RIVISTA ITALIANA DI

ERGONOMIA

ORGANO UFFICIALE DELLA S.I.E. - SOCIETÀ ITALIANA DI ERGONOMIA

N.29 - 2024

- RETHINKING NEONATAL CARE
- NEW FRONTIER IN HOME-CARE EEG MONITORING
- ENHANCING HOSPITAL NAVIGATION THROUGH GAMIFICATION
- NEIGHBORHOOD EDUCATIONAL CENTER
- A CLASSROOM TAILORED TO STUDENTS WITH CHRONIC MEDICAL CONDITIONS

Poste Italiane S.p.A. – Sped. in Abbon. Post. DL 353/2003 conv. in L.27/02/2004, n.46, art.1 comma 1 DCB Milano – rivista quadrimestrale - anno 13 - n. 29, 2024

RIVISTA ITALIANA DI
ERGONOMIA

RIVISTA QUADRIMESTRALE
NUOVA EDIZIONE
NUMERO 29 - 2024

Organo ufficiale della
SOCIETÀ ITALIANA DI ERGONOMIA
www.societadiergonomia.it

SEDE LEGALE REDAZIONE, AMMINISTRAZIONE
Segreteria SIE c/o R.M. Società di Congressi srl
Via Ciro Menotti 11, 20129 Milano
tel. +39 02 70.12.63.67 – segreteria@societadiergonomia.it

GRAPHIC DESIGN AND LAYOUT
Frush [Design sostenibile] – www.frush.it

ISSN 2531-8845
Rivista Italiana di Ergonomia

RIVISTA ITALIANA DI ERGONOMIA

THE RIVISTA ITALIANA DI ERGONOMIA, *of the S.I.E. - Italian Society of Ergonomics, is a scientific journal that operates nationally and internationally for the promotion and development of ergonomics and the study of human factors, and the dissemination and systematization of knowledge and experiences related to the ergonomic approach, in close relationship with the social, environmental and productive realities where human beings, operate and live, coherently with the goals of the SIE.*

Supported by an international scientific committee and using a double-blind reviewing process, the journal publishes original contributions from research and applications on ergonomic issues, in its various aspects and related to the different contexts and human activities.

The RIVISTA ITALIANA DI ERGONOMIA *is aimed at ergonomic professionals and all those interested in applying the principles and methods of ergonomics / human factors in the design, planning and management of technical and social systems, in work or in leisure.*

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Each article must be submitted both in English and must include: title, author/s name, affiliation, abstract and bibliography. Each version must have a maximum of 25,000 characters spaces included. In particular: The abstract length shall range between 100 and 250 words. Keywords: 3 to 6 keywords should be provided after the abstract. The article must contain the full names and affiliations of author(s). A short bio of each author is required at the end of the paper and placed in a dedicated section. Its maximum length is no more than 100 words each. They are excluded from the overall counting.

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EDITORIAL

ERMINIA ATTAIANESE

Ergonomics for children: designing supportive environments for healthy and sustainable growth

Children are not little adults. This is the title of a training course organized by WHO in 2019 about the relationship between children and the environment, focusing on the principle that sustainable development has at its core healthy children, and it is the responsibility of today's adults to identify hazards and conditions in the complex and changing environments that impair children ability to grow and mature safely and in good health (WHO,2019).
Ergonomics and childhood have been separate topics for a long time, due to the predominant focus of the HFE conventionally reserved on the adults in their working environment. The interest toward children began in the late 1990s, when computers spread also to school, and most classrooms in western countries started to be equipped with PCs for education purposes. The need to face musculoskeletal disorders amongst school students due to postures at the computer workstation and body size compatibility with ICT devices (topic that is still critical today, as EU-OSHA stated in 2021), expanded the observation toward the effects of more "traditional" risk factors for children and youth health underrated until then, such as desks, chairs and schoolbags (Barrero and Hedge, 2002).
Thanks to the work of International Ergonomics Association (IEA) Technical Committee on Ergonomics for Children in Educational Environments, and of some special interest groups

of the UK and New Zealand Ergonomics Societies, interest of ergonomics community for children increased (Legg and Jacobs, 2008). An important milestone on the topic was the volume "Ergonomics for children" by Rani Lueder and Valerie J. Berg Rice (2007) which, as Nigel Corlett affirms in his preface to the book, is a first attempt to put the lives of children in the context of the society, to give a comprehensive analysis with explanations, reasons, and design recommendations for the betterment of their lives, going beyond the schools, where the lens of ergonomics was confined, in homes, on playgrounds, and in public and private spaces.

Built environment, after all, plays a significant role in the human health and well-being, and this is particularly relevant for children. Early exposure to stimulating and positive environments helps children to build abilities necessary for learning, communicating, solving problems and making decisions, since healthy development in the early years greatly affects physical, social, emotional, and cognitive performance and lays the foundations of physical and mental health in adulthood. Nevertheless, complex and nonlinear changes differentiate children from adults. In addition to growth in physical size, modifications in body proportions, body composition, physiology, neurologic maturation, and psychosocial development take place during infancy and childhood.

These changes are of equal if not greater importance than growth in physical size in terms of the child's development and response to environmental stimuli, producing significant differences on how children respond to the environment, since their adaptation ability change with age (Lueder and Rice, 2007), adding complexity to designing environments, including equipment, furniture and services, with *children in mind*.

Children do not interpret environment in terms of shapes and structures as adult do, but view it holistically. They evaluate all the ways they can interact with it, looking at for the opportunities environment affords them to do things, its possible function rather than its form. Thus, any element of the environment becomes a functional item for the child, which can positively stimulate his development, or constitute a hazard, posing them at greater risk of injuries than adults.

Movement is one of the basic environmental needs of children, that has to be favored within safe and tolerable limits, but not too restricted for avoiding frustration and fidget.
Since human behavior is optimized in a state of comfort, it is important in children's interaction with the environment, although the right levels of stimulation are difficult to identify. Children are particularly vulnerable to hot environments and heat stress than adults, but they prefer a lower than standardized comfort temperature and show very different thermal sensations even among homogeneous groups (Attaianese et al, 2019). Noise can negatively affect a child's ability to communicate and learn, as well as their overall health, behavior, performance, and safety. An overload of sensory stimulation exacerbate children's feelings of discomfort and result in undesired behaviors (Burton, 2011). Insufficient daylight exposure is linked to depressive symptoms in children, and strong evidence supports a link between asthma, poor respiratory health and poor air quality, dampness and mold, as well as between lead exposure (paint and cigarette smoke) and neurological disorders in young children, cognitive impairment in adolescence, and problems with impulsivity (Lueder and Rice, 2007). Children are explorers by nature and their orientation skills in the environment improve significantly with age and practice. The navigability of an environment or the self-explanatory nature of a product affect children perceived safety and autonomy, making them competent users, without forcing them to constantly confront intimidating and frustrating experiences, as those usually affect children in the living environments (White, 2004)
Designing supportive environments for children is a complex task. Considering human variability and diversity is one of the pillars of ergonomic design, and about children, HFE can give answers on how they differ from adults, how such differences connote each developmental stage, and how the distinct physical and mental phases which are experienced between ages may affect the design of products and places.
While ergonomic domain have been expanded toward children, more need to be done about application of HFE principles to design, according to their abilities, limitations, growth and development patterns. The goals is balance contrasting

needs of safety and support that inevitably come into play in conceiving solutions for children, especially in a framework of the digital world we are living.
Global challenges require to consolidate the ecological perspective in design for children. In a context in which promoting sustainable behavior is ineludible, children become the main target for experiencing compatible patterns and pushing toward life-styles environmental-free that make the difference in adulthood.
Moreover, in the today ageing society, an ecological framework of health is also considered, focusing on health as result of a full continuum process, where each stage of development, each age, builds on the last, in a lifelong dimension. So, for an healthy ageing and a sustainable society, we need to start from children, and designing enabling environments also thanks to HFE approach is the condition in which this may be possible.

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ERMINIA ATTAIANESE

Full time Associate Professor in Architecture Technology at the University of Naples Federico II, Italy, she is President of CREE Centre for Registration of European Ergonomist, and Chair of the Technical Committee "Ergonomics in Design for All", of International Ergonomics Association (IEA). Her research interest and areas of expertise relate to human-centred design, particularly referred to ergonomics of the built environment, buildings and product accessibility, safety and usability. Her studies also include the intersection between HF/E and sustainability applied to the environmental design of buildings and public spaces.

Pediatric Ergonomics: an Opportunity for Growth

GABRIELE FRANGIONI
SIE Toscana and NOS ERGOMeyer

Pediatric ergonomics is an emerging field that holds immense potential for the well-being and development of children across all stages of their growth. As our understanding of the importance of early childhood development deepens, so does our awareness of how crucial it is to create environments and products that meet the specific needs of children. Pediatric ergonomics focuses on carefully designing and adapting spaces, tools, and activities to optimise children's physical, cognitive, and emotional growth from infancy through adolescence.

The importance of ergonomics in pediatric settings cannot be overstated. The physical and cognitive development of children is highly dynamic and varies significantly across different stages of growth. As a result, it is essential that the environments in which children live, learn, and play be thoughtfully designed to foster their health, comfort, and development. Whether in schools, homes, playgrounds, or healthcare settings, ergonomically sound design can significantly impact children's well-being and overall quality of life.

This issue of the "Rivista Italiana di Ergonomia" seeks to highlight the opportunities that pediatric ergonomics presents for the future. Starting from emerging topics from the 3rd Pediatric Ergonomics Conference, held in Florence in May 2024, alongside national contributions in pediatric care, this publication aims to provide insights into the potential of this interdisciplinary field. It serves as an initial mo-

ment of reflection and dissemination, setting the stage for a broader, cross-disciplinary dialogue between professionals and society.

These questions revolve around key challenges in pediatric ergonomics, such as the adaptation of environments to cater to the diverse developmental stages of children, the role of creativity in ergonomic design, and how we can address the growing intersection between digital technology and childhood development.

The selected contributions in this issue provide answers to these fundamental aspects and also foresee significant future developments within the field of pediatric ergonomics.

In these years of work in the pediatric field, while analyzing products (devices, equipment), services, and procedures, a recurring statement has emerged, which can be summarized as follows: "Pediatrics is a niche; companies have little interest in investing in this area and prefer to focus on adults, where the cases and revenues are much greater..." (Frangioni 2021). This observation raises critical questions: Why do companies not invest? What limits them in research and investment in the pediatric field?

In a work environment rich with skilled professionals and significant on-field experience, we observe the lack of a structured network between companies and services, insufficient long-term planning of political and managerial interventions, and the underestimation of pediatric contexts and needs. The pediatric age spans from birth to 18 years, representing 22% of the average life expectancy in Europe (81.5 years, according to Eurostat data, April 2023). This is a significant portion of human development that, therefore, requires substantial attention. The term "pediatric" does not solely refer to a profession (pediatrician) or the early years of life, as is often misunderstood, but rather to an evolving age range from 0 to 18 years (Frangioni, 2024).

A child is not a young adult. From birth to adulthood, the human being undergoes physiological and proportional growth of all bodily components—bones, muscles, organs, tissues—and this process is accompanied by continuous cognitive, perceptual, and emotional development, which evolves in tandem with the exploration of surrounding living environments. If we broaden the scope of observation beyond our immediate focus, the perception and impact of the pediatric age expand, encompassing infrastructures, technologies, services, welfare (including nurseries and workplace childcare), social relationships, integration, and stakeholders. This includes everything surrounding pediatric development, which serves as vital support for

parents, families, and educators.

This framework, although not exhaustive, allows us to assert that the pediatric field cannot be considered a "niche" but rather a structural component of a broader process of human development. To speak of Pediatric Ergonomics is to speak of human beings, to build the foundation for what will become adult life.

As the world continues to evolve, the importance of considering ergonomics in the design of products, environments, and systems for children becomes more evident. This is particularly true as we face the challenges of an increasingly digital world, where children's interaction with technology, play, education, and healthcare requires new, innovative approaches. By recognizing the unique needs of children and integrating principles of ergonomics into design, we have the opportunity to create safer, more engaging, and supportive environments that contribute to their physical, cognitive, and emotional development.

In this context, pediatric ergonomics is not just a matter of physical comfort, but a foundation for fostering growth, creativity, and resilience. It is an opportunity to rethink how we shape the world for the younger generation, ensuring that the environments they inhabit are conducive to their overall well-being and future success.

The interdisciplinary nature of pediatric ergonomics invites collaboration across multiple sectors—design, healthcare, education, and beyond. By coming together to address the shared goal of enhancing children's development, we can create solutions that are both innovative and practical. This issue aims to spark conversations that will lead to new approaches, informed by evidence and real-world experience, to better meet the diverse needs of children.

Ultimately, pediatric ergonomics represents an opportunity for growth—not only for the children who benefit from these designs but for the broader field of ergonomics itself, as it expands its reach into areas that directly impact the foundation of human development. Let us embrace this opportunity to shape a future where the next generation can thrive in environments that support their full potential.

"The well-being of individuals is built through an evolutionary and formative journey that spans all stages of human development, from childhood to adulthood. It is a process of physiological, psychological-relational, emotional, and cognitive growth where the individual, from birth, interacts with the surrounding environment, discovers their abilities, and begins their journey toward adulthood.In this evolutionary process [...] the child discovers and learns about the world: they explore, manipulate, experiment, practice, build their challenges, and shape their future.A development that is fueled by external stimuli and constant inner transformation. The people, places, activities, and objects with which the child interacts resonate with the developmental process and nurture it. [...] Ergonomics can serve as an interpreter of the needs and opportunities of this growth process and translate them into spaces, objects, and activities designed for a healthy and harmonious growth process."
(1st Pediatric Ergonomics Conference, 14 April 2021)

GABRIELE FRANGIONI

Architect I., Eur.Erg., has been working as an Ergonomist for over 10 years in the fields of Ergonomics in Healthcare and Ergonomics in Pediatrics and Risk Management. He is involved in Clinical Risk Management, Facility Management & Safety, Pediatric Simulation in the areas of Patient Safety and Quality of Care. He provides support and training to healthcare professionals and students, undergraduates, masters and doctoral students in Clinical Risk Management and Ergonomics and Human Factors. Promoter of Conferences in the pediatric field since 2016. A member since 2013 of the Italian Society of Ergonomics and Human Factors (SIE), he has been president of the SIE Tuscany Section since 2019 and member of the Order of Architects of Florence since 2024.

Rethinking neonatal care: Addressing risks and improving safety in ventilation practices

ESTER IACONO[1], ALBERTO CIRULLI[2], CLAUDIO MONDOVECCHIO[3]

[1]Laboratory of Ergonomics and Design (LED), Department of Architecture, University of Florence, ITALY

[2] Pq design group, Pisa, ITALY

[3] AOU Meyer, Firenze, ITALY

Keywords: Medication errors, Healthcare Design, Human-Centred Design, Usability of Medical Devices, Neonatal portable ventilator

Abstract

This study, conducted at the Meyer Children's Hospital in Florence, addresses the challenges of neonatal care, with a particular focus on mechanical ventilation, an area with a high risk of errors. Despite advanced technologies, newborns are exposed to risks three times greater than adults due to the complexity of treatments and equipment used. One of the main issues identified is related to the use of lung ventilators, which can lead to human errors and physiological complications. The objective of the research was to improve both the well-being of the small patients and the working conditions of the medical staff. By applying Human-Centred Design methods, user needs and usability issues of existing ventilators were analysed. The analysis involved direct observations, interviews, and questionnaires to identify difficulties related to the digital interface and the organization of care phases. The results led to the design of the Andy ventilator, which stands out for its user-friendly interface, versatility, and ease of transport. Andy reduces risk factors by allowing continuous use without disconnecting the patient. This innovation not only enhances the safety and effectiveness of

ventilatory assistance but has also been awarded the iF DESIGN TALENT AWARD 2022, highlighting the importance of ergonomics and user-centred design in the healthcare field.

Introduction

Research and innovation are fundamental in addressing paediatric healthcare challenges, especially in critical contexts such as Neonatal Intensive Care Units (NICUs). The continuous evolution of clinical issues, enrichment of scientific knowledge, and adoption of multidisciplinary approaches pave the way for new solutions that can revolutionize paediatric patient care.

A central aspect of this innovation is adopting digital technologies, which are essential for improving medical devices' safety and effectiveness. These devices must be designed to meet the needs of paediatric patients, healthcare professionals, and families, ensuring increasingly intuitive and safe solutions (Tosi & Rinaldi, 2015; Iacono et al., 2019).

The complexity of care flows can lead to errors in product use and understanding of digital interfaces, creating risks to patient safety. A human-centred design approach, which includes the application of ergonomic methodologies, helps anticipate risks and simplify interactions with devices, reducing operational errors.

Interdisciplinary collaborations between designers, engineers, and doctors are crucial for developing practical solutions that address the complex challenges related to child health, optimize workflows, and improve the quality of care. Additionally, the inclusion and involvement of users in the design process are key factors in creating relevant and effective devices. A participatory approach increases user satisfaction and improves clinical outcomes. Moreover, integrating artificial intelligence and machine learning presents an excellent opportunity to optimize NICU processes. Recent studies (Tscholl et al., 2018) show that these technologies can improve decision-making accuracy and reduce errors through real-time data analysis.

A concrete example of applying usability and safety evaluation methodologies typical of Human-Centred Design (HCD) and User Experience (UX) has been developed at the Meyer Children's Hospital in Florence. The study presented in this article aimed to improve paediatric patients' well-being and medical staff's working conditions. By focusing on facilitating interaction and simplifying procedures, the goal was to minimize the risk of operational errors, thereby helping

create a safer and more efficient healthcare environment. The results highlight the importance of design and innovation as strategic levers for improving paediatric care and the safety of young patients, contributing to building a better future for child healthcare.

Clinical risks and safety in neonatal ventilation: a critical analysis

In recent years, the growing focus on risks and harm in healthcare settings has brought the topic of medical errors to the forefront as part of the broader issue of clinical risk. A widely cited 2016 study conducted by Johns Hopkins University classified medical errors as the third leading cause of death in the United States, bringing public attention to the frequency and seriousness of these preventable incidents. In particular, a 2020 study estimates that 6% of hospitalized patients suffer harm from medical errors, often preventable, especially in critical areas like intensive care, where the rate of preventable events rises to 18%, with higher risks associated with invasive procedures, medication errors, and misdiagnoses (Atanasov et al., 2020). In healthcare, unlike other fields such as aviation and nuclear power plants, implementing human factors engineering and ergonomic techniques remains limited, making it challenging to reduce operational errors (Brixey et al., 2002). This issue is particularly critical in paediatrics and in Neonatal Intensive Care Units (NICUs), where newborns face a risk three times higher than adults for complications related to medication administration and respiratory care (Kaushal et al., 2001). Respiratory diseases are one of the leading causes of hospitalization in NICUs, significantly contributing to neonatal mortality and resulting in a frequent incidence of bronchopulmonary dysplasia (BPD) in low-birth-weight infants who require specialized ventilatory support to reduce complications and improve survival (Jacob et al., 2015; Klingenberg et al., 2017; Dyer, 2019). Despite technological advancements, mechanical ventilation exposes patients to the risks of lung damage, infections, and physiological complications.

The WHO suggests a systemic approach to improving patient safety, which includes effective communication among healthcare teams, proper workload management, and standardization of safety protocols. Particular attention should be given to “human factors”, such as cognitive overload and operator fatigue, contributing to errors. To reduce mortality related to healthcare errors, healthcare providers must adopt well-designed technological solutions, streamlined pro-

cesses, and continuous staff training.
Studies show that healthcare incidents are often linked to human errors and organizational and device design issues, creating latent errors and compromising patient safety (Ward & Clarkson, 2004; Derrico et al., 2009; Drews, 2012). As highlighted by the Center for Devices and Radiological Health (CDRH), poor device design and ignorance of human factors can lead to serious incidents, including injuries and deaths. Specifically, ergonomic and usability deficiencies in medical devices used in NICUs can exacerbate risks associated with using and understanding digital interfaces (Iacono et al., 2019). To improve the safety and effectiveness of devices, designers must adopt a holistic design approach that considers the dynamics of use in intensive care settings and during intra- and inter-hospital transportation.

Methodology

The study conducted at the Meyer Children's Hospital in Florence was based on the use of theoretical and practical methodologies from Ergonomics for Design (Tosi, 2020), explicitly following the principles of Human-Centered Design (HCD) and User Experience (UX). These approaches allowed for managing and analysing the complexity of the clinical context, ensuring the centrality of the human factor and reducing the risk of "adverse effects" linked to improper use of devices, with benefits for patient safety, efficiency, and health. By using data collected directly from individuals in their real work environments, the study enabled the development of design solutions to address the daily challenges faced by healthcare staff. The research process included the direct involvement of various professionals (neonatologists, paediatricians, nurses, and respiratory therapists) working in Neonatal Transport and the use of ventilators, focusing on their needs and expectations and the specific skills related to product use.
The main phases of the research were as follows:

1. Definition of user profiles
2. Evaluate the ventilators in use
3. Data analysis
4. Development of concepts and intervention scenarios

Phase 1: Definition of user profiles

The first phase of the research identified the various users involved in the neonatal care process, from those who directly benefit from the treatment to the professionals and families who support the new-

born. Four user groups were identified:

1. The **beneficiary user** is the preterm newborn or one with specific medical conditions.
2. **Primary users** are medical personnel directly responsible for the care, such as neonatologists, paediatricians, specialized nurses, and respiratory therapists.
3. **Secondary users** are support figures such as volunteers and healthcare staff.
4. **Indirect users** are the newborn's parents.

This analysis allowed for a deeper understanding of each user's role and interactions with the ventilator, detailing their specific activities. For example, neonatologists assess and set the ventilation modes, paediatricians monitor respiratory parameters and care for the newborn, and nurses manage medication administration and device organization. Respiratory therapists analyse oxygenation levels to implement the necessary therapies, and support staff help strengthen the bond between the newborn and the parents. This phase highlighted critical interactions and challenges related to ventilator use, supporting a design approach centred on the real needs of the different users.

Phase 2: Evaluate the ventilators in use

The next phase of the research evaluated neonatal ventilation services and devices in use, specifically focusing on neonatal ventilators' usability in the ward and during transport. Different evaluation methods involving users (User Trials) were used to collect practical data useful for redesign, analyse critical issues, and suggest improvements.

1. Direct observations (Stanton et al., 2014). Through observation sessions in the field, researchers recorded staff actions and behaviours during ventilator use. This analysis involved photographic and video recordings, allowing for accurate documentation of the operator-device interaction.
2. Semi-structured interviews (Patton, 2015). Interviews with neonatologists, nurses, and technicians allowed it to understand the needs, difficulties, and intuitions regarding ventilator use. These interviews revealed hidden needs and operational critical issues that often escape direct observation.
3. Questionnaires (Wilson & Sharples, 2015). These were submitted to a targeted sample (7 neonatologists and 9 nurses). The questionnaires measured satisfaction and collected opinions through a 5-point Likert scale and open-ended questions. This facilitated

the collection of quantitative and qualitative data to evaluate the staff's experiences in the ward or during transport. Significant statistical data was obtained by administering predetermined items.

4. Scenarios (Hanington & Martin, 2019), workflow (Nikookar et al., 2013) and Task Analysis (Tosi, 2020). These allowed us to visualise the workflow in distinct contexts, such as the ward and transport. Thanks to tools such as personas and storyboards, it was possible to represent the activities and objectives of the users in a detailed way (see Fig. 1); in the specific case of neonatal ventilation, the objectives and activities were summarised in 3 steps: preparation, use, recovery, highlighting the problems of interaction with the device.
5. User journey maps (Hanington & Martin, 2019). Maps, tracing the users' actions, emotions and perceptions in each interaction phase, offered a complete view of the user experience. This approach revealed critical points and opportunities to improve the interaction and user experience.

The research evaluations focused on four main areas: the size and functionality of the product, the cognitive and emotional management of the operators, the perceptive aspects during the interaction with the device and the operators' skills. The collected data were used to develop a project proposal to improve the usability, safety, and effectiveness of the neonatal ventilator, which was done within a collaborative process that involved the research group in creating innovative solutions to optimise the service.

Phases 3-4: Data analysis and development of project concepts

The analysis and synthesis phase of the collected data allowed it to identify the critical issues and define the requirements for the system under examination. The data obtained from interviews, questionnaires and observations were organised and summarised in maps and diagrams to highlight the problem areas. The results of the questionnaires were represented in graphs that illustrate the response percentages to facilitate interpretation. Subsequently, in the development phase of the design concepts, the problems that emerged were addressed through the use of design-orienting scenarios (Manzini & Jégou, 2004), allowing the team to outline strategic visions for an innovative neonatal ventilator oriented to the needs of patients and operators in the context of the Neonatal Intensive Care Unit.

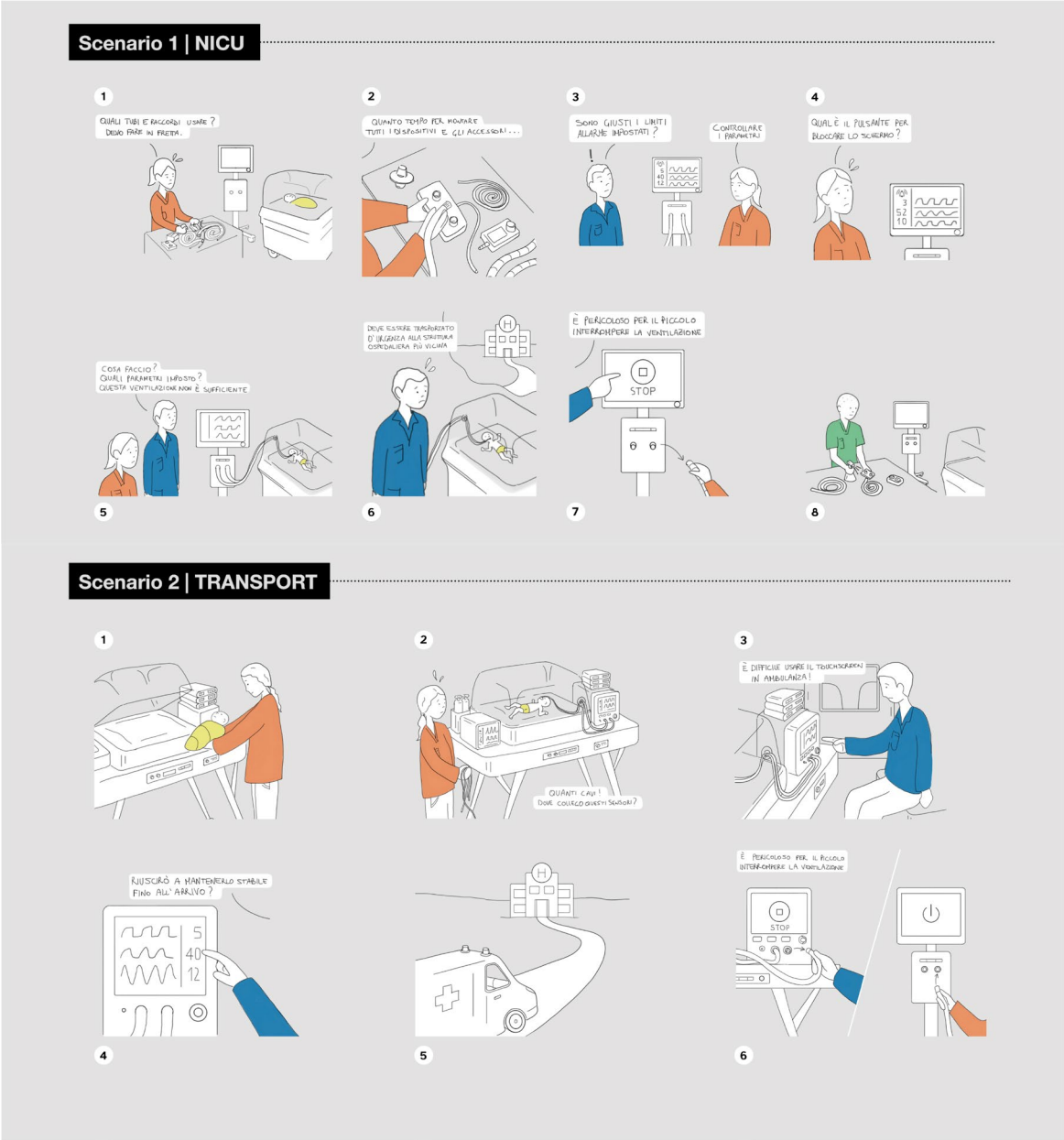

Figure 1. Developing of two different scenarios: in-ward and during transport.

Results

Evaluation and analysis of critical issues

The data analysis revealed several problems using neonatal ventilators in the ward and during transport. In the ward, the main critical

issues concern the difficulty assembling the components and switching between the different ventilation modes, problems such as alarm management, recognisability of the controls, and excessive condensation production by the humidifiers. Furthermore, possible errors were found during the assembly of the valve, as well as a lack of connections and non-shared updates.

The devices' weight, size, and complexity amplify the difficulties during transport, especially in emergency situations such as in an ambulance or helicopter. The touch screen is difficult to use in the ambulance, and the limited space in the vehicle makes it difficult to interact with the ventilator. Switching from ambulance gas to cradle gas is also difficult.

Further critical issues concern the arrangement and functionality of the connection ports, the usability of the graphic interface and the ventilation modes. In particular, the redundancy of connection ports, difficulty reading icons and graphs, and inefficiency in organising information emerged as obstacles. Problems were also found in using the humidifier and devices for ventilation with nitric oxide, with long assembly times and little practicality of use. Furthermore, the inability to detect dangerous environmental gases while using iNO (nitric oxide) was identified as a safety risk. Overall, the critical issues encountered in using neonatal ventilators mainly concern the assembly of the components, which varies according to the ventilation modes, and the difficulties related to the transportability of the device.

Furthermore, problems were highlighted in both the physical and digital interface, with difficulties viewing information and adjusting the necessary parameters. The presence of numerous additional devices during transport increases the complexity of use. Some actions (switching between ventilation modes or disconnecting the patient during transport) can be potentially dangerous. These issues, combined with the increased risk of operational errors, have led to low levels of user satisfaction. As a result, design solutions have been developed, in collaboration with industry experts, to improve the ventilator's reliability, safety and effectiveness.

Design solutions

The analysis of the critical issues that emerged from the study led to the development of a new generation lung ventilator called Andy, designed to simplify each phase of ventilatory assistance, reduce the risk of error and ensure continuous use without the need to discon-

nect the patient, both in the department and during transport. The project aimed to develop a single ventilator usable in different contexts, with simplified maintenance and an intuitive digital interface, and reduce the clutter of devices and cables. The main expected benefits included (see Fig. 2):

- For the workflow: reduced preparation times, ease of use and more significant order in workspaces.
- For the patient: continuity of ventilation even during transport, reducing the risk associated with disconnections.
- For the hospital structure: optimisation of resources and reducing maintenance and staff training costs.

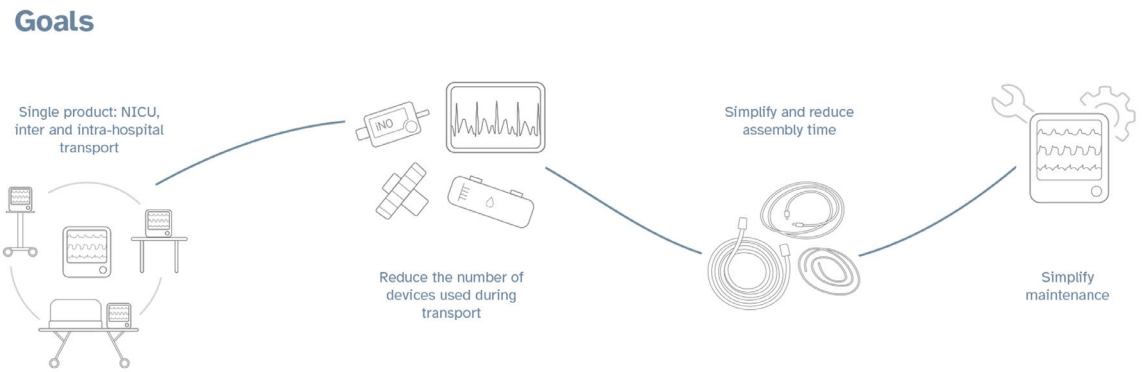

Figure 2. Main goals of Andy: ensure versatility in neonatal intensive care and transport, reduce device count, simplify assembly, enable seamless mode transitions without disconnections, and ease maintenance.

This integrated approach improves operational efficiency and quality of care, providing advantages for healthcare personnel and patients. The new lung ventilator has been designed considering three key concepts:

1. *Simplified morphology and physical interface*: The device integrates various devices, such as humidifiers and nitric oxide (iNo) delivery systems, to reduce the number of devices used and simplify ventilatory assistance, especially in emergencies or transport. This integration within the device simplifies the assembly of components and the monitoring of ventilatory parameters, eliminating the need for additional control devices. A small device, which can be positioned inside the incubator, collects the neces-

sary sensors, improving the organisation of cables and reducing the risk of connection errors thanks to easily recognisable ports and wireless technology (see Fig. 3).

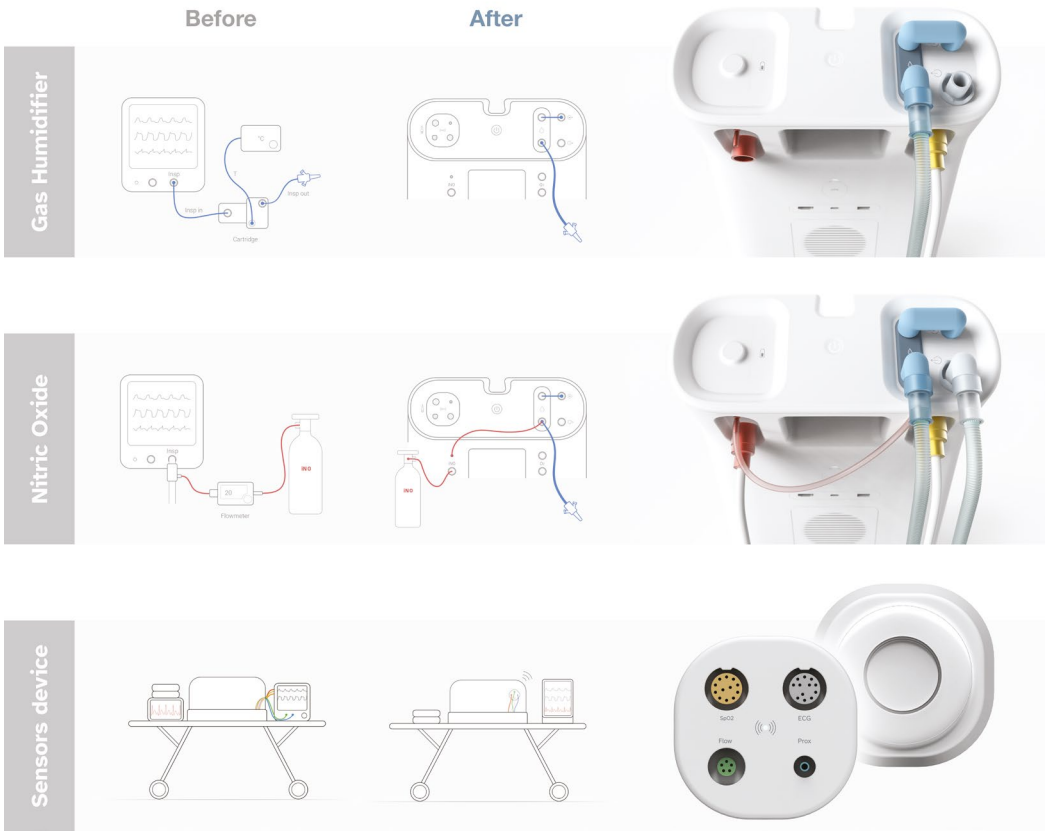

Figure 3. Morphology and physical interface of the new device: simplifying the care workflow and reducing the excessive number of devices used.

2. *Intuitive and simple digital interface*: A reclining and extractable tablet facilitates the control and modification of parameters, while a simple graphic interface, with clear icons and optimised visual contrast, reduces the cognitive load for healthcare professionals and speeds up medical operations. Furthermore, optimal colours and contrasts have been used to improve visibility and reduce visual stress. At the same time, the "neomorphic" graphic style visually distinguishes the selectable buttons through extruded elements that give the touch interface a physicality, at least visually, making the user experience more pleasant and tangible.

Furthermore, visual and sound feedback (yellow: low priority; red: high priority) helps to report any problems, reducing the risk of errors (see Fig. 4).

Figure 4. *Reclinable and removable tablet to facilitate the reading and adjustment of ventilation parameters (top) and digital interface of the new ventilator, which communicates detected issues to the user through visual and auditory feedback (bottom).*

3. *Versatility and portability*: Suitable for both the department and transport, the ventilator is compact, lightweight and made of high-performance biocompatible material with excellent mechanical resistance (Tecapro MT). An ergonomic handle and an anchoring base simplify fixing and handling, and a bag with dedicated compartments allows the ventilator to be transported together with all its components and accessories (see Fig. 5).

These improvements aim to optimise ventilatory assistance by reducing risks and simplifying the user experience for medical personnel.

Figure 5. Versatility and portability of the product.

Conclusions

The results of this study and Andy's design demonstrate the potential of human-centred design methodologies and ergonomics applied to the design to create safer and easier-to-use healthcare devices, improving the patient's care experience and the staff's workflow. Andy represents an evolution in neonatal ventilation, overcoming the limitations of current devices, which require disconnecting the patient when switching between different ventilators. This ventilator, designed for continuity and ease of use, reduces the risks associated with managing multiple interfaces and devices, ensuring more excellent safety for the neonate and smoother use for the healthcare staff. The recognition received from the iF DESIGN TALENT AWARD 2022 emphasises the importance of this innovation, highlighting how the combination of ergonomics and human-centred design has created a revolutionary solution for the medical sector. Andy represents a paradigm of innovation with the potential to change the approach to the

design of medical devices, with significant impacts both in neonatal care and in the training of healthcare professionals. With an intuitive interface and reduced number of devices required, training and maintenance time could be reduced, which would help optimise hospital resources. For the future, it is essential to create a prototype of Andy to implement a study capable of improving users' quality of life in a real context. Developing a prototype would open the possibility of direct user testing, allowing for real-world feedback and further refinement of the device. These tests would optimise practical and functional aspects and allow Andy to be adapted to a broader range of patients and clinical situations, thus expanding its applications beyond the neonatal context.

Furthermore, Andy provides an ideal basis for future technological evolutions, such as integrating artificial intelligence and remote monitoring systems, which could allow real-time adjustment and customisation of ventilator parameters based on patient conditions. This prospect paves the way for a generation of even more intelligent and integrated ventilators capable of adapting to the individual patient's needs and the healthcare context's different clinical needs. Andy, therefore, represents not only an answer to the current challenges of neonatal ventilation but also a promising starting point for future scenarios of medical ventilation that are more efficient, safe and centred on the needs of patients and operators (see Fig. 6).

Figure 5. *Andy - NICU Portable Ventilator.*

Acknowledgements: The authors would like to thank Francesca Tosi (Scientific Director of the Research) and all the medical staff of the Meyer Children's Hospital in Florence, in particular Dr. Marco Moroni and Maurizio Ginepro for their availability and valuable suggestions in all phases of the development of the research work.

Author Contributions

Conceptualization, E.I.; methodology, E.I. and A.C.; infographics, rendering and data curation, A.C; writing–original draft preparation, E.I.; writing–review and editing, E.I. (all sections except “Design Solution”) and A.C.; Supervision, E.I. and C.M. (technical part). All authors have read and agreed to the published version of the manuscript.

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ESTER IACONO

PhD in Design, she is a research fellow and adjunct professor of the course "Design and Ergonomics for Communication and Services" at the Department of Architecture of the University of Florence. Since 2017, she has been researching at the Ergonomics & Design Laboratory (LED) on topics related to Emotional Design in the health sector, Human-Centred Design/User Experience, Interaction Design, Ergonomics for Design, Design for Healthcare and inclusion. She has participated in national and international research projects and collaborated in research programs funded by the EU, public administrations and public and private companies. She is also the author of articles and essays published in national and international scientific journals and proceedings conferences.

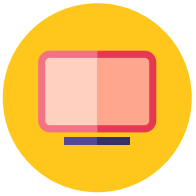
ALBERTO CIRULLI

A designer specialising in designing physical and digital experiences, who strives to push the boundaries of innovation in every project. A graduate in Design from the University of Florence, he currently works at the PQ Design Group studio, where he contributes to the development of experiences that combine functionality, aesthetics and sustainability, working effectively within multidisciplinary teams to realise innovative and cutting-edge projects. His professional career is characterised by a continuous interest in exploring the connections between materials, forms and innovative technologies, with a strong focus on topics related to Ergonomics and Inclusive design.

CLAUDIO MONDOVECCHIO

Since 1999, he has worked in clinical engineering in several public hospitals, following specific projects, procurement planning, and supervising services related to electromedical and laboratory equipment. He has collaborated with the School of Engineering of the University of Florence, accompanying future engineers during their training. Currently, in the Meyer Children's Hospital (Irccs), he supports the continuous renewal of equipment and the introduction of new technologies by verifying their actual usability, from the preliminary assessment to their best use during their entire life cycle with HTA methodology, supporting accreditation processes and clinical trials.

Cosmo+: New Frontier in Home-Care EEG Monitoring



ESTER IACONO[1], SALVO ANDREA DENARO[1], CLAUDIO MONDOVECCHIO[2], FRANCESCA TOSI[1]

[1]Laboratory of Ergonomics and Design (LED), Department of Architecture, University of Florence, ITALY

[2] AOU Meyer, Firenze, ITALY

Keywords: Paediatric Neurophysiology, Wearable EEG devices, Usability, Human-Centred Design, User Experience, Home care

Abstract

Modern neurophysiological techniques have expanded the understanding of cortical dysfunctions in paediatric neurological diseases, such as brain injuries and epilepsy, which are associated with high rates of mortality and disability. Electroencephalography (EEG), a crucial method for diagnosing and monitoring critical patients, presents significant challenges in paediatric use due to usability and comfort issues associated with traditional systems. The research at the Meyer Children's Hospital in Florence aimed to develop innovative solutions to optimise brain activity monitoring in paediatric patients. The interaction between the patient and the device was analysed using Human-Centred Design (HCD) and User Experience (UX) approaches. The investigation revealed critical issues in the current workflow, highlighting usability problems and discomfort caused by traditional EEG devices. These findings led to the design of the Cosmo+ EEG System, a modular device that offers personalised monitoring, providing a more user-friendly and less invasive experience. This device could improve workflow

and patient satisfaction, representing a significant advancement in neurophysiology with potential clinical and research applications, including home use.

Introduction

Advancements in neurophysiological techniques have greatly improved the understanding of cortical dysfunctions underlying neurological conditions such as traumatic brain injuries, status epilepticus, hypoxic-ischemic lesions, stroke, and meningitis/encephalitis, which are increasingly prevalent and linked to higher mortality and disability rates in paediatric patients (Williams et al., 2019; Chang & Rasmusen, 2022). Emerging neuro-monitoring technologies, particularly continuous, non-invasive electroencephalography (EEG), are vital in diagnosing acute brain injuries and monitoring critically ill patients, including those without neurological injuries (Kirschen et al., 2022; Caricato et al., 2018). EEG offers a reliable method for various clinical applications, such as detecting seizures, psychological evaluation, and anaesthesia monitoring (Reyes, 2018). Despite its advantages, the use of EEG in paediatric patients faces challenges related to usability and acceptability, especially in current systems that rely on wired electrodes with conductive gel, limiting mobility and patient comfort (Webster, 2009). Though gel-based electrodes are still the standard, studies indicate that portable, gel-free EEG systems can offer comparable signal quality with faster, more straightforward setup and better comfort (Di Flumeri et al., 2019). Recent developments have led to the creation of wearable, wireless, flexible EEG devices that maintain high signal quality while being discreet and minimally invasive, making them suitable for everyday use (Sciaraffa, 2022; Guermandi et al., 2018; Celik, 2017). However, wearable EEG devices still lag behind other wearable technologies, with challenges in balancing comfort, usability, aesthetics, and adaptability for long-term home-based monitoring (Jamil et al., 2021). These challenges prompted a multidisciplinary team from the University of Florence and Meyer Children's Hospital in Florence to develop a next-generation wearable EEG device designed to meet the needs of both patients and healthcare professionals. The main objective of this research was to optimise the EEG monitoring system and improve the overall experience for patients and medical staff by developing a new wearable medical device for EEG monitoring

in both hospital and home settings. Specific objectives included: (i) analysing the human-device interaction in paediatric EEG monitoring; (ii) identifying needs, workflow issues, and innovation opportunities; (iii) evaluating the effectiveness and usability of current EEG devices; (iv) defining the requirements for a new EEG device. The following outlines the applied methodology and the most significant findings of the research.

Methodology

In healthcare, many medical devices focus primarily on technical and regulatory aspects, often overlooking patient and staff needs. This lack of attention to human factors can lead to usability issues and user errors (Iacono et al., 2019). A design approach that considers the context of medical devices, phases of care and workflow is needed to address these challenges. The research at Meyer Children's Hospital in Florence applied Human-Centred Design and User Experience principles to improve the human-device interaction in EEG monitoring systems.

The study, developed in multiple phases, included field investigations and the involvement of various stakeholders (doctors, healthcare professionals, neurophysiology technicians, and biomedical engineers) who interact with the EEG monitoring service, particularly those using EEG devices in paediatric settings. The focus was placed on their needs and expectations, as well as the expertise and perspectives of professionals involved in the planning and designing of such products/services. The research precisely followed these operational phases:

- Phase 1: Literature review and benchmarking analysis;
- Phase 2: Evaluation of current EEG systems;
- Phase 3: Data analysis;
- Phase 4: Development of design concepts and intervention scenarios.

Literature review and benchmarking analysis

In the initial phase, the study involved a review of the literature related to the research topics to outline the relevant scientific background. The research was conducted on major platforms such as Google Scholar, PubMed, and ResearchGate, using the following search strings to identify relevant scientific articles: TITLE-ABS-KEY (“EEG Device”, “wearable device”, “Paediatric neurophysiolo-

gy", "medical device", "EEG technology", "emotional impact EEG"). It allowed the selection of national and international key research contributions that were most relevant to the study. In parallel, a benchmarking analysis was carried out, enabling the research team to examine various types of EEG devices available in the target market from functional, technological, and morphological perspectives. This analysis also included assessing each device's application areas (Soufineyestani et al., 2020) and understanding their operating principles. The main findings from this phase were summarised in data sheets (see Fig. 1), facilitating the subsequent research phases.

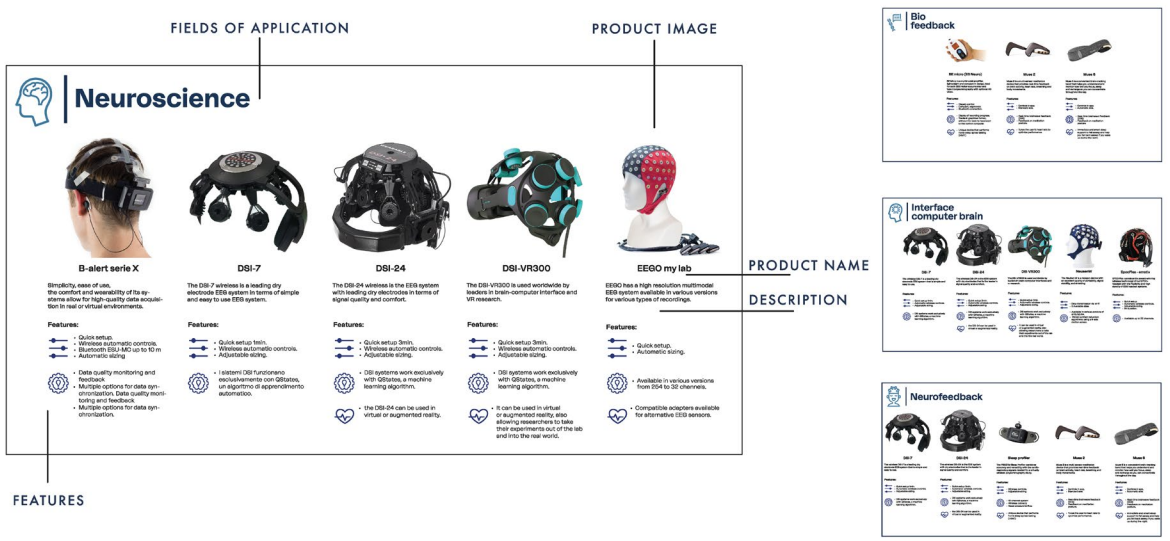


Figure 1. Visualization of the structure of the summary sheets developed for different types of EEG devices on the market, based on six application areas identified in the literature (Neuroscience, Biofeedback, Ergonomics and Biometry, Computer Brain Interface, Neuromarketing, Neurofeedback).

Evaluation of current EEG systems

Building on the involvement of healthcare professionals and patients, the subsequent phase of the research focused on evaluating the EEG monitoring service and the equipment used in the paediatric units. The primary aim was to assess the usability of the current EEG devices. To achieve this, the research team employed a combination of observational and participatory methods, which provided valuable insights into the overall user experience. The methods used included:

- *Direct User Observations* (Stanton et al., 2014). Observations were conducted during all operational steps before, during, and after the EEG monitoring process in the clinical setting. The actions performed by patients (ages 6-14), parents, and healthcare personnel were filmed, photographed, and documented to capture their thoughts, feelings, and behaviours. This observational data helped to better understand the users' experience, identifying pain points and emotional responses, which are crucial for redesigning the device to improve usability.
- *Semi-Structured Interviews* (Wilson & Sharples, 2015). Interviews with healthcare experts and professionals provided deeper insights into the operational activities, revealing unexpressed needs, challenges, and information about the interaction between users and the product/service. These discussions enriched the overall analysis and pointed out areas where improvements could be made to enhance the user experience.
- *Questionnaires* (Wilson & Sharples, 2015). A set of questionnaires was distributed to neurophysiology technicians, neurologists, and paediatric epileptologists at Meyer Hospital, as well as professionals from other national and international institutions. The survey included Likert-scale questions (5 points) and open-ended questions to gather feedback on user satisfaction and opinions regarding various aspects of the EEG monitoring process. The responses provided valuable quantitative and qualitative data that informed the design considerations for the new EEG device.
- *Personas*, *Scenarios* (Hanington & Martin, 2019) (see Fig. 2) and Task Analysis (Tosi, 2020). These tools were pivotal for analysing the activities of healthcare operators in the paediatric units. Storyboards were used to visualise the operational phases of EEG monitoring, identifying potential issues in the interaction between the users and the product. This method helped to better define the users' needs and expectations, ensuring a comprehensive design approach.
- *User Journey Maps* (Hanington & Martin, 2019) (see Fig. 3). These maps helped visualise the users' actions, emotions, and perceptions during their interaction with the EEG device. They provided a clear picture of weak points in the current system and highlighted opportunities for improving the user experience. By identifying pain points, the team was able to determine key areas for optimisation in the design process.

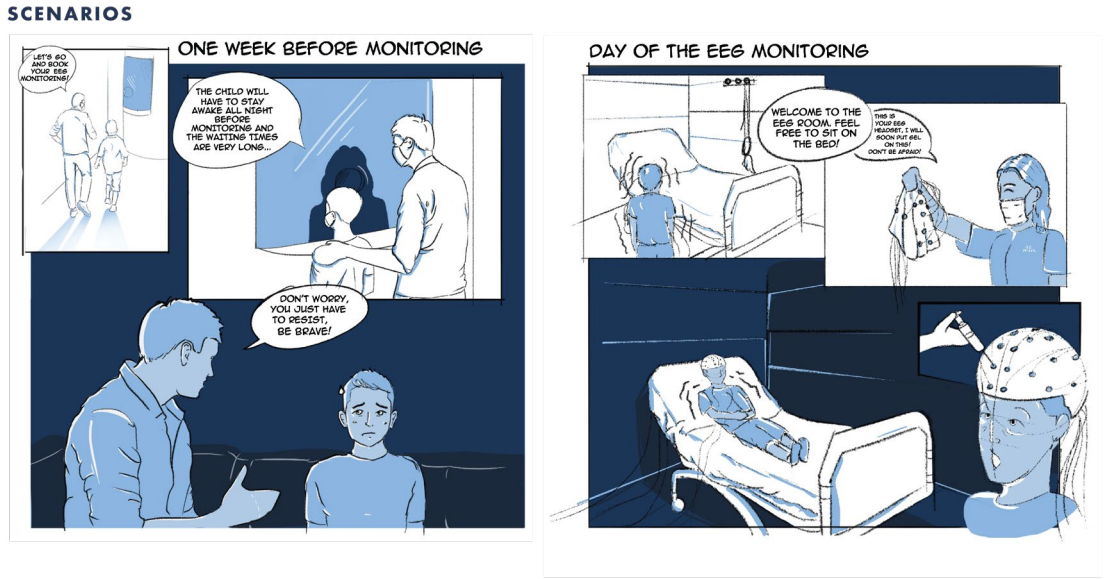


Figure 2. Scenario of some EEG monitoring phases within the paediatric hospital.

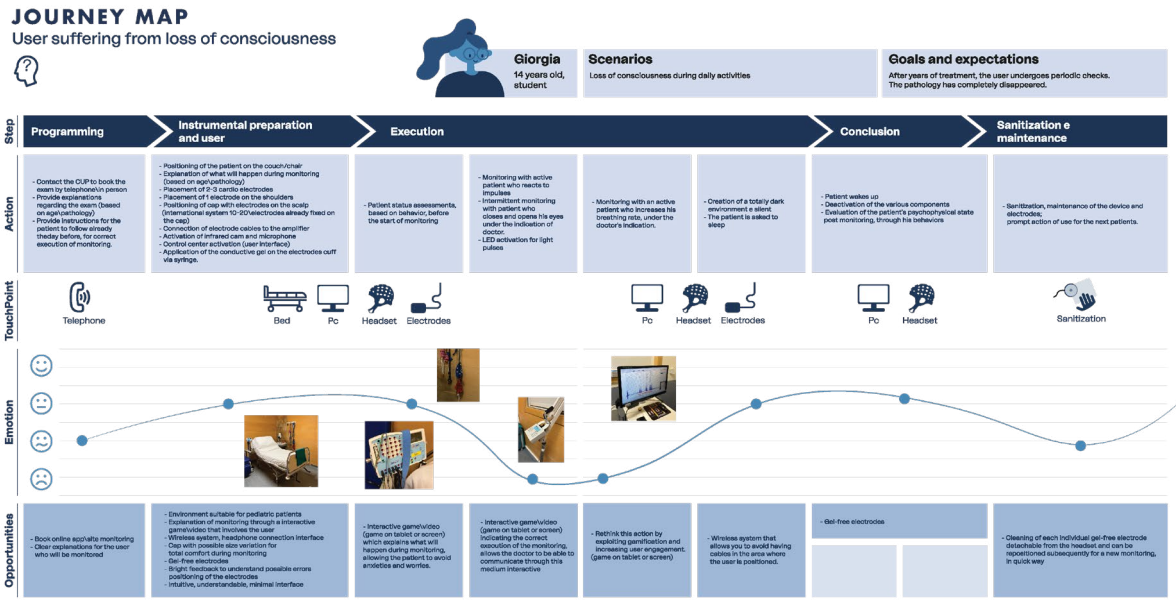


Figure 3. An example of a User Journey map relating to a patient suffering from loss of consciousness during daily activities, developed by the team.

These integrated methods not only allowed for a thorough understanding of the challenges faced by users but also provided a strong foundation for the redesign of the EEG monitoring system, ultimately aiming to create a device that meets the needs of both patients and healthcare providers.

Data analysis

As The data collected in the previous phase proved essential in identifying critical issues within the EEG monitoring workflow and outlining new requirements and innovation scenarios. One of the core challenges in the design process is accurately determining the proper requirements to address the identified problems. Thus, data collection aims to gather sufficient, relevant, and actionable information that can form a solid foundation for developing the system's specifications.

Data from interviews, questionnaires, and direct observations were systematically analysed and synthesised into maps and diagrams. These visual tools helped highlight the research's critical areas and essential system requirements. Additionally, to enhance the clarity and interpretation of the questionnaire data, the results were presented in graphical form, displaying the percentage distribution of user responses. This approach allowed for a more intuitive understanding of the data and facilitated the identification of patterns, preferences, and issues that required attention. Through this comprehensive analysis, the research team was able to pinpoint specific pain points in the EEG monitoring process, which ultimately informed the design of the new device, ensuring it addressed the real needs and expectations of both patients.

The data collected during the investigation phase played a crucial role in assessing the critical issues and defining the requirements for the new EEG monitoring device. The evaluations focused mainly on (a) the product's dimensions, functionality, and usability and (b) cognitive and emotional aspects related to service management and user interaction with the product.

In general, within the neurophysiology department, critical issues emerged regarding the bulkiness and excessive number of cables connecting to the patient, which made the examination uncomfortable and unfamiliar, especially during sleep monitoring. Additionally, the current use of the gel-based electrodes and cap is unpleasant to the touch, leaving the user with a wet sensation. The system often

appears unattractive and generates anxiety and fear in patients.
Beyond the general discomfort reported by patients and their families, healthcare providers also encountered difficulties, particularly with placing electrodes on the scalp, due to a lack of feedback from the device. Based on these challenges and others identified during the analysis, specific objectives and new requirements were defined and subsequently incorporated into the design of the Cosmo+ EEG monitoring device.

Development of design concepts and intervention scenarios

The final phase of this research focused on formulating and developing new design solutions. These solutions mainly focused on enhancing usability and addressing the emotional impact on users. A key element in this phase was the use of design-orienting scenarios, which enabled the development of innovative ideas tailored to all users' needs. This approach provided a strategic vision for the team regarding the potential development of a more user-friendly and familiar wearable EEG monitoring system. The following outlines the main results of the research.

Results

The new Cosmo+ EEG system

Cosmo+ is designed to diagnose and monitor brain activity anomalies in paediatric patients, such as detecting and managing seizures, monitoring wakefulness and sleep, and identifying brain dysfunctions. The primary goal of this device is to ensure long-term monitoring, even outside the hospital setting, such as in a home environment, making the technology more accessible and more comfortable to wear while also being highly emotionally acceptable. Key aspects that guided the design process were *user-friendliness*, *versatility*, and *modularity*.
Cosmo+ features three modules that can be placed on various areas of the scalp—frontal, occipital, parietal, and temporal lobes. This configuration allows for more accurate analysis and recording of electrical activity and provides a more comfortable and familiar system for both the patient and healthcare personnel.
Cosmo+'s *modularity and versatility* allow users to monitor specific areas of the scalp based on their needs and the doctor's instructions (see Fig. 4). For example, the first module, with dry electrodes placed

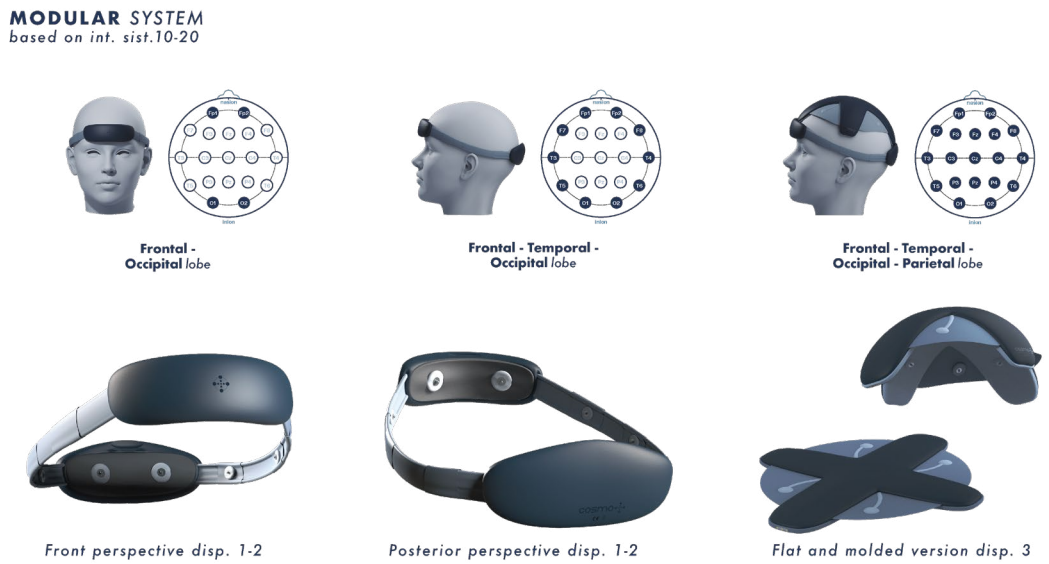


Figure 4. Modular Cosmo+ system, positionable at various points of the international 10-20 system.

on FP1 and FP2 of the 10-20 international system, enables monitoring of the frontal lobe activity, which is involved in higher cognitive functions such as executive control, planning, emotion regulation, and more. The second module, positioned on the O1 and O2 points of the 10-20 system, tracks the occipital lobe's electrical activity, primarily responsible for vision and visual processing. When used together, the two modules monitor the temporal lobe, which is involved in functions like memory, hearing, language, and facial recognition, through elastic bands placed on points F7, F8, T3, T4, T5, and T6.

The third module, placed on points F3, Fz, F4, C3, Cz, C4, P3, Pz, and P4, allows monitoring of the parietal lobe, which handles various cognitive functions such as sensory processing, spatial perception, attention, and working memory. These three modules, equipped with dry electrodes, are interconnected with adjustable elastic bands to accommodate the size of the scalp. Using dry electrodes eliminates the need for conductive gel, simplifying the procedure and enhancing comfort.

Moreover, the absence of connecting cables around the patient ensures accurate and reliable measurements, preventing movement artefacts. The dry electrodes detect electrical impulses and transmit them to an amplifier, which sends the brainwave signals to a com-

puter to visualise EEG tracings. The system also includes a physical interface with two different LED feedback (green and red) indicating correct or incorrect electrode placement, ensuring high usability and perceived reliability.

Cosmo+ is *portable, easy to use, and compatible with telemedicine services*. It enables home monitoring, storage of EEG traces, and real-time transmission of results to medical specialists via an app available for smartphones, tablets, and computers (see Fig. 5). It could positively impact the management of EEG monitoring services, optimising specialists' workflow, reducing patient wait times, and minimising department overcrowding.

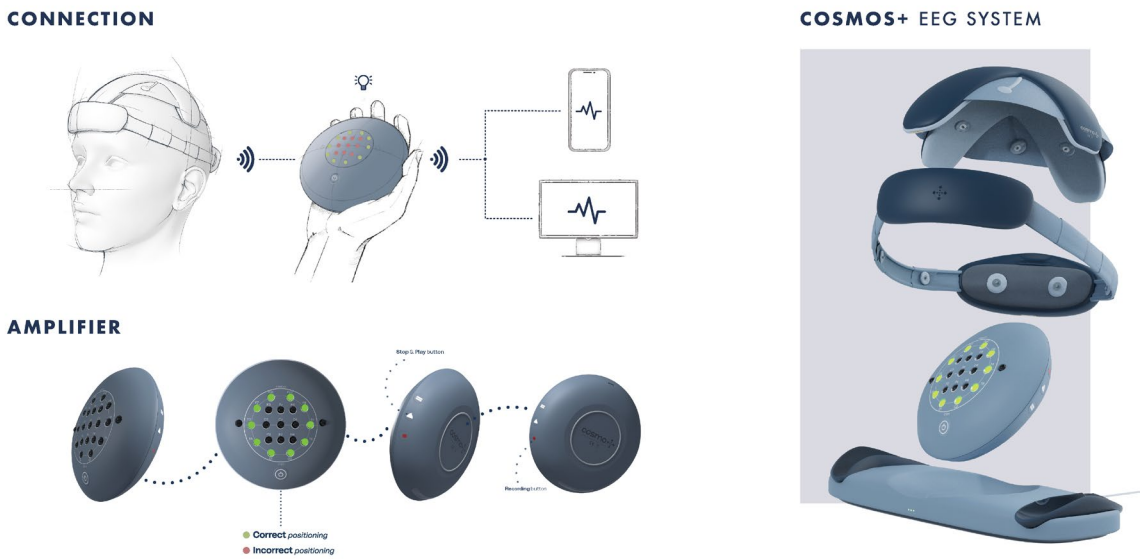


***Figure 5**. Ease of use of the device through light feedback (green or red) and the wireless connection of the Cosmo+ system via applications and external devices.*

From a morphological standpoint, the device's sleek design, colour choices, and finishes ensure better interaction with young patients, minimising negative impact and promoting a sense of calm. The use of Medical Grade materials, such as Tecafine PP for devices 1 and 2, medical-grade silicone for device 3, and Memory Foam padding, enhances the system's suitability for medical applications, ensuring excellent sterilisation, lightness, comfort, sensor wearability, and adaptability to the scalp.

Discussion and conclusions

The Cosmo+ concept represents a promising step forward in neurophysiology, introducing innovative ideas that redefine the design and functionality of EEG monitoring devices. The research focused on the device's usability and morphology, aiming to create a more user-friendly solution adaptable to the needs of patients and healthcare providers. Cosmo+ stands out for its modular system, which allows for personalized use based on specific clinical needs, and its light feedback system, which ensures an intuitive and hassle-free interaction. The dry electrode technology and the ability to connect to external devices via apps allow for overcoming the limitations of traditional hospital devices, offering continuous, remote brain activity monitoring, both in the ward and at home (see Fig. 6).

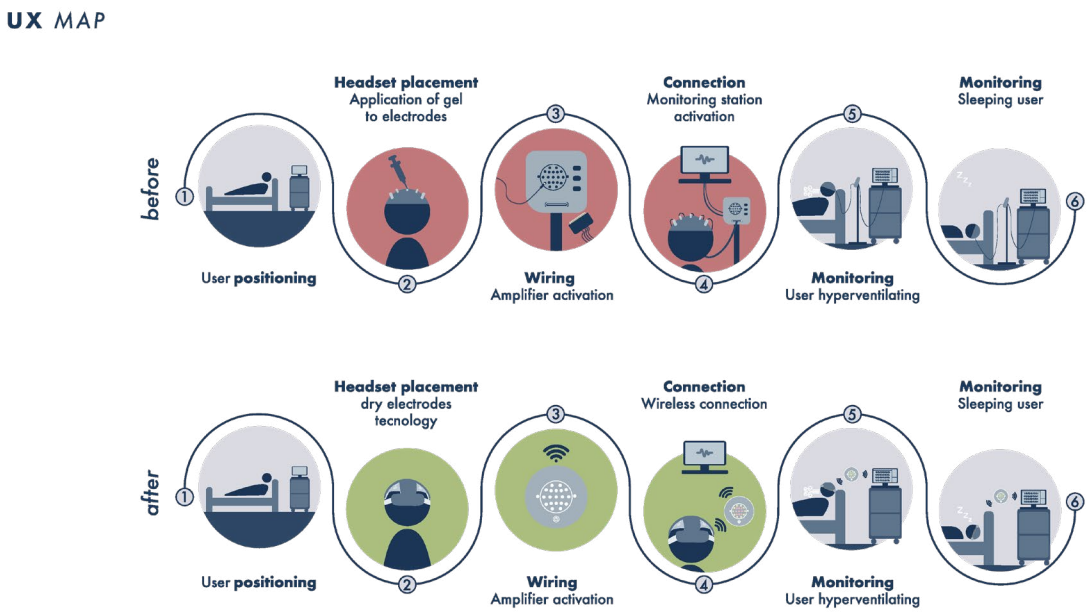


Figure 6. EEG Monitoring UX Map: Visualization of the activities planned for EEG monitoring before and after the design of Cosmo+.

In particular, Cosmo+ opens new perspectives in the field of EEG homecare, a sector that has the potential to transform the management of neurological and psychiatric disorders radically. Thanks to the possibility of continuous monitoring, improved comfort for patients, reduced costs related to hospital stays, and personalized treatment,

Cosmo+ could become a key tool in providing more accessible and less invasive healthcare. Home-based monitoring, for example, would allow patients to remain under observation continuously, avoiding long waits and frequent trips to the hospital, positively impacting both the psychological well-being of patients and the efficiency of healthcare services.

However, despite the clear advantages and innovative potential, there are still challenges to overcome to ensure the long-term success of this system. First, it is essential to guarantee the accuracy and reliability of the data collected by the device, preventing errors that could compromise diagnosis and treatment. Additionally, protecting privacy and securing sensitive data are crucial issues in a medical and digital context, requiring advanced cybersecurity solutions. The economic accessibility of the device represents another significant challenge, as the technology can be genuinely helpful to all population segments, including those with limited financial resources.

Looking to the future, Cosmo+ is not just a prototype intended for technological improvements but a continuously evolving system. Future iterations of the device could enhance its technical capabilities and integrate new forms of interaction, such as gamification, to make monitoring more engaging, particularly in the paediatric setting. By introducing interactive games or visual incentives, younger patients could be encouraged to cooperate actively during monitoring, improving the user experience and the accuracy of the collected data.

Furthermore, the introduction of augmented reality (AR) and virtual reality (VR) could be an additional step forward in the evolution of Cosmo+. These technologies could be used to visualize EEG data in real time or to create immersive environments that reduce patient anxiety during monitoring, especially in the paediatric setting. Adopting artificial intelligence for automatic EEG data analysis could make the system even more precise and responsive, enabling real-time monitoring and diagnosis of abnormalities without needing for constant human intervention.

Therefore, Cosmo+ has the potential to evolve not just as a monitoring device but as a digital healthcare ecosystem that adapts to the needs of patients, healthcare providers, and healthcare systems. With the introduction of new technologies and continuous improvements in user interfaces, the future of Cosmo+ appears rich in opportunities to revolutionize neurophysiology and expand accessibility to neurological and psychiatric treatments.

Future research activities will focus on developing functional prototypes to facilitate the transition from concept to realization and to validate the feasibility of the design and technology. This phase will be followed by usability and field tests conducted in clinical and home environments to evaluate the system's performance and reliability. Data collected from real-world use cases will then be observed and analysed to refine the device's functionality and enhance the user experience. Lastly, the focus will be on refining the system's engineering to enable scalable production while maintaining high quality and cost-efficiency standards.

Acknowledgements: The authors thank the medical staff of the Meyer Children's Hospital in Florence, in particular, Prof. Renzo Guerrini, Dr. Katia Romano, Dr. Martina Giudice and Nicola Rizzo (CTO of Micromed group).

Author Contributions

Conceptualization, E.I. and F.T.; methodology, E.I. and S.A.D.; infographics, rendering and data curation, S.A.D.; writing–original draft preparation, E.I.; writing–review and editing, E.I. (all sections except "The new Cosmo+ EEG system") and S.A.D.; Supervision, F.T, E.I. and C.M. (technical part). All authors have read and agreed to the published version of the manuscript.

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ESTER IACONO

PhD in Design, she is a research fellow and adjunct professor of the course "Design and Ergonomics for Communication and Services" at the Department of Architecture of the University of Florence. Since 2017, she has been researching at the Ergonomics & Design Laboratory (LED) on topics related to Emotional Design in the health sector, Human-Centred Design/User Experience, Interaction Design, Ergonomics for Design, Design for Healthcare and inclusion. She has participated in national and international research projects and collaborated in research programs funded by the EU, public administrations and public and private companies. She is also the author of articles and essays published in national and international scientific journals and proceedings conferences.

SALVO ANDREA DENARO

Industrial designer and research grant at the University of Florence. He has participated in national and international conferences and collaborated on a project, involving physicians and neurophysiopathology technicians from various Italian and international hospitals, to develop a concept for a next-generation paediatric electroencephalography (EEG) device based on Human-Centred-Design (HCD) approach.

He is currently working as a research grant, at the Ergonomics & Design (LED) laboratory, in the field of ergonomics, HCD methodology and medical devices. He is also a tutor for the course “Laboratory of Design & Ergonomics - Product”.

CLAUDIO MONDOVECCHIO

Since 1999, he has worked in clinical engineering in several public hospitals, following specific projects, procurement planning, and supervising services related to electromedical and laboratory equipment. He has collaborated with the School of Engineering of the University of Florence, accompanying future engineers during their training. Currently, in the Meyer Children’s Hospital (Irccs), he supports the continuous renewal of equipment and the introduction of new technologies by verifying their actual usability, from the preliminary assessment to their best use during their entire life cycle with HTA methodology, supporting accreditation processes and clinical trials.

FRANCESCA TOSI

Francesca Tosi, Architect, is Full Professor of Industrial Design at Department of Architecture - DIDA, University of Florence. She develops her research and didactic activities in the

fields of Product and Interior Design, Human-Centred Design/ User Experience and Inclusive Design, in particular on: daily use products and environments, and products and services for health and care. On the same subjects: she is author of books, essays and articles, she organized conferences and events, and she was/is scientific responsible of research funded by European Union, Italian Ministry of University, Ministry of Labour and Social Policy, and by public administrations and private companies. Since 1996 to 2007 she was Assistant and, then, Associate Professor at the Faculty of Design of Politecnico di Milano. Since November 2007 she is Full professor at the Faculty of Architecture of University of Florence. Currently she is: past-President (President since 2010 to 2018) of SIE, Italian Society of Ergonomics and human factors; President of CUID Italian Design Academic Conference (since 2018).

Enhancing Hospital Navigation through Gamification: The “My Meyer” App at Meyer Children's Hospital

ESTER IACONO[1], VIRGINIA PIOMBINO[1], CLAUDIO MONDOVECCHIO[2]
[1]Laboratory of Ergonomics and Design (LED), Department of Architecture, University of Florence, ITALY
[2] AOU Meyer, Firenze, ITALY

Keywords: In-hospital wayfinding; Human-Centred Design, User Experience, UI App mobile, Gamification in hospital.

Abstract

Navigating within hospitals, especially paediatric ones, represents a complex challenge for patients and their families. This study explores the implementation of gamification in hospital wayfinding systems, aiming to enhance user experience and reduce the anxiety associated with moving through maze-like environments. Through research conducted at Meyer Children's Hospital in Florence, the Ergonomics & Design Laboratory team from the University of Florence developed “My Meyer”, a mobile app that integrates navigation, booking, and entertainment functions. The application offers an intuitive and customizable interface, with game modes for paediatric patients and optimized routes for parents. The results highlight the benefits of a human-centred approach, based

on game design elements, to facilitate navigation and improve patients' physical and psychological well-being. Future developments suggest extending these solutions to the entire hospital structure, creating an inclusive and welcoming environment.

Introduction

Navigating complex indoor environments can be challenging. The wayfinding challenge intensifies in spaces characterised by maze-like corridors and anonymous, crowded areas. In such contexts, where visibility is limited and spatial variability is high, the absence of advanced mobile tools for orientation necessitates innovative approaches to facilitate spatial comprehension and exploration, reducing users' anxiety.

In this scenario, gamification emerges as a promising solution. Integrating game elements into non-gaming contexts makes the orientation experience more intuitive and promotes greater user participation and engagement (De Leeuw et al., 2020). This strategy, which combines technology with game dynamics, opens new perspectives for improving indoor wayfinding. In particular, the application of gamification in paediatric hospital settings has gained increasing attention for its potential to enhance the patient experience, simplify navigation, improve healthcare management, and relieve the stress and anxiety associated with medical visits. Hospitals, often complex and disorienting, can generate fear, anxiety, and cognitive stress, impeding users' understanding of the environment and decoding informational signals (Pilozzi & Torresan, 2019). Disorganised spaces and inadequate wayfinding systems amplify patients' and families' anxiety and sense of disorientation, compromising emotional well-being (Harper et al., 2020).

Implementing wayfinding systems that simplify navigation, communicate clear messages, and make the environment more welcoming and reassuring is essential to address these difficulties, particularly in helping children identify their location (Lambert et al., 2014). An interdisciplinary approach integrating semiotics, cognitive psychology, and design allows for creating intuitive pathways using visual cues such as shapes, colours, and lights, enhancing the hospital experience (Dalke et al., 2006).

In recent years, integrating mobile apps and interactive systems has improved orientation, communication, and personalised care (Smolenaers et al., 2019). Several studies show that gamification makes

the hospital environment more welcoming and intuitive, facilitating wayfinding in complex spaces and creating an inclusive, reassuring atmosphere. In addition to encouraging adherence to healthcare procedures, gamification enhances patients' physical and psychological well-being and the overall quality of care (De Leeuw et al., 2020). Game design elements engage users and encourage positive behaviours (Deterding et al., 2011), increasing patient engagement and making interaction with services more satisfying (Hamari et al., 2014). In practical terms, these solutions include apps that guide patients through the facility while offering entertainment and learning opportunities. Augmented reality, for example, can transform a potentially monotonous care journey into an interactive experience, reducing anxiety and improving waiting times. Additionally, gamification simplifies access to information on appointments and procedures, empowering patients to actively manage their care journey (Schunk & Zimmerman, 2008).

The study conducted by the Ergonomics & Design Laboratory at the University of Florence at Meyer Children's Hospital in Florence analysed the use of gamification in paediatric hospital wayfinding systems. The research explored innovative strategies and technologies to improve patient's well-being and autonomy, offering design solutions based on a human-centred approach. In particular, the study examined how game design and communication design can support wayfinding, entertainment, and service management, highlighting benefits for patients and families and, importantly, fostering the community's sense and support among healthcare staff.

Case Study AOU Meyer

The context of this research is the Meyer University Hospital in Florence, a nationally recognised paediatric hospital. Founded in 1891, it offers highly specialised treatments to a large population, with approximately 250,000 children in the Florentine area and over 600,000 in the entire region. With over 7,000 annual surgical interventions and 610,000 outpatient services, Meyer combines high specialisation and a humanised environment, including a hospital school and socialisation services. The structure, which combines historical and modern sections, presents logistical and orientation challenges related to its architectural heterogeneity. Therefore, the main objective of this research was to provide an effective navigation service regarding the Meyer Medical Day Hospital, which pro-

motes autonomous orientation and optimisation of the hospital users' experience in terms of time and psycho-physical well-being.
The specific objectives include: (i) analysing the navigation space and the human-environment interaction; (ii) identifying the users' needs and the critical issues in the navigation flow; (iii) evaluating the effectiveness and usability of the current orientation system; (iv) defining the requirements for a new orientation system; (v) developing ways of involving and entertaining patients while ensuring the autonomy of guardians in managing health services.
The final goal was to ensure smooth and informative navigation that integrates entertainment and utility, creating a more welcoming and reassuring hospital environment for everyone.

Methodology

The research involved the application of theoretical and methodological tools deriving from Ergonomics for Design (Tosi, 2020), Human-Centred Design (HCD) (ISO 9241-210: 2019) and User Experience (UX) (Garrett, 2010) to develop design solutions to improve the orientation system in the paediatric hospital setting. The research project was divided into several phases and included field surveys involving healthcare workers in the Day Hospital service. Particular attention was paid to the needs and expectations of patients and the skills and opinions of professionals engaged in communication.
The operational phases of the research were the following:

1. Preliminary study and literature review;
2. Evaluation of the current orientation system;
3. Processing and synthesis of collected data;
4. Development of the design concept.

Preliminary study and literature review

In the initial phase of the study, a literature review was conducted to define the scientific context of reference, using platforms such as Google Scholar, PubMed and ResearchGate with the following search strings: TITLE-ABS-KEY (“Hospital Wayfinding”, “Navigation Application”, “Paediatric Hospital”, “Gamification-Based Approach”). This review allowed us to identify the most significant contributions to hospital orientation and navigation systems. In parallel, a benchmarking analysis of wayfinding and intra-hospital navigation systems was carried out, examining pictograms and technologies currently available, such as Bluetooth beacons, indoor GPS systems

and mobile applications. The use of gamification in educational and healthcare contexts was also explored, analysing interactive systems and technologies, including apps and serious games, to improve user orientation and entertainment. Existing applications that implemented gamification in wayfinding were evaluated, highlighting positive results in terms of engagement and satisfaction. This phase led to the structuring of two categories of case studies:

- Cases selected based on specific indicators emerging from the literature regarding structural requirements, interaction with the environment and typographic choices in paediatric hospitals, both at the national and international levels (see Fig. 1).
- Cases selected based on Game Design elements identified in the literature (see Fig. 2).

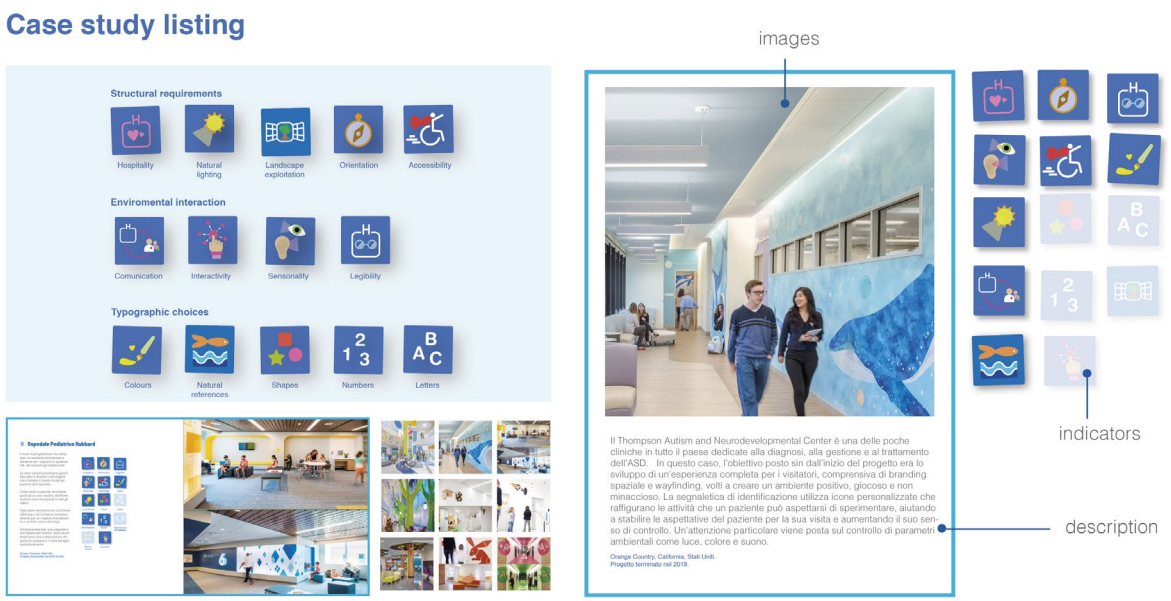

Figure 1. Example of organizing selected case studies according to specific indicators—structural, environmental, and typographical—identified through literature analysis.

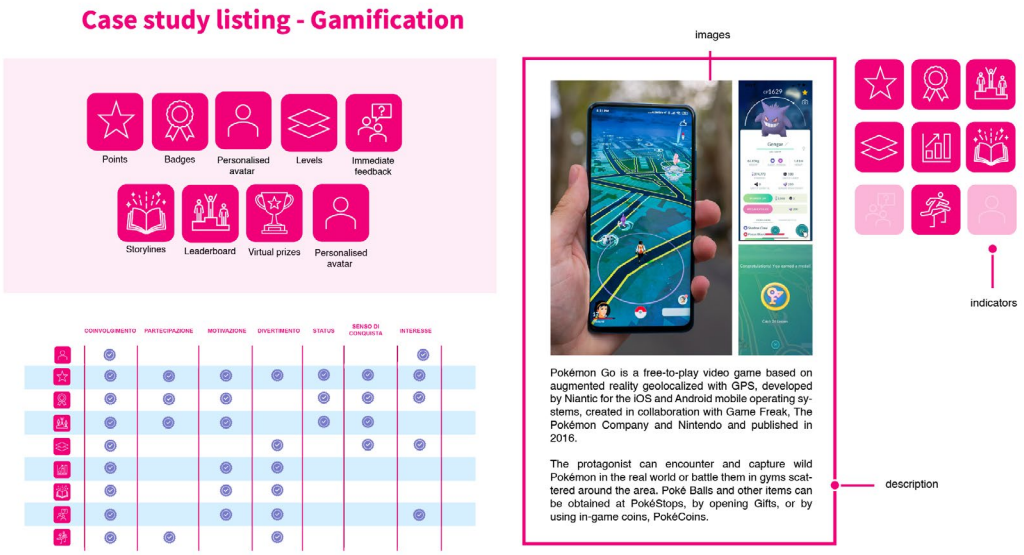

Figure 2. Example of organizing selected case studies based on Game Design elements identified in the literature.

Evaluation of the current orientation system

After phase 1, field surveys were conducted with industry professionals (engineers, architects) and healthcare workers (doctors, nurses), using Human-Centred Design (HCD) and User Experience (UX) methodologies. These approaches allowed us to examine users' paths, needs and requirements and to evaluate: a) functionality and usability of the orientation system; b) perceptive aspects related to the interpretation of space; c) cognitive and emotional aspects related to the management of the Day Hospital. The activities carried out include:

- *Direct observations* (Stanton et al., 2014) on patients, parents and healthcare personnel in the real context of the Medical Day Hospital to analyse users' behaviours, thoughts and emotions during the orientation process, providing valuable information for the system's redesign.
- *Architectural surveys* of floors 0 and 1 of the Meyer Children's Hospital to map the entire structure and analyse navigation paths and flows from entry to discharge. This activity facilitated the simplification of the floor plans and the collection of photographic material of elements and reference points useful for creating cognitive maps.

- *Semi-structured interviews* (Wilson & Sharples, 2015) with experts and professionals in the sector, which enriched the analysis of the activities, bringing out critical issues and unexpressed needs, and collecting information on the interaction between the user and the environment.
- *Personas*, *Scenarios* (Hanington & Martin, 2019), and *Task Analysis* (Tosi, 2020) (see Fig. 3) were created to analyse and design the new orientation system. These tools allowed for the representation of users' and operators' activities through storyboards, analysis of the operational phases of the Day Hospital, and identification of problems in the interaction with the environment.

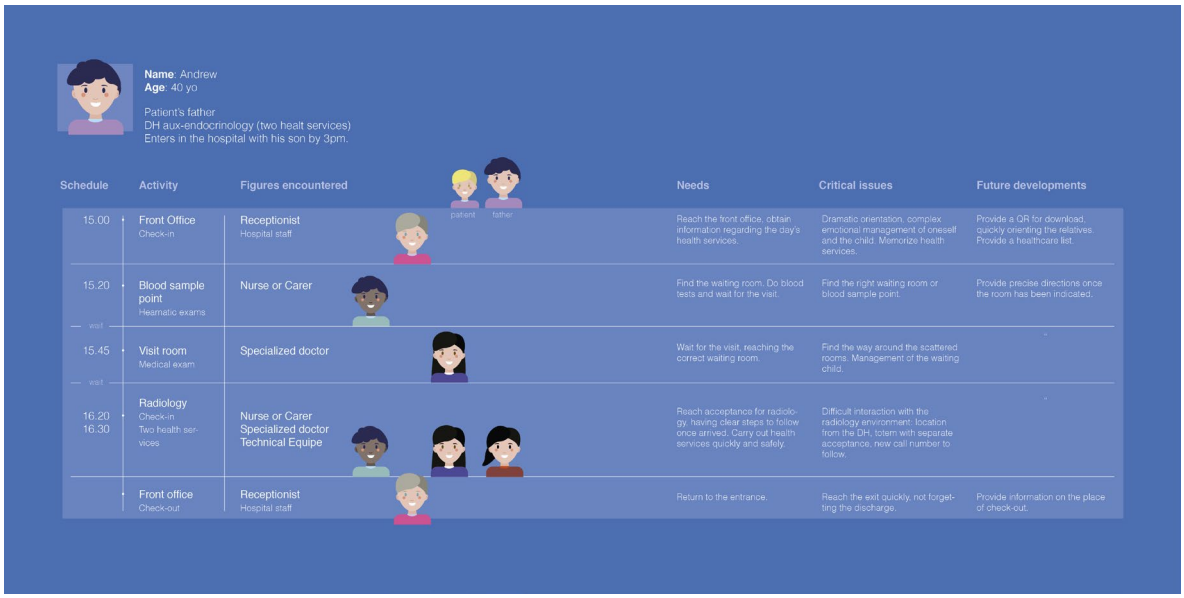

Figure 3. An example of a Task Analysis focused on the wayfinding experience of a patient's parent in a Day Hospital.

Data Synthesis and Concept Development

The data collected were essential to identify the main problems of orientation in the hospital and define new requirements and innovative scenarios. The field investigations produced a clear set of requirements, represented in maps and diagrams, including design indicators to overcome perceptual barriers, functional requirements for the mobile app and key routes for the medical day hospital. In the final phase of the research, based on the problems that emerged,

design solutions focused on usability and user experience were developed through the use of *design-orienting scenarios* (Manzini & Jégou, 2004) and focus group and brainstorming sessions to verify and refine the functionalities of the new orientation system.

Results

Analysis of issues and requirements for the new app

Field investigations have highlighted considerable disorientation among patients and their companions, who often turn to healthcare personnel for directions. The hospital structure, divided between historic and modern buildings, has complex routes and a lack of clear and coherent signage, making it challenging to locate areas such as elevators and departments and forcing patients to walk through the garden even in bad weather. The services of the Day Hospital, distributed over several floors, require frequent returns to reception to receive information. Furthermore, the lack of staff dedicated to supporting foreign or visually impaired patients, combined with the absence of entertainment spaces for children, exacerbates the difficulties. For example, in the "cow corridor", children often do not understand the artistic value of the sculptures and climb up them. Even the information totems and payment stations for services are positioned far from the examination rooms, causing delays in discharge procedures. The analysis of these critical issues provided the basis for defining the requirements of a mobile app designed to improve patients' orientation and overall experience within the hospital. The main requirements are:

- *Simple and accessible interface for all users*, with clear communication of the routes, real feedback on the reference points and diversified content views for specific categories of users.
- *Inclusion and involvement of companions* even in services that by regulation prohibit their access together with the patient, using new forms of communication, and respecting the privacy of the child.
- *Complete management of medical services*, such as booking, payment, modification, information to the patient before the visit (e.g. pre-sampling fasting) and directions to the examination rooms.
- *Educational entertainment for patients* during waiting times through the application of the 9 game design elements (points,

levels, badges, avatars, progress bars, feedback, storyline, leaderboard, rewards) identified in the literature and in the mobile apps studied and based on Skinner's (2014) reinforcement theories.

My Meyer App

The collected data inspired the development of "My Meyer", an app downloadable at the hospital entrance, which connects directly to the Single Booking Centre (CUP 2.0) through a quick scan of the patient's health card barcode. The app was designed with three core functions: navigation, booking, and entertainment.

The app includes a digital map with the main reference points that users can trace directly in the architectural space and a reserved area for booking and managing the clinical dossier, even remotely. Specifically, for developing the app's User Interface (UI), aspects such as displaying content and choosing paths, the layout and wireframe, and the UI interaction styles for specific categories of users were considered. In particular, the main screen (Home) summarises the main features of the app: (a) a search bar, (b) a "profile" section, (c) proposed routes and departments, (d) a lower menu with four icons, including (e) the "map" (see Fig. 4). The interface, entirely customisable, offers three different graphic themes, each with a mascot that accompanies and supports families, reducing the feeling of confusion and loneliness. The graphic variants differ in the colour palette but maintain a pictogram language and a uniform structure. From the "Home", searching for destinations by doctor name, room number, or floor or selecting them directly from the hospital map is possible. An innovative aspect of the app is the double navigation (see Fig. 5): a "parent" mode focused on efficiency in completing activities in the shortest possible time and a "child" mode that empowers and entertains the patient through a gamification process. This last mode includes several game elements (see Fig. 6), such as:

- *points* accumulated as they complete activities and reach goals.
- *badges* earned for reaching specific milestones, such as discovering the "Meyer treasure".
- *personalised avatar* representing the child in the game.
- *progress bars* indicate how far away they are from completing an activity or reaching a goal.
- *immediate feedback* to provide real-time information to parents and patients on the position and steps to take.

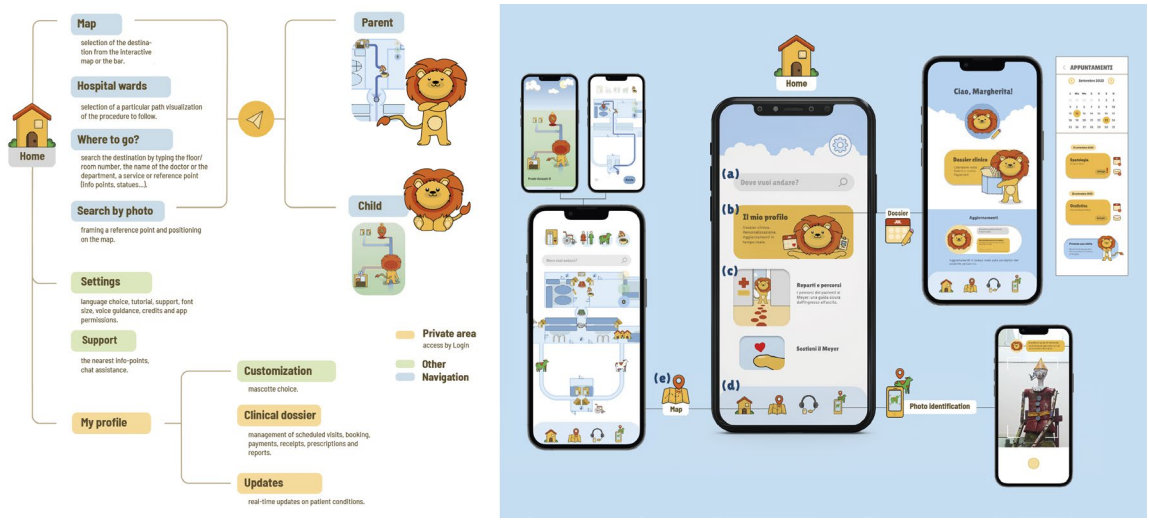

Figure 4. Main features of the 'My Meyer' application: Key functions and connections between the Home, Navigation Maps, Patient Clinical File (accessible via login), and Photo Recognition of spaces.

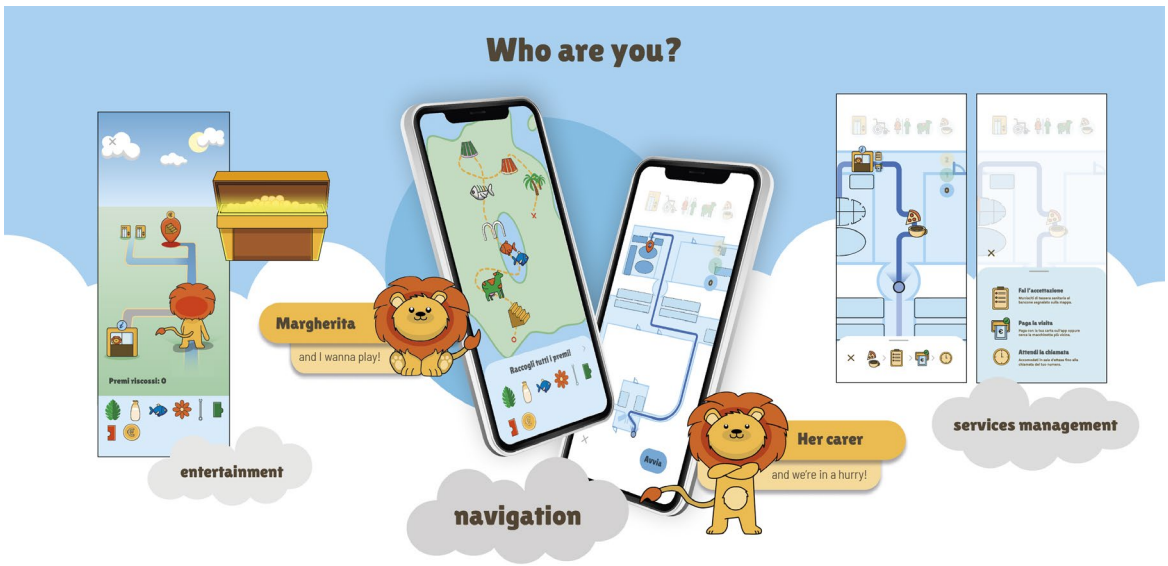

Figure 5. The two navigation options: a prize-based adventure for the child, guiding them along the route (left), and a classic view for the carer, displaying the paths on a planimetric map of the hospital section (right).

Figure 6. Game elements featured in the My Meyer app.

- *storylines* that propose an adventure and a more immersive experience capable of making the patient responsible.
- *virtual prizes* for completing activities.

On the other hand, parents are offered the shortest routes, which can be modified by adding services (the hospital bar, toilets or elevators) and displaying the various steps to be taken, such as paying for the visit or being discharged.

The reserved area, accessible by scanning the health card barcode, allows users to view their clinical dossier and fully manage bookings, changes, payments, and reminders of medical services. By selecting a scheduled service, navigation to the destination is automatically started. There is also an "updates" section for companions who cannot access sensitive areas of the hospital, where real-time information is provided on the patient's location and services without specifying the outcomes in compliance with privacy.

Furthermore, considering aspects of inclusion related to the presence of users with sensory fragilities and from different cultures,

the app includes accessibility tools such as voice guides, choice of languages, and editable text size. The “support” section of the app offers helpful information, such as wheelchair collection and elevator location, to provide practical support. In case of loss or technical problems, a “photo recognition” function is available, which, via the camera, identifies the patient's location in the hospital by framing some reference points.
“My Meyer” offers a patient-centred experience, combining efficiency, entertainment, and safety to improve patient orientation in the hospital.

Discussion and conclusions

The research confirmed that communication artefacts in the paediatric hospital context are crucial to orient users and create an inclusive environment that is attentive to children's cognitive and emotional needs. Investing in these solutions can translate into concrete benefits, such as increased patient satisfaction, operational effectiveness improvements, and well-being within healthcare facilities.
The in-depth analysis of user needs, combined with the study of interaction models between hospitals and patients and the assessment of the critical issues of current communication tools, allowed us to identify problematic scenarios and potential areas of intervention. This process clearly defined the functionalities and requirements necessary for developing a new orientation system to improve the experience and effectiveness of wayfinding within hospital spaces.
Considering the complexity of the hospital structure examined, the research was limited by focusing the analysis on a single case study of the medical day hospital without considering the entire hospital structure. However, the following steps will extend the investigation to the whole facility, involving a larger sample of users and foreseeing more extended observation periods to develop a Beta version of the app to be tested in the field.
Furthermore, the limited connectivity in some hospital areas could reduce the app's effectiveness, hindering user access and use. Therefore, future developments could focus on creating offline solutions, allowing access to the functionalities without an Internet connection. Technological alternatives and infrastructural strategies could also be explored to improve connectivity within the hospital, ensuring reliable access to digital resources and maximising the app's utility.
Another research direction will be to analyse the combined effec-

tiveness of game design elements in mobile apps, studying how the synergy of components such as levels, point systems, and immediate feedback increases user engagement. Future research could investigate the most effective combinations for specific groups, such as paediatric patients, and their impact on well-being, motivation and therapy adherence.

Equally important is the continued refinement of features designed to support users with sensory and cognitive disabilities. While the app already includes accessibility tools such as voice guides, multiple language options, and adjustable text sizes, future developments could explore more advanced solutions tailored to specific needs. Additional features for users with visual impairments could include high-contrast modes and colour-blind-friendly palettes to address conditions such as Daltonism. Furthermore, incorporating screen reader compatibility enhancements and dynamic text-to-speech options could provide more inclusive support. For users with cognitive disabilities, advanced adaptive interfaces that dynamically simplify content or limit the display of overwhelming information could further enhance usability. Customizable navigation paths, which adjust based on user preferences or limitations, could also improve accessibility and reduce stress. Examining the effect of apps on reducing anxiety during hospital orientation through metrics such as navigation time and user satisfaction could offer further insights.

Additionally, real-time translation tools and cultural customization options would ensure inclusivity for non-native speakers and diverse user backgrounds.

By addressing these diverse needs, “My Meyer” can further reinforce its mission of creating a patient-centred experience that is efficient, entertaining, and welcoming for all users. This direction highlights the importance of continuous feedback and testing with diverse user groups, ensuring accessibility remains a cornerstone of future developments.

Acknowledgements: The authors would like to thank Francesca Tosi (Scientific Director of the Research) and all the medical staff of the Meyer Children's Hospital in Florence, in particular Dr. Donata Dini, Dr. Daniela Elettra Papini, architect Sheila Belli, and engineer Carlo Becucci.

Author Contributions

Conceptualization, E.I..; methodology, E.I. and V.P.; infographics, rendering and data curation, V.P.; writing–original draft preparation, E.I.; writing–review and editing, E.I. (all sections except “My Meyer App”) and V.P.; Supervision, C.M. (technical part) and E.I. All authors have read and agreed to the published version of the manuscript.

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ESTER IACONO

PhD in Design, she is a research fellow and adjunct professor of the course "Design and Ergonomics for Communication and Services" at the Department of Architecture of the University of Florence. Since 2017, she has been researching at the Ergonomics & Design Laboratory (LED) on topics related to Emotional Design in the health sector, Human-Centred Design/User Experience, Interaction Design, Ergonomics for Design, Design for Healthcare and inclusion. She has participated in national and international research projects and collaborated in research programs funded by the EU, public administrations and public and private companies. She is also the author of articles and essays published in national and international scientific journals and proceedings conferences.

VIRGINIA PIOMBINO

Industrial designer and tutor since 2023 for the course “Laboratory of Design & Ergonomics for Communication and Services”. She has participated in national and international conferences and collaborated on a project with paediatric hospitals. She is currently conducting research in ergonomics, Human-Centred Design methodology, and UX/UI design. In particular, understanding how gamification can be applied across various fields - such as medical settings, wayfinding, education, and daily life - can reveal its potential benefits and innovative uses.

CLAUDIO MONDOVECCHIO

Since 1999, he has worked in clinical engineering in several public hospitals, following specific projects, procurement planning, and supervising services related to electromedical and laboratory equipment. He has collaborated with the School of Engineering of the University of Florence, accompanying future engineers during their training.

Currently, in the Meyer Children’s Hospital (Irccs), he supports the continuous renewal of equipment and the introduction of new technologies by verifying their actual usability, from the preliminary assessment to their best use during their entire life cycle with HTA methodology, supporting accreditation processes and clinical trials.

Neighborhood Educational Center: Starting with the Youngest and Families to Contribute to the Well-being of Society

ELENA GERBINO, MELODY CREA, SHADI PARSA
Volunteer Educator, Florence

Keywords: Education, Ergonomics, Empowerment, Well-being, Society, Families

Abstract

Each person has an inherent relational and communal nature that education must bring forth in order to foster awareness of social and political actions.

The effects of the process of social transformation find their greatest expression in a small context, such as a neighborhood, in which a community of people gradually becomes the active protagonist of their own well-being. Based on this principle, in a neighborhood in Florence, a group of volunteers launched a project drawing on their skills to cultivate "life skills" essential for children's socio-emotional and relational development.

The project aims to inspire the youngest population segments to adopt an open approach to learning, fostering a constant desire to explore reality and take individual and collective actions to improve the society they live in.

While the program follows international educational and training

guidelines, each context uniquely adapts them to its local characteristics, talents and needs, through a Human-Centered design approach.
In the educational center of the Rifredi neighborhood of Florence, the experience over four years has shown cognitive and relational-emotional benefits in children and teens both in an educational setting and at home.
The transformation encouraged by the educational program will yield improved outcomes to the extent that an increasing number of individuals assume responsibility for the comprehensive education of younger generations, addressing physical, intellectual, and spiritual dimensions, as well as their own.
Everyone can be a protagonist for change, contributing to a shared effort based on reciprocity and mutual support from multiple backgrounds.

Introduction

The word "community," which comes from the Latin word *communitas*, reflects the innate co-existence of all human beings, suggesting that from the moment of birth, everyone is destined to live in a community. Thus, individuals don't initially come together to form communities; rather, each person has an inherent relational and communal nature that education must bring about in order to foster awareness of social and political actions (Esposito, 2006).
Zamengo and Valenzano, in their recent studies on contemporary educational communities, state that if a community creates the necessary context within which education takes place, it becomes an educational community when viewed as a set of individuals, means, and instruments that bring about educational action in practice (Zamengo, Valenzano, 2018).
The first example of community education dates back to the second half of the 19th century, attributed to popular educational initiatives by Danish Lutheran pastor Nikolai Frederik Severin Grundtvig (1783-1872). In 1844, he established the first Folkehojskoleri, a residential folk high school providing educational, civic, and democratic training to farmers and open to adults of all ages, social statuses, and educational levels. Based on his point of view, the goal of education is to spread the common good, empower individuals to achieve self-realization, engage actively in public life, and acknowledge their ties to the community (Lawson, Grundtvig, 1994).

Society's transformation, therefore, results from a twofold process: the development of one's own capacities and a proactive contribution to collective progress. This dual process finds its most effective expression in small settings, such as neighborhoods, where a group of people gradually takes an active role in promoting their own well-being.

For American scholar Dewey, only within a community can a better engagement with diversity, an increased understanding of others, and opportunities to build experiences of solidarity and cooperation take place. He proposed that communities offer a starting point for larger society, helping transform the "Great Society into a Great Community" (Dewey, 1971).

At the heart of community engagement lies the belief in human potential, where one must regard each person as a mine rich in gems of inestimable value and that education alone can cause it to reveal its treasures and enable mankind to benefit from it (Universal House of justice, 1981).

Based on this principle, a group of volunteers in the Rifredi neighborhood of Florence launched a project drawing on their capacities to cultivate "life skills" essential for children's socio-emotional and relational development. This includes self-awareness, creative initiative for collective well-being, managing emotions and conflicts as well as developing moral and spiritual qualities.

To nurture a comprehensive approach to educating younger generations, it's essential to address multiple types of education: material, human, and spiritual.

Objectives

The project aims to inspire young people to adopt an open approach to learning, fostering a constant desire to explore reality and take individual and collective actions to improve the societies they live in.

- Discover personal talents and intrinsic spiritual qualities.
- Develop constructive social behaviors (e.g. self-control, responsibility, socialization).
- Strengthen friendships and collaboration.
- Create a supportive environment free from prejudice and stereotypes.
- Promote actions that respect the social environment.

Materials and Methods

The program follows international educational guidelines by the Universal House of Justice, an institution whose purpose is, among other things, to exert a positive influence on the welfare of humankind, to promote education, peace and global prosperity. These guidelines emerge from a shared vision among those inspired to build vibrant communities—people who want to create active and conscious resources capable of reflection and meaningful local action. Insights and feedback generated through local working groups are collected in reports and sent to the International Teaching Center, which converts said information into educational material, thus making these insights globally accessible (Ruhi Institute, 2019).

The guidelines cover concepts, principles, and methods for creating inclusive communities that are committed to collective well-being, such as systematic action, consultation, and service. However, each context uniquely adapts these elements to its local characteristics, talents, and necessities.

Using Human-Centered Design (HCD) principles, the guidelines aim to develop services that reflect people's needs and aspirations. HCD applies methods for designing useful, enjoyable, and meaningful products or services. This approach involves families' needs and aspirations, with a multidisciplinary approach and collaboration with professionals and institutions.

Currently, the project includes a program organized into three books titled "Teaching in Children's Classes" (Ruhi Institute, 2023), covering different levels:

- Level 1 (ages 5-6): Understanding, distinguishing, and developing spiritual qualities (e.g. justice, honesty, trust).
- Level 2 (ages 6-7): Developing behaviors that reflect acquired qualities (e.g. being a good friend, pursuing knowledge, consulting in groups).
- Levels 3 and 4 (ages 7-9): Introducing diverse faiths as sources of spiritual understanding to build inclusive, well-being-focused communities.

In the future, the program will expand to ages 9-11. Currently, levels 3 and 4 are under development, with testing in regions where children's education programs are systematic in nature and well-supported by a large number of volunteer educators and families. The guidelines undergo various stages of testing and feedback before becoming the official version, translated into over 90 languages.

The primary goal is the empowerment of populations, their children and families, thus allowing them to take ownership of their own spiritual and material well-being. Every educational activity must be an enhancing experience that helps participants develop the necessary understanding, qualities, attitudes and skills to become a new type of social actor. The energies of such actors are dedicated entirely to promoting the welfare of the community and their actions are inspired by the vision of a new civilization that incorporates, in every structure and process, the fundamental principle of the unity of humankind (Ruhi Institute, 2024).

In order to achieve this goal, volunteer educators carry out weekly planning meetings of activities with an ergonomic approach, reflecting on previous meetings and creating educational materials and methods appropriate for its participants.

The elements of the method are:

- Memorization of quotations: reading and memorizing noble and inspiring words generates reflection in the children and supports their decision-making capacities in their daily challenges and future choices. (Fig. 1)
- Stories: children learn, through the example of true or fictional stories, about spiritual qualities so that they become more achievable and within reach. (Fig. 2 Telling life stories to new generations)
- Art and Music: these are used as means of communication and exploration. (Fig. 3 Creative activity during the summer camp)
- Play: collaborative games are the arena where the attitudes explored can be actively developed such as the habit of listening, mutual support, empathy and the collective pursuit of common goals. (Fig. 4 Playful e joyful group moments)
- Prayer: dedicating time to foster the connection with our higher nature generates open-mindedness, unity and equality from an early age among different paths of faith. (Fig. 5 Candle with each child's name as a flame to be guarded and nurtured with prayer)

Results

The educational program has positively impacted global community life, with effects proportionate to the populations involved. Increasing participation contributes to the growth of volunteer educators who engage in organizing activities with neighborhood educators, parents, and institutions (Training Institutes, 2017).

Figure 1. *Playful activities for memorizing quotations.*

Figure 2. *Telling life stories to new generations.*

Figure 3. *Creative activity during the summer camp.*

Figure 4. *Playful e joyful group moments.*

Figure 5. Candle with each child's name as a flame to be guarded and nurtured with prayer.

Feedback from thousands of areas shows that many feel actively involved in personal and community development. Families, friends, and acquaintances engage in discussions on spiritual and social issues, initiating activities that shape a dedicated way of life and cultivate service-oriented capabilities in youth, benefiting both the local community and potentially the world at large (Universal House of Justice, 2023).

To expand the community's network of knowledge, structured and purposeful gatherings are organized, sometimes taking the form of camps and festivals. In these events, music and singing play a prominent role. The arts, integral from the beginning to the community's development process, emerge as significant instruments for generating joy, strengthening unity, disseminating knowledge, and consolidating understanding. Moreover, they serve as a means to communicate the values cultivated through various activities to other members of the community. (Universal House of Justice, 2021).

In the educational center of the Rifredi neighborhood in Florence, experience over the last four years has shown cognitive and relation-

al-emotional benefits in children and teens within the educational setting and at home. Parents are increasingly aware of the space's purpose: children are active participants in society, while parents, in turn, use their talents and experiences to enrich the social environment.

Parents have gained an awareness of the center's objective: children are viewed as active members of society from the beginning, and parents do not see themselves as peripheral to their children's educational experiences. Instead, they contribute with talents and experiences to their social environment's well-being, envisioning themselves as an ever-evolving unit that plans and acts together. (Fig. 6) (Fig. 7).

Figure 6. Together with neighborhood families plant new flowers in the park

At the same time, children develop behaviors, attitudes, and spiritual qualities that they share with their families, thus positively influencing family dynamics. The educational dimensions explored at the neighborhood center have made the children more open to dialogue with individuals different to themselves (peers, family, society). Through their own language, children express their understanding of how spiritual qualities affect the environment, such as responding to a provocation with an act of kindness; a conflict in the group can

Figure 7. Children pick up trash to clean up neighborhood park with volunteers.

be transformed into an opportunity to understand, listen, and show empathy.

This environment, in turn, fosters prosocial behavior within the group. Although this is still an early stage in the educational process, one can foresee the long-term effects of an interconnected set of qualities—justice tempered by compassion, generosity free from prejudice, sincerity expressed through kindness—and how these very qualities can contribute to a completely new narrative in both individual and collective life within society.

Discussion and Conclusions

To foster personal educational growth that positively affects the social environment, collective collaboration for common well-being is necessary, beginning with the youngest and emphasizing human nobility. Italy's constitution states that "[...] every citizen has a duty to pursue activities that contribute to the material or spiritual progress of society" (Italian Constitution, 1948).

The transformation encouraged by the educational program will yield

improved outcomes to the extent that an increasing number of individuals assume responsibility for the comprehensive education of younger generations—addressing physical, intellectual, and spiritual dimensions—while also engaging in their own self-development. Gradually, each person's qualities will manifest within their respective families, educational, and professional environments, displacing behaviors characterized by conflict tendencies, suspicion, and domination. Instead, these qualities will foster dynamic interpersonal interactions, establishing the foundations for reciprocity and mutual support.

Evidence from various experiences highlights that building vibrant communities requires a combination of qualities, attitudes, skills, and capacities that can be developed through a dynamic interaction between training and action. This capacity-building process must occur across individuals, communities, and institutions. Each participant is an active agent of change, contributing to a shared effort based on reciprocity and mutual support.

Thriving communities emerge when diverse forces intersect harmoniously. Leaders from various sectors of the community must collaborate to initiate sustainable growth, a process that involves not only local governance but also business and educational leaders working collectively to manage change and promote civic engagement, as well as other community segments. Individual and collective growth progresses in parallel with a commitment to both community welfare and broader social responsibilities, manifesting through initiatives—including entrepreneurial ones—aimed at caring for oneself, others, and the environment (Pulcini, 2009).

In the near future, we would like to increase our network of resources (volunteers), children and families participating in the center's activities to create links and comparisons among families, multiple generations and professions for the support and support of the neighborhood. In fact, we are already taking steps to collaborate with schools and sports, recreational, educational and professional entities in the neighborhood with the aim of raising awareness of our project and extending it to bordering areas.

The educational program initiates an empowerment process directed toward social action, wherein individuals, organizations, and communities acquire the agency to influence their lives and transform their social and political contexts, ultimately enhancing equity and quality of life (Wallerstein, 2006).

Just as each component in the human body contributes to the well-being of the whole, the collaborative efforts of society in all its parts will contribute to the health of the 'body' of humanity.

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ELENA GERBINO

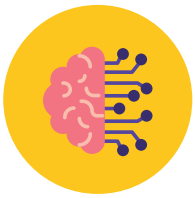
Graduate in education and training, specializing in children's and adolescent literature. Currently working as a bookseller at the bookstore inside the Meyer Children's Hospital IRCCS in Florence where she is involved in the promotion of reading starting with children. Volunteer educator at the neighborhood educational center, she is in charge of organizing and managing children's activities and the creation of the children's theater workshop and performance in collaboration with families.

Member of the LaAV association in Florence, dealing with the promotion of reading, reading aloud in schools.

SHADI PARSA

Graduated in healthcare Professions and currently finishing the Medical University in Florence. Working in the educational field to promote the basic knowledge of Italian language to foreign students. Volunteer educator at the neighborhood educational center, working in the team of people that's focused in the capacity building process - in themselves and other people, specifically younger generations - to ultimately serve the wellbeing of the neighborhood.

A classroom tailored to students with chronic medical conditions. A systematic review



TOMBERLI LUCREZIA, CIUCCI ENRICA
Università di Firenze (FI)

Keywords: Chronic illness; School climate; Sense of school belonging; Inclusion; Disability.

Abstract

Childhood chronic medical condition increases the risk of school dropout due to frequent hospitalizations, leading to emotional and physical challenges in attending school. Students with chronic conditions may face bullying, particularly when their medical condition is visible, and classroom environments are often not adapted to their needs. This is particularly relevant for students with mobility, sensory, respiratory, or neurological impairments. Schools must create environments that support hospitalized students, even during absences, and accommodate chronic medical conditions requiring continuous care. This study explores how to design inclusive classroom environments suited to the needs of students with medical conditions, focusing on both physical spaces and organizational aspects. A systematic review was conducted to investigate how classroom environments should be structured for children

with chronic medical conditions to ensure inclusivity and promote their participation in both academic and recreational activities. No empirical studies specifically address classroom design to support students with chronic medical issues. While some research focuses on digital tools or hybrid learning, it does not consider post-hospitalization classroom modifications. Drawing on disability studies, this review suggests that classrooms should be equipped with technology, internet access, appropriate lighting, and comfortable, adaptable spaces. Further research will examine the specific needs of chronically ill students, guiding classroom modifications to improve students' sense of school belonging, well-being, and health-related quality of life through a mixed-methods approach.

Introduction

Having a chronic medical condition during childhood or adolescence represents a significant challenge for the individual, as chronic diseases are characterized by the persistence, at least in part, of symptoms and are often not curable, but rather manageable. This means that individuals living with these conditions must adapt to them in various contexts. Chronic medical condition may require daily management, such as blood glucose monitoring for a diabetic patient, or may involve daily discomfort, such as the physical pain experienced by individuals with juvenile rheumatoid arthritis.

In the school environment, the presence of a chronic medical condition may generate specific needs for the student, especially when it is associated with motor, physical, neurological, or cognitive impairments (Bargerhuff, 2013; Edwards et al., 2019; Marlow et al., 2005; Raghavendra et al., 2012). Numerous studies have highlighted how students with chronic medical conditions, such as diabetes, epilepsy, asthma, or oncological diseases, are at a significantly higher risk of school dropout compared to their healthy peers (Barnett et al., 2023; Freudenberg & Ruglis, 2007). Main causes include frequent hospitalizations and prolonged absences, which disrupt educational continuity and diminish the student's sense of belonging to the school environment (Spencer et al., 2024; Tomberli & Ciucci, 2021; Weibel, et al., 2023). However, even when a studenFt does not require frequent hospitalization, the mere presence of the disease may hinder academic or social participation, such as in cases where a visually impaired student cannot learn in the same way as others, or a student with celiac disease faces dietary challenges during school

meals, or a student with motor disabilities encounters difficulties during physical education or school field trips.

When a student is hospitalized, digital technologies offer a crucial opportunity to ensure educational continuity. Tools like tablets, laptops, and interactive whiteboards, supported by a stable internet connection, allow students to attend lessons remotely and maintain contact with their classmates (Benigno et al., 2017; Klunder et al., 2022; Tomberli & Ciucci, 2021). While technology can also assist students with certain sensory deficits or disabilities, it is often insufficient for pupils who regularly attend in-person classes. Although hospitalized students are physically absent from the classroom, students with chronic medical issues who are not hospitalized spend most of their time in the classroom, and if the environment is not properly designed, it can become a barrier to their participation in educational and social activities, such as recess or physical education. As is the case for students with motor and/or physical disabilities - a group that has been studied more extensively than students with chronic conditions - when the environment fails to accommodate the student's specific needs, they will encounter barriers to accessing and participating in the activities carried out within it (e.g., Gaudiot et al., 2019; Martins & Gaudiot, 2012).

A student with diabet may need frequent breaks to monitor blood glucose levels and administer insulin, while a student with asthma may require immediate access to medication in case of a respiratory crisis. Seizures, on the other hand, can occur suddenly and, if not managed appropriately, may cause distress among classmates and school staff. These medical aspects are typically addressed within the school system (e.g., Armas, et al., 2022; Edwards et al., 2014; Pansier & Schulz, 2015), but are the psychological aspects equally considered? For instance, a student with asthma may require particularly clean air in the classroom, while a student with epilepsy may need warm lighting rather than cool lighting to reduce discomfort, particularly during acute phases of the condition, especially if photosensitivity is present.

While it is expected that an individualized educational plan is developed for students with sensory deficits or disabilities (Benigno et al., 2018; 2023; Capurso & Dennis, 2017; Capurso et al., 2024; Giovannetti et al., 2019) and procedures for medication use are followed (Tomberli & Ciucci, in press), this does not necessarily address the spatial and relational needs that enable the student to actively engage in

the school community. In other words, while the right to education is guaranteed through personalized educational plans, this does not ensure that the classroom environment is prepared to accommodate the students' needs, allowing them to move freely within the space. For example, visually impaired or blind student may have access to Braille textbooks (though not always), but the school corridors may lack Braille signage or auditory signals to guide them from the classroom to the restroom or cafeteria. Similarly, not all schools are spatially equipped to accommodate students with motor disabilities.

One of the most complex aspects of managing students with chronic medical conditions is integrating them into an environment that is not always adequately prepared to meet their specific needs. Literature increasingly emphasizes the positive role that a strong sense of school belonging plays in promoting better academic performance and overall well-being. Students who feel part of their school environment are more likely to engage in proactive behaviors that support their school attendance (Akar et al., 2020; Arslan & Allen, 2021; Sebokova et al., 2018; Vang & Nischina, 2022).

To foster a sense of school belonging, it is crucial that the spaces are ergonomically designed to meet the needs of the individuals who use them. The school environment brings together individuals with diverse needs, and as such, the space must be designed to be inclusive for the majority of students, as well as for specific groups, such as young people with chronic medical conditions. The school setting should aim to be as *barrier-free* as possible. The concept of *Barrier-Free Design* originated in the United States in the 1950s, initially focused on making spaces accessible for war veterans. Over time, this approach has evolved to promote the principles of universal design (*Design For All*) and inclusive design, with the goal of ensuring accessibility for everyone (Berube, 1981; Holmes-Seidle, 2012; Tosi, 2022).

From a psychological perspective, an environment is considered accessible when it facilitates social interaction and places the individuals in a comfortable position, allowing them to participate without feeling stigmatized or different. However, creating an environment that is always inclusive for everyone is challenging, which is why it must be flexible and adaptable. Schools should offer activities that provide maximum comfort for all students, taking into account the resources available.

Even an environment designed with inclusivity in mind, such as

with proper lighting and ergonomic seating, cannot guarantee inclusiveness if the activities are not aligned with these adaptations or if the classroom climate does not support their effective use. A clear example is students with specific learning disabilities: if students are ashamed to use compensatory tools, such as concept maps or formularies, for fear of being judged, they may not utilize these resources, thus negating the benefits of a personalized educational plan. It is essential to foster a positive classroom climate to avoid stigmatizing attitudes. The same dynamic applies to students with chronic medical issues: if the social conditions do not support the use of specific devices or accommodations without prejudice, these students may refuse to use them, jeopardizing their health. For example, an ergonomic chair designed for a student with juvenile rheumatoid arthritis can be highly beneficial, but if the student feels embarrassed to use it, the chair may go unused. Similarly, choosing a bus that accommodates a wheelchair is inclusive in principle, but it becomes ineffective if the student chooses not to attend the trip due to fear of ridicule or criticism from peers.

These examples, although not distant from reality, are supported by findings in both psychology and ergonomics. In the 1970s, Fishbein and Ajzen (1975) developed the *Theory of Reasoned Action*, which posits that an individuals beliefs and attitudes toward a particular action influence their likelihood of engaging in that action. If individuals believe that an action will benefit them, they are more likely to take that action. Conversely, if they believe it will lead to negative consequences, they will avoid it. For instance, if students anticipate that wearing a brace in class will expose them to negative comments, they may choose not to wear it, putting their health at risk.

In ergonomics, the concept of "*emotional design*" (Norman, 2004) refers to the connection between the design of a product or service and the emotional impact it has on the user. Therefore, an ergonomic chair must not only be functional for a student with arthritis but also emotionally and socially acceptable to both the student and their peers to ensure it is actually used. Similarly, attending to the emotional climate of the classroom is crucial to ensuring the effectiveness of proposed solutions. Without a supportive and stigma-free environment, tools and adaptations will remain unused, undermining efforts to achieve genuine inclusivity.

The present study

Building on the existing literature and the reflections presented in the introduction, we asked ourselves how the classroom environment for students with chronic medical conditions should be structured in order to ensure inclusivity and promote their participation in both academic and recreational activities.

Method

To achieve the aim of this study, we conducted a systematic review using the PRISMA statement method (*Preferred Reporting Items for Systematic reviews and Meta-Analyses*; Moher, Liberati, Tetzlaff, Altman; 2009). The PRISMA method involves systematically identifying and analyzing the literature on a given topic through specific steps, namely: (1) identifying the research question, (2) formulating inclusion and exclusion criteria, (3) selecting the databases to search for studies, (4) developing a query to be run on these databases, (5) extracting articles retrieved through the query, (6) selecting studies through multiple stages (screening titles, abstracts, and full papers), and (7) synthesizing the results.

Search strategy and study selection

The preliminary process leading to the start of the PRISMA review proved to be particularly challenging. Keeping the objective of the study in mind, we selected the following inclusion criteria:

(a) literature in English;

(b) quite recent literature (from 2000s);

(c) empirical research (either qualitative, quantitative, or mixed-methods), case studies, reports, dissertations, abstracts in symposium;

(d) studies focusing on pediatric or adolescent populations with chronic or complex conditions;

(e) studies focusing on the topic of ergonomics, specifically those that have explored not so much the emotional and relational needs of students with chronic conditions in the classroom, but rather the need for spatial readjustments based on medical requirements.

However, when identifying the keywords, we encountered the issue that they were either too broad or too specific. This posed two major risks: either identifying an overly extensive and irrelevant body of literature or a literature base that was too narrow. Both risks are particularly problematic when conducting a systematic review, as they could lead to missing relevant literature; in fact, if the keywords are

too specific and precise, there is a risk of identifying only a limited amount of literature that might address the topic tangentially or indirectly. Conversely, if the keywords are too broad, there is a risk of retrieving an overly large body of literature, much of which may be irrelevant.

For this reason, we ultimately decided to realize three parallel systematic reviews, hoping so to find out interesting literature on the topic, reducing the risk to miss literature because of the keywords' choice. So, we conducted the systematic review using three English separate queries and carried out the search strategy through each one, comparing the various results and utilizing a snowballing process to hopefully arrive at a sufficiently robust selection of articles for further analysis. Finally, given the limited number of preliminary results, we also created a fourth query in Italian language, imagining that this would allow us to identify more grey literature, such as theses or works presented at conferences and symposia.

Databases we selected for this review were *PubMed*, *ERIC*, and *PsycInfo*. Only for the fourth query in Italian language we used *Google Scholar*.

Table 1 summarizes the number of articles found for each query across the selected databases.

The initial attempt to launch the query was conducted using boolean

	("children" AND "chronic illness") AND ("classroom") AND ("ergonomics" or "barriers")	Children chronic medical condition classroom ergonomics	children chronic illness classroom ergonomics	bambini malattia cronica classe ergonomia
PsycInfo	1	0	657	/
Eric	30	12	684	/
Pubmed	1	1	1	/
Google Scholar	/	/	/	233

Table 1. *Number of articles retrieved from the four queries, categorized by individual database.*

indicators and the most commonly utilized specialized vocabulary, identified through preliminary research in *thesauri* (refer to the first graph from the left, Fig. 2).

As very few results emerged, we eliminated the boolean indicators and attempted the same search using umbrella terms, prioritizing the term "*chronic medical condition*" instead of "*illness*" (refer to the second graph from the left, Fig. 2). This choice was made because "*illness*" refers to the subjective experience of people regarding their disease, while "chronic medical condition" or "disease" pertains to the objective presence of a pathology and/or disability.

Even in this instance, the results were limited, prompting us to formulate a third query that employed "*chronic illness*" in place of "*chronic medical condition*" (refer to the third graph from the left, Fig. 2). This adjustment yielded a greater number of results.

To ensure that we were not excluding grey literature (for example, theses or symposiums), we conducted a fourth query in Italian (refer to the last graph from the left, Fig. 2).

No articles were identified as meeting the inclusion criteria, after the PRISMA screening process (see Figure 2).

Figure 2. PRISMA diagrams (adapted from Moher et al., 2009) for each query.

Results

To date, there do not appear to be any studies that have specifically explored how classroom environments should be structured for children with chronic medical conditions. In fact, after conducting three separate screenings, no articles were found on this topic, not even in the Italian language. The literature review highlighted that research on this broader topic primarily focuses on: musculoskeletal issues among students and the importance of addressing posture and designing school environments to prevent such problems (e.g., Ismail et al., 2010); the role of backpacks in these issues and how to manage the weight burden (e.g., through the use of lockers) (e.g., Mououdi, et al., 2018); creating inclusive classroom environments for issues related to the presence of a disease or disability (e.g., Legg & Jacobs, 2008); fostering peer relationships and promoting a positive classroom climate (e.g., Smith, 2012; Titsari & Kaltsum, 2023); the role of technology in supporting hospitalized students with chronic conditions (e.g., Benigno et al., 2018; Charteris, 2022; Hopkins, 2014); self-management for students with compromised health conditions (e.g., Barton et al., 2020; Richardson et al., 2014); prevention of various medical issues through the promotion of healthy lifestyles (e.g., Abrignani et al., 2019; Spring et al., 2015; Vizcaìno, et al., 2013); the psychological and/or social barriers present in classrooms when a student has a particular disease (e.g., Barroso et al., 2005); lack of teachers' knowledge about chronic medical conditions children management (e.g., King, 2018; Neuharth-Pritchett, et al., 2023; Roux, 2009;); the important role of a personalized learning plan for the student with chronic medical condition if the disease has implications on school performance (e.g., blindness and deafness) (e.g., Hopkins et al., 2015); school psychologist and nurse role in the support of children with chronic medical conditions (e.g., Wodrich & Cunningham, 2007).

Discussion and conclusions

In line with the suggestions of several authors (Dickersin, 1994; Marks-Anglin & Chen, 2020; Sutton, 2009), we have chosen to highlight our findings despite the fact that the review did not identify any relevant papers. This decision was made to avoid research bias, where only easily observable and measurable results, often confirming the initial hypothesis, are published. Indeed, in our view, the absence of scientific literature on this topic is, in itself, an interesting finding

that deserves attention and requires reflection, both methodologically and psychologically. Initially, we expected to find a response that could later be transformed into best practices for teachers and school administrators.

From a methodological perspective, we can ask ourselves:

(a) whether the keywords used to index this type of studies are different, and therefore, relevant literature was not retrieved using the terms we identified;

(b) whether this literature pertains exclusively to the field of ergonomics, meaning that it may be necessary to search databases outside the psychological, healthcare, and educational fields that we employed. However, this latter hypothesis seems unlikely to us, as our interest is not strictly in educational fields but in educational, didactic, and relational ones, which inherently involve other disciplines;

(c) another question we considered is whether the relevant literature might have been published in non-indexed journals, whose abstracts are not available in the databases we searched, thus making them inaccessible. If this was the case, it would raise an intriguing issue: the urgent need for professionals to engage in a multidisciplinary dialogue and open the doors of ergonomics to other fields, allowing for the discovery and in-depth analysis of this literature;

(d) finally, we wondered whether the existing material on this topic is purely applied and has not been subjected to formal research and/or publication (even in non-scientific outlets). Although we chose to include grey literature in the present review, no grey results emerged, leading us to think that such literature may not be well indexed, as it did not surface. This is consistent with the impression we gathered from attending ergonomics training in the pediatric healthcare field, such as the 2024 event held at Meyer Health Campus[1] named "CreAzioni per l'innovazione e la ricerca. Prospettive d'insieme" (translated in English: "CreActions for Innovation and Research: A Holistic Perspective"). On that occasion, interesting practical and applicative insights arose, which could also be transferable to the topic at hand; yet, these insights were not available online unless one already knew the name of the project or the specific school website to search. If this was the case, it would raise another issue: the importance of creating more opportunities for the dialogue between professionals from different backgrounds, so that practical experiences in school settings can be documented, narrated, and disseminated, not only in popular channels but also in scientific ones, through meticulous case study work

[1] *https://campus.meyer.it/corso/convegno-di-ergonomia-pediatrica-2024-creazioni-per-linnovazione-e-la-ricerca-prospettive-dinsieme/#:~:text=Il%20giorno%209%20maggio%202024,NOS%20ERGOMeyer%20AOU%20Meyer%20IRCCS.*

or other methods for exploring what teachers—likely those most engaged with the topic—have implemented, despite lacking the technical-scientific skills to synthesize and share their work with the scientific community.

Alternatively, psychological considerations arise if we assume that the topic has not yet been of scientific or applicative interest. If this is the case, a question emerges: can students feel part of a school community that does not take their needs into account? In our view, the answer is no, as it is impossible to feel part of a context that excludes rather than includes, in line with numerous authors who have emphasized the importance of fostering a sense of belonging to the school that also considers the physical environment of the school space (Allen, Vella-Brodrick & Waters, 2015; Allen & Kern, 2017; De Freitas, Rousell & Jager, 2020; Gowing, 2019; Libbey, 2007).

Implication for educators and policymakers

The findings of this study allow us to make some useful considerations for those working in the field of education and for policymakers. Regarding professionals working in schools (educators and teachers), we believe it would be appropriate for them to acquire knowledge about the spatial and logistical needs of students upon entry, especially when dealing with chronic or complex conditions, similar to how accommodations are made for students with disabilities. In practice, this could take the form of a preliminary meeting with the family at the beginning of the school year, when parents are asked to explain the implications of their child's condition in the school context, specifically focusing on the physical classroom environment. In cases where architectural or other barriers might be present, the teaching team could meet to brainstorm how to rearrange the classroom space to accommodate the student's needs. For instance, chairs could be rearranged, or curtains could be installed to block sunlight if a student is sensitive to light.

At the same time, attention to the physical environment should be accompanied by a focus on the relational climate. For example, teachers should consider how these surrounding changes might impact classroom relationships: could peers exhibit stigma or bullying behaviors? Could the rearrangement of the classroom cause discontent? As we have seen, this topic remains largely unexplored in the literature. Consequently, based on this systematic review, it is not currently possible to provide more detailed, evidence-based guidelines. For this reason,

following our work, we decided to create a book for teachers, specifically designed to offer practical suggestions based on our professional experience outside university (e.g., clinical and school psychology, collaborations with local associations). We hope such a resource will be helpful for teachers in implementing inclusive strategies for students, addressing both relational and spatial aspects, and dealing with topics related to ergonomics (see Tomberli & Ciucci, in press).

We also urge policymakers to invest more in this issue, both empirically and through concrete actions. Specifically, we propose the creation of working groups that bring together researchers, citizens, students with chronic or complex conditions, teachers, and administrators to discuss and reflect on key themes related to the broader issue of ergonomics, classroom structure, and chronic illness. In this process, research could act as a promoter by listening to the needs of stakeholders. Once these needs are identified, dedicated roundtables could be established to facilitate dialogue and focus on the development and implementation of inclusive educational practices. These practices should encompass spatial rearrangements of classrooms to ensure that students can actively participate in the school environment.

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TOMBERLI LUCREZIA

Psychologist-Psychotherapist, PhD; expert in chronic illness and oncological disease. She works in private practice providing clinical services and collaborates with third-sector organizations and the University of Florence on topics related to chronic illness. She is the author of articles and books on illness and hospital-based schooling. ORCID: 0000-0002-6822-9800

CIUCCI ENRICA

PhD and Associate Professor in Developmental and Educational Psychology at the Department FORLILPSI of the University of Florence, Italy. She is the coordinator of the master's program in Hospital Pediatric Psychology co-designed by the FORLILPSI department and Meyer Children's Hospital IRCCS. She is the author of articles and books on illness and hospital-based schooling. ORCID: 0000-0003-0401-2634