child is not at home. It could be solved by allowing carers to override this restriction, making it possible to administer doses when required. The pill dispensing mechanism could allow the dispenser to be filled by selecting the day in the app, reducing errors and making the process more efficient. To do this, it would be necessary to develop a solution to prevent pills from falling into the hole of the pill selector.

Acknowledgements

This work was partially funded by National Funds through the Portuguese funding agency, FCT – Fundação para a Ciência e a Tecnologia, within project UIDP/50014/2020 (DOI: 10.54499/UIDP/50014/2020 | https://doi.org/10.54499/UIDP/50014/2020.

References

1. Adobe Business: Market segmentation: definitions, type and examples. Available at https://business.adobe.com/blog/basics/market-segmentation-examples (2024), [Accessed in June 2024]
2. Ashley Rapske: How to teach your child to swallow pills in 6 easy steps. Available at https://ukhealthcare.uky.edu/wellness-community/blog/how-teach-your-child-swallow-pills-6-easy-steps (2018), [Accessed in June 2024]
3. Budzinska, G., Hansen, J., Malheiro, B., Fuentes-Durá, P.: European Project Semester. In: Malheiro, B., Fuentes-Durá, P. (eds.) Handbook of Research on Improving Engineering Education With the European Project Semester, pp. 1–22. IGI Global, Hershey, Pennsylvania, USA (2022). https://doi.org/10.4018/978-1-6684-2309-7.ch001
4. Duarte, A.J., Malheiro, B., Silva, M.F., Ferreira, P.D., Guedes, P.B.: Active learning strategies for sustainable engineering. In: Malheiro, B., Fuentes-Durá, P. (eds.) Handbook of Research on Improving Engineering Education With the European Project Semester, chap. 8, pp. 146–164. IGI Global, Hershey, PA, USA (2022). https://doi.org/10.4018/978-1-6684-2309-7.CH008
5. Facebook: Facebook Business. Available at https://www.facebook.com/business/ (2024), [Accessed in June 2024]
6. Gogooda: Gogooda Weekly Pill Organizer. Available at https://www.amazon.com/Organizer-Friendly-Compartments-Medication-Supplements/dp/B08G88WFDQ (2024), [Accessed in June 2024]
7. HeroHealth: Hero – A dose of calm for the whole family. Available at https://herohealth.com/ (2024), [Accessed in June 2024]
8. Jin Schofield: The rise of allergies. Available at https://cdn.vanderbilt.edu/vu-wordpress-0/wp-content/uploads/sites/16/2021/05/19123334/Jin-B.-L.-Schofield.pdf (2023), [Accessed in June 2024]
9. Karie: How The Karie Automatic Pill Dispenser Works. Available at https://kariehealth.com/how-karie-automatic-pill-dispenser-works/ (2024), [Accessed in June 2024]
10. LiveFine: Automatic Pill Dispenser with Clear Lid and Large Display. Available at https://www.livefineproducts.com/products/automatic-pill-dispenser-with-clear-lid-and-large-display (2024), [Accessed in June 2024]
11. Medacube: MedaCube™ Automatic Pill Dispenser. Available at https://www.medacube.com/products/medacube (2024), [Accessed in June 2024]
12. Shari Blanch: Three Pillars of Sustainability. Available at https://www.ache.org/blog/2021/designing-for-healthcare-sustainability-a-framework (2024), [Accessed in June 2024]
13. Tow, H.: What is market segmentation. Available at https://learn.g2.com/market-segmentation (2024), [Accessed in June 2024]
14. World Economic Forum: How has technology changed - and changed us - in the past 20 years? Available at https://www.weforum.org/agenda/2020/11/heres-how-technology-has-changed-and-changed-us-over-the-past-20-years/ (2020), [Accessed in June 2024]