

Smart Companion Pillow – An EPS@ISEP 2019 Project

Abstract. This paper describes the design and development of a Smart Companion Pillow, named bGuard, designed by a multinational and multidisciplinary team enrolled in the European Project Semester (EPS) at Instituto Superior de Engenharia do Porto (ISEP) in the spring of 2019. Nowadays parents spend most of the day at work and become naturally worried about the well-being of their young children, specially babies. The aim of bGuard is to provide a 24 hour remotely accessible baby monitoring service, contributing to reduce parenting stress. The team, based on the survey of related products as well as on marketing, sustainability, ethics and deontology analyses, developed a remotely interactive Smart Companion Pillow to monitor the baby's health and room air quality. The collected data is saved on an Internet of Things (IoT) platform and is accessible through a mobile application (app). The bGuard pillow, thanks to its shape, reduces the risk of the baby rolling from back to tummy, lowering the risk of Sudden Infant Death Syndrome (SIDS).

Keywords: Baby's Health · Interaction · Parent Stress Relief · Room Air Quality · Smartphone Application · Sudden Infant Death Syndrome.

1 Introduction

The bGuard smart companion pillow was an EPS@ISEP project developed by a team of undergraduate students in the spring of 2019. The team was composed by students from different study fields and countries as follows: biomedical engineering from Germany; electrical engineering from Estonia; mechanical engineering from Germany and Portugal, industrial product engineering from Netherlands and product development from Belgium. This project provided the team with the opportunity to create an out-of-the-box object to contribute to the good health of babies and support parents.

Parents are always worried about the health of their children. According to a study looking into the parental worries of 2000 parents conducted by OnePoll in conjunction with LICE Clinics of America [11], the average parents worry about their children around 37 h a week. In addition, according to the American Academy of Pediatrics, SIDS remains unsolved [32]. As referred by Kinney and Bradley [15] and the National Institute of Child Health and Human Development of the United States of America [20], the biggest risk factors of SIDS are the sleeping of the baby on the stomach or side, overheating, exposure to tobacco smoke and bed sharing. Therefore, the problem statement of the project focus on worried parents and SIDS.

Based on the problem statement, the objectives of this project are to lower the risk of SIDS and parent stress by monitoring the baby’s sleeping environment. The next chapters report the teamwork performed to achieve these objectives.

This document includes a background chapter, where related projects, marketing, sustainability, ethics and deontology analyses are presented. Then, the design and development are explained. Afterwards, planned functional tests are described. Finally, the conclusions of the project are summarised.

2 Background

The background studies, which included a survey on related products together with marketing, sustainability and ethics analyses, allowed the team to derive bGuard’s requirements.

2.1 Related Products

The survey on domestic products addressing the monitoring of the room environment and vital signs, sleep and motion of babies contemplated:

- **Smart Pillows** are designed to improve the quality of the night rest. The more advanced pillows, like the iSense Sleep [14] contain sensors that monitor the pulse and respiratory rate. These pillows can often be considered as gadgets because they include built-in speakers for streaming music or playing audio books as is the case of ZEEQ [36] and Sunrise [31].
- **Sleep Trackers** are focused on giving detailed information about sleeping patterns. Smart pillows are often equipped with a sleep tracker. These devices come in different forms such as wearable accessories (Fitbit Versa [10]), bed accessories (Withings Sleep [35]) or bed-side accessories (S+ [25]). They track the different sleep stages, the duration of sleep and overall sleep quality. The researched products also measure the pulse of the user.
- **Environment Monitors** gather information about their location. Although the market has a wide offer, this study selected three types of contact-less monitors: GLOCO, Sense Sleep, and Withings Aura. GLOCO [9] monitors temperature, humidity, and carbon monoxide levels of the child’s room. It consists of a home station, which indicates when something is wrong, and an app with additional information. The Sense Sleep [13] and Withings Aura [34] monitor the room conditions, the sleeping pattern and give advice on how to improve them.
- **Baby Monitors** are focused on the baby well-being. They monitor aspects such as temperature, movement and respiration of the baby. This is the case of Owlet [22], Nanit Plus [17] and Sproutling [30]. In addition, Sproutling alerts when the baby rolls over during sleep and Nanit Plus displays live images of the child.

Table 1 compares the products analysed, ordered by category. According to this research, the market lacks devices which, simultaneously, reduce the risk of

Table 1. Product Comparison

Category	Product	Media ^a	Pulse (bpm ^c)	Room			App
				RH ^b (%)	Temp. (°C)	CO ₂ (ppm ^d)	
Smart Pillows	ZEEQ	✓					✓
	Sunrise	✓					✓
	iSense Sleep		✓				✓
Sleep Trackers	Withings Sleep		✓				✓
	S+		✓		✓		✓
	Fitbit Versa		✓				✓
Environment Monitors	Sense Sleep	✓		✓	✓		✓
	GLOCO			✓	✓		✓
	Withings Aura	✓	✓		✓		✓
Baby Monitors	Owlet		✓				✓
	Nanit Plus	✓		✓	✓		✓
	Sproutling			✓	✓		✓

^a Image, Music, Sound or Video

^b Relative Humidity

^c beats / minute

^d parts / million

rolling from back to tummy, allow interaction, monitor the health of the baby, measure the room air quality and provide access to all this information through a mobile application. Taking into account these findings, the team embraced the concept of a 4 in 1 product for babies: (*i*) pillow with a special shape (to reduce the risk of rolling); (*ii*) microphone and speaker integrated in the pillow; (*iii*) pulse sensor incorporated in the sock; and (*iv*) room sensors (temperature, relative humidity (RH) and CO₂) in the home station. To contribute to relief the stress of parents, the team chose to create a mobile application to display the collected data and allow remote interaction.

2.2 Marketing

The saying “Customers don’t buy products, they buy benefits” was the motto of the team. Concerning the psychological segmentation, nowadays, parents worry considerably about the well-being of their children [11]. Consequently, bGuard aims to lower the stress of parents by providing remote access to the baby’s health and environment parameters. The benefits provided by bGuard comprise lower risk of SIDS, sleeping environment quality monitoring and parenting stress relief. Thus, the proposed promotional claim is "**Sleepcurity for your baby**".

bGuard was positioned with the help of the Porter model [16]. This model describes three different strategies a company can use from an outside-in point

of view: cost leadership, differentiation and focus strategy. The target group is concerned parents (25 to 35 years), ranging from middle-class through upper-class, who were raised with technology and constantly rely on their smartphone. The team decided on differentiating the product compared to its competitors by creating a unique product combination. bGuard stands out from the crowd, inducing potential customers to pay more.

The 4 P marketing mix [21], which considers Product, Price, Place and Promotion, has been followed. First, bGuard is a pillow with a special shape to reduce the risk of rolling from back to tummy, with a speaker to sooth the baby when crying, a sock to measure the baby's pulse and a home station to monitor room air quality. The combination of all these elements makes it a unique Product in the market. Secondly, most of the comparable products vary between 113.00 € and 313.00 €. The estimated Price should be around 249.00 €. Being a smart product, the target group should be familiar with online shopping. Thus, in terms of Place, bGuard should only be sold through its website, saving money negotiating with large retail shops or re-sellers. Finally, advertisement on the Internet and social media will be considered for Promotion.

On the whole, bGuard will be promoted on the **Internet and social media**, sold on its **own website** and, due to its **unique combination of features**, the target group will be willing to pay 249.00 € for its **benefits**.

2.3 Sustainability

The team considered the 3 Pillars of Sustainability [24], the 12 Principles of Green Engineering [2] as well as the Good Health and Well-Being, Industry, Innovation and Infrastructure and Responsible Consumption and Production Sustainable Development Goals defined by the United Nations Educational, Scientific and Cultural Organization (UNESCO) [33]. Finally, the Life Cycle Analysis [3] was performed.

All bGuard parts were thought to fulfil these sets of principles. Firstly, the easy way parts can be disassembled, on the home station, the pillow and the sock allow to take the electronic components out in a really simple way. This means that all materials can easily be sent for recycling. The main raw material of the home station - Acrylonitrile Butadiene Styrene (ABS), can be recycled up to 99 % [23]. A further advantage of the home station is that it can still be used when the baby grows and the pillow and the sock will no longer be needed. It will keep on monitoring the room air quality - temperature, humidity and CO₂. Secondly, the cover textiles of the pillow and sock are made in Lyocell (Tencel) [28, 12] fabrics that are naturally biodegradable. During the manufacturing, 99 % of the water can be recycled and non-toxic solvents can be used, resulting in an eco-friendly production. Thirdly, the foam of the pillow is certified with OEKO-TEX STANDARD 100 [19], class I, which corresponds to the strictest baby requirements. The STANDARD 100 by OEKO-TEX contributes to high and effective product safety.

Thus, bGuard will contribute to **relieve the stress of the parents** and **improve the quality of life of the family** with **minimum waste** over its life cycle, **without jeopardising the needs of future generations**.

2.4 Ethics and Deontology

Ethical issues inevitably arise when developing a product. Engineering Ethics [18], Sales and Marketing Ethics [26], Environmental Ethics [27] and Liability [4, 8, 6, 5, 7] help to deliver a safe and environmentally friendly product both for the users and the world. Objectively, this means the team wants to limit the commercialisation of the product to the European market in order to keep the footprint small, work with local providers and design according to the Design for Disassembly (DfD) [29] principles. Furthermore, bGuard wants to deliver a safe and user-friendly product. The aim is to ensure that users and manufacturers are guarded from dangers and liabilities, respectively. To help the user, bGuard is to be shipped with a manual detailing operation and maintenance instructions. Last but not least, the team envisages launching marketing campaigns to build a realistic image and promote this solution.

Above all, bGuard wants to **be safe** and live up to **customer expectations**.

3 Design and Development

Based on the conducted background studies, the team defined the design, concept and proceeded with the development of the bGuard proof of concept prototype.

3.1 Design

Figure 1 displays the bGuard design, which was driven by safety, sustainability and aesthetics concerns.

The pillow and the sock are covered with Lyocell (Tencel) [28, 12]. Lyocell is a breathable hygienic material, which means it is less prone to the growth of bacteria. The pillow has two side bumpers to reduce the risk of rolling from back to tummy. These side bumpers are made of polyurethane foam. The home station, to avoid sharp angles, has a round shape. In terms of sustainability, bGuard was designed according to the DFD [29] principles like, for instance, the manual screwing of the home station parts. This means that when the product is at the end of its life it can be easily disassembled and the parts recycled. Considering the aesthetics, the home station has a clean look, presenting a smooth and bright surface made of ABS.

As a result, bGuard will be a **safe, eco-friendly** and **attractive** product.

3.2 Concept

Fig. 2 illustrates the bGuard concept with the sock and the pillow on the left, the home station in the middle and the IoT platform an mobile application on the



Fig. 1. bGuard design

right. The smart pillow has two side bumpers to minimise the risk of the baby rolling from back to tummy. One of the bumpers contains a micro-controller, a battery, a microphone, an MP3 player and a speaker. This equipment allows the pillow to play music or voice recordings when the baby cries. In the case of the end product, the sock integrates a pulse sensor, a small battery and a thin micro-controller. In the case of the prototype, the sock pulse sensor is wired to the micro-controller of the pillow.

The home station measures the room temperature, humidity and CO_2 , the sock reads the pulse of the baby and the pillow records the sound of the baby. The data collected by the sock and pillow are sent to the home station through a Bluetooth link and the home station sends all the gathered data to the IoT platform through a Wi-Fi link.

Finally, the baby and room data can be monitored online and seen on a smartphone. When the measured values are outside the predefined ranges, a **notification** is sent by the mobile **app** to the smartphone. Because of the limited time, the app will not be developed for the prototype. Nevertheless, the measurements will be monitored on the IoT Platform to prove the concept.

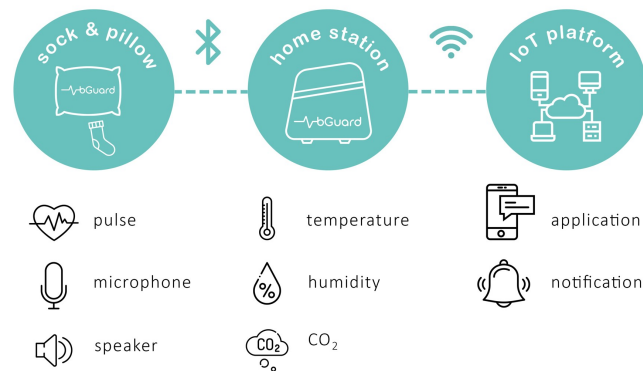


Fig. 2. Concept of the Prototype

3.3 Development

bGuard, as a 4 in 1 product for babies, was a great challenge for the team not only because of the technological part of the project but also with other aspects as to design a home station in order to allow the proper ventilation of the sensors inside, to develop a special cage to hold the pulse sensor as also to find a special textile that should be waterproof due to the potential spillage of liquids but, at the same time, not airproof to allow the microphone and the speaker to work properly.

All things considered, the decisions were made taken into account ethical and sustainability concerns what led the team to research a lot for the appropriate solutions.

4 Tests and Results

In order to examine the final function of the prototype, the team devise a set of tests. The planned Functional Tests concern the physical product itself, the software and the hardware. Table 2 lists the tests and the results.

Table 2. Tests and Results

Item	Results
Temperature and Humidity Sensor	After the installation of the DHT22 Sensor for temperature and humidity a test was done to compare the error of the sensor with a reference device. The measurements were done for the temperatures of 20 °C, 26 °C, 28 °C, and 30 °C. The required accuracy for the temperature is $\pm 3\%$ and for the humidity $\pm 5\%$. All the values were according to the accuracy.
CO ₂ Sensor	After the installation of the carbon dioxide sensor, a calibration in the outdoor air was done. The outdoor CO ₂ concentration considered was 400 ppm [1] so the calibration was done to this value. A comparison with another device was not carried out, due to a lack of resources.
Pulse Sensor	The pulse signal of the sensor was compared to the expected pulse curve. The pulse signal was exactly as it was expected to be for a young person. In the following, the sensor was compared to the medical device Silvercrest SPO55. The required accuracy of the pulse sensor is $\pm 5\%$ and all the values were acceptable.
Interaction	The microphone was calibrated in comparison to the SC-30 of CESVA. A baby cry has a frequency range from 336.9 Hz to 502 Hz. Due to that, the frequency stability was tested. In conclusion, the microphone is in the acceptance range of 5%. Furthermore, the cry detection is tested. A baby crying record was played and the reaction of the reference was compared. The test shows that the reaction is accurate enough to detect the baby crying. Moreover, the MP3 player played the sound files through the speakers.
IoT Platform	In the last step, the IoT Platform was implemented. All values are shown in real-time on the IoT Platform Thingsboard. The measurement is visualized in detail in a history diagram. Moreover, the minimum and maximum values can be edited by the user. An alarm interface shows if the values are out of the range.

5 Conclusion

Based on preliminary analyses, the team designed an out-of-the-box product, providing parents with remote access to information about the health and environment of their baby. Thus, bGuard contributes to the well-being of both parents and babies. Moreover, even when the infant naturally outgrows the pillow and the sock, the home station will continue to monitor the air quality of the room. The bGuard Smart Companion Pillow is a product of the IoT era, where smart devices become part of daily lives. The target group is made of worried parents (25 to 35 years old), ranging from middle-class through upper-class, who were raised with technology and can't live without their smartphone. Taking everything into account, the team is confident that **bGuard** has the potential to become a real product in the market due to its unique combination of features that **lower the risk of SIDS, monitor the quality of the sleeping environment and reduce parenting stress.**

EPS@ISEP, as a cross-cultural and multidisciplinary project, challenged the team to execute an integrated design-implementation-and-business solution - bGuard. The collective effort of the team was the key for the success. Besides the different kinds of expertise and the distinct visions of the problem - worried parents and SIDS, the team was able, with the help of the supervisors and the teachers, to establish its own way to plan and navigate along the semester - in an agile way, using SCRUM. Here are the testimonials of the team members:

- “Living in a globalised world, the EPS gives students the possibility to spend a semester in a foreign country while working with people from all over the world in close cooperation. Putting together a team from different academical backgrounds, different countries and different strengths, has the potential to create something big. The project allowed me to learn many things with the others and to improve my skills just by recognising how they tackle things and find solutions. What I liked especially about the EPS is that it simulates a start-up company in quite a realistic way. All the know-how was transferred in a practical way to be directly used for the project. It is great to see how motivated students can be and how much effort they put inside when they have a great project which is really progressing” – Tobi.
- “EPS@ISEP was really a great experience for me, specially because of the different fields of expertise of the team members. Furthermore, it was very interesting how the team always managed the time in order to distribute tasks towards the success of the project. On the whole, I must say that EPS@ISEP was really above my best expectations” – Alex.
- “Choosing to participate in the European Project Semester was one of the best choices of my life. I learned a lot during these few months. Not only did I develop new skills as a Product Designer, but I also learned so much about teamwork. It wasn't always easy to work with people who don't speak the same language as you or study the same courses, but we always managed to communicate one way or another. I would definitely say that our different backgrounds were not a weakness but a strength, which made us stronger as a team” – Elien.

- “The EPS is a good way to interconnect with students from different countries and cultures as well as the way to create a complete advised product for the real market is a great challenge” – Ko.
- “I am grateful for the experience EPS has provided. It is such a nice opportunity to meet so different people from other countries, see how they work and get to know other areas than my speciality. EPS is a good way to learn how to make things work in a totally new environment and in a group where each person has different ideas and viewpoints. It has taught me to be patient, tolerant and to consider much more the ideas of others. The opportunity to see and learn about this beautiful country is also priceless.” – Vaido.
- “I am thankful for having the opportunity to take part on the European Project Semester. During the semester I learned a lot about the different cultures and their way of working. It was great to see that every part of the team was much focused to create a product that supports young parents in the daily life. Also, I liked the way of thinking about ethical and sustainable topics during the project. This experience gave me a new view of generating solutions during the project. Moreover, the EPS enabled me the best way to improve my English skills.” – Marcel.

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