

Toward Human-Centered Medical and Protective Textiles: Integrating Human-Centered Design and Sensitive Design

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RÉSUMÉ

The development of medical and protective textiles is undergoing a paradigm shift toward human-centered approaches that integrate technical performance with user well-being. This study investigates the integration of Human-Centered Design (HCD) and Sensitive Design in the development of microencapsulated textile systems intended for medical and protective applications. The research combines textile engineering, material science, and user-oriented design principles to enhance usability, comfort, and safety. An experimental framework based on microcapsule preparation, characterization, and textile fixation is presented and evaluated through HCD criteria. The results demonstrate that low-temperature processing, controlled microcapsule morphology, and user-oriented application strategies contribute to improved sensorial comfort, material stability, and suitability for prolonged human contact. This work highlights the relevance of Human-Centered Design as a methodological and ethical framework for innovation in advanced medical and protective textiles.

Mots-clé: Human-Centered Design, Sensitive Design, Medical Textiles, Protective Clothing, Microcapsules, UX Textile

INTRODUCTION

Medical and protective textiles play a critical role in healthcare, occupational safety, and daily well-being. Beyond mechanical and functional performance, contemporary textile innovation increasingly requires attention to comfort, usability, and human experience. Traditional performance-driven approaches often overlook sensory perception, emotional acceptance, and long-term interaction with the human body.

Human-Centered Design (HCD) offers a comprehensive framework that places human needs, values, and contexts at the core of the design process. When combined with Sensitive Design and UX-oriented textile approaches, HCD enables the development of textile products that are not only efficient but also physically and psychologically supportive. This article explores the integration of these design philosophies through an experimental study focused on microencapsulated textile systems for medical and protective use.

State Of Art

Human-Centered Design and Textile Innovation

Human-centered design (HCD) emphasizes empathy, co-design, and iterative development to ensure alignment with real human needs. In textile design, HCD extends beyond functionality to address comfort, safety, emotional response, and ethical responsibility. Based on a usability-oriented framework, this study highlights the central role of the person-product relationship in shaping user experience, particularly in the evaluation and application of cosmetotextiles for vulnerable individuals. A scenario-based retrospective design method was employed to identify user needs, constraints, and risks, supporting the development of safe, effective, and user-adapted cosmetotextile solutions.



Figure 1: Norme ISO 9241 Partie 210 (Usability) : conception centrée sur l'humain, 2017

Sensitive Design and UX Textile

Sensitive Design complements human-centered design by addressing sensory and emotional dimensions, including tactile perception, thermal comfort, and olfactory experience, which are essential in textile–body interactions. In this context, UX Textile integrates usability and user experience principles into textile systems, ensuring that materials, finishes, and embedded treatments actively contribute to comfort, safety, emotional well-being, and positive daily interactions, particularly for vulnerable users.



Figure 2: Sensitive Design and UX Textile Design

MATERIALS AND METHODS

Quantitative et qualitative approach: Direct User Involvement in the Study of "Cosmetotextiles"

Although our study follows a human-centered design approach, we integrated both the perspective of the general population and that of vulnerable individuals, to obtain a comprehensive understanding of the intelligent textiles market, specifically "cosmetotextiles." This dual approach allows us to capture the needs, expectations, and experiences of users in all their diversity, and to formulate tailored recommendations for the development of truly user-centered products.

A. Quantitative Study of the General Public

An online questionnaire (17 questions, mostly multiple-choice) was conducted to gather opinions on "Well-being" and "cosmetotextiles." The objectives were to :

- Identify behaviors, expectations, and perceptions of consumers.

- Understand the influence of sociodemographic factors (age, professional category) on knowledge and acceptance of "cosmetotextiles."

The survey was distributed through personal networks and online platforms to ensure a diverse and representative sample. Results highlighted common manifestations of discomfort or skin-related issues (insomnia, dehydration, stretch marks, obesity, UV sensitivity, etc.) and identified needs in terms of physical comfort, skin health, and psychological well-being.

B. Qualitative Study: Interviews with Vulnerable Individuals

To complement the quantitative study, semi-structured interviews were conducted with two specific cases:

1. Ms. Lamia Lahkim Chbak, affected by Xeroderma Pigmentosum ("child of the moon"), to understand constraints related to sun sensitivity and her needs for protective and cosmetic textiles.
2. Ms. Rim Mnejja, experiencing anxiety and stress, to identify psychological and sensory needs that could be addressed by "cosmetotextiles."

These interviews provided an in-depth understanding of individual needs and explored solutions adapted to the constraints of vulnerable users.

C. Analysis and Interpretation of Results

The combined analysis of survey and interviews revealed:

- For the general public: strong interest in textiles providing comfort, protection, and psychological well-being, with curiosity about "cosmetotextiles" as a "second skin."
- For vulnerable individuals: critical importance of specific features such as UV protection, calming effects, and integration of cosmetic products suited to individual sensitivity.

These findings emphasize the need to develop "cosmetotextiles" that meet both general and specific needs, in a multidimensional and multisensory perspective.

D. Towards Empirical Testing

The next step is to validate these findings through controlled laboratory experiments, assessing the efficacy of active ingredients integrated into textiles, their durability, and their effects on user well-being.

Empirical testing will:

- Objectively measure interactions between textiles and skin.
- Adjust formulations to meet individual needs safely and comfortably.
- Provide quantitative and qualitative data to strengthen the scientific credibility of the human-centered design approach.

As noted by Raïche-Savoie and Déméné (2022), design research, particularly through "Project-Based Research," combines field observation with controlled experimentation, enabling the evaluation of feasibility and effectiveness of innovative concepts such as "cosmetotextiles."

Microcapsules based on polycaprolactone were prepared via solvent diffusion, characterized by microscopy and FTIR, and fixed on textiles under HCD constraints.

Experimental Approach

The experimental research approach, grounded in Human-Centered Design, was adopted, integrating material development with user-oriented criteria focused on comfort, safety, and suitability for prolonged skin contact. This work was carried out at the Textile Engineering and Materials Laboratory (GEMTEX) with two groups MTP et HCD at ENSAIT

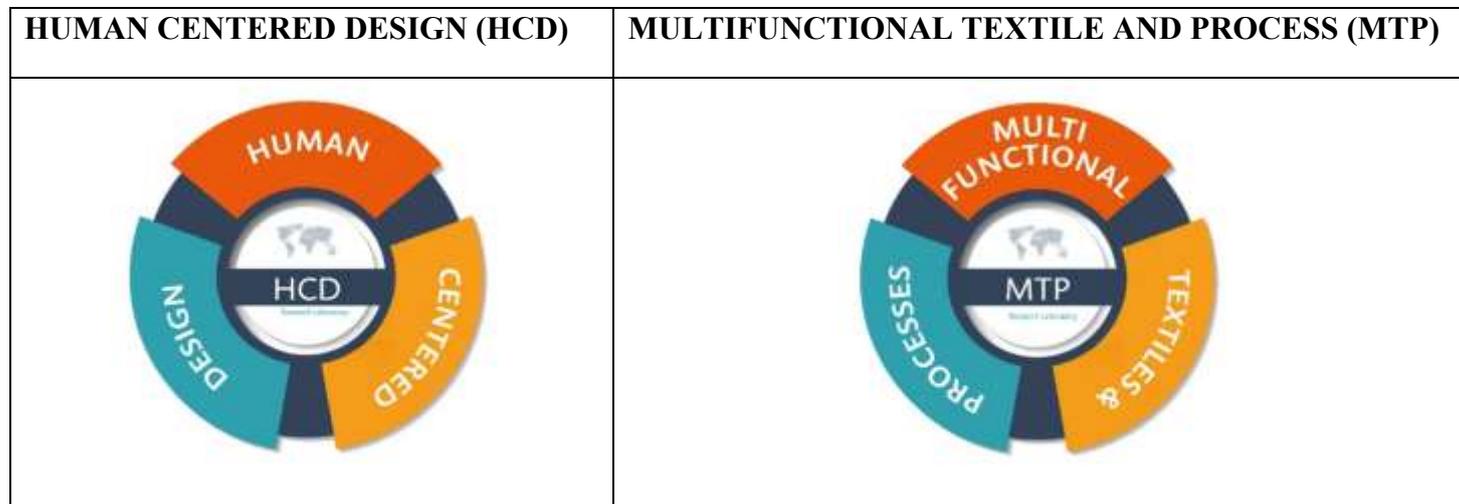


Figure 3: The experimental workflow at GEMTEX involved two groups, integrating material development with textile application under the Human-Centered Design framework.

Materials

Polycaprolactone (PCL): polymeric shell

Ethyl acetate: solvent

Essential oil: active core

Span 80 and Tween 80: surfactants

Polyether polyurethane binders and rheological additives: for textile fixation

Microcapsule Preparation

Microcapsule Preparation Protocol

Microcapsules were prepared in four main phases:

1. **PCL solution:** 100 g of PCL was melted in 27 ml of ethyl acetate under constant stirring.
2. **Organic phase:** 10 ml of essential oil mixed with 1 g of Span 80 was incorporated into the PCL solution.
3. **Microcapsule formation:** The organic phase was added dropwise to an aqueous Tween 80 solution at 500 rpm for 10 minutes. Solvent diffusion formed the microcapsules; residual solvent was removed under a fume hood and at 40 °C.
4. **Washing and drying:** Microcapsules were washed and air-dried, producing stable particles ready for textile application.

Characterization Methods

Optical microscopy was employed to analyze microcapsule morphology and size distribution. FTIR spectroscopy was used to confirm chemical composition and validate successful encapsulation of active compounds.



Figure 4: The first phase of PCL solution preparation, MEJJA, H (GEMTEX Laboratory)



Figure 5: The second phase: preparation of the organic phase, MNEJJA, H, (GEMTEX Laboratory)



Figure 6: The third phase of the microcapsule preparation protocol, MNEJJA, H, (GEMTEX Laboratory)

Microscopic view of microcapsules ranging from 0 to 100 micrometers



Figure 7: Microscopic view, 0–100 μm , MNEJJA, H, (GEMTEX Laboratory)

Under microscopic observation, the previously prepared microcapsules exhibit a well-defined size distribution, with diameters ranging from 0 to 100 μm . Upon closer inspection, smaller microcapsules are also visible, with diameters between 0 and 20 μm . These smaller microcapsules display a homogeneous distribution as well, reflecting a well-controlled and successful fabrication process.



Figure 8 : Microscopic view, 0–20 μm , MNEJJA, H , (GEMTEX Laboratory)

The PCL shell surrounding the encapsulated essential oil droplets remains clearly visible, even in the smallest microcapsules, indicating effective and reliable encapsulation of the active compound. Overall, microscopic observation of the microcapsules shows a well-controlled size distribution, with a significant proportion of microcapsules within the targeted diameter ranges. This uniformity in size is crucial for ensuring consistent and predictable performance across various applications and highlights the quality of the microcapsule preparation.

It should be noted that the ranges of 0–20 μm and 0–100 μm correspond to the observed diameters of the microcapsules under the microscope. This indicates that some microcapsules are smaller, with diameters between 0 and 20 μm , while others are larger, with diameters up to 100 μm .

Textile Application Protocol

Two textile treatments were prepared: a control formulation (Solution A) and a microcapsule-based formulation (Solution B). Due to the thermal sensitivity of PCL microcapsules, Solution B-treated textiles were air-dried, while control samples underwent thermal fixation. Weight gain measurements were used to assess deposition efficiency.

In-Depth Evaluation and Precise Characterization of Microcapsules: A Key Step in Advancing Innovative Textiles

Fourier Transform Infrared Spectroscopy (FTIR) is an analytical technique used to study the chemical bonds present in a sample. It is based on the interaction between infrared light and molecules, producing a characteristic spectrum of the chemical bonds.

The first step in the FTIR characterization of microcapsules is sample preparation: a sample of microcapsules (MPH) is prepared and placed on a suitable support for FTIR analysis (KBr pellet). It is essential to ensure that the sample is completely dry before analysis to obtain accurate and reliable results.

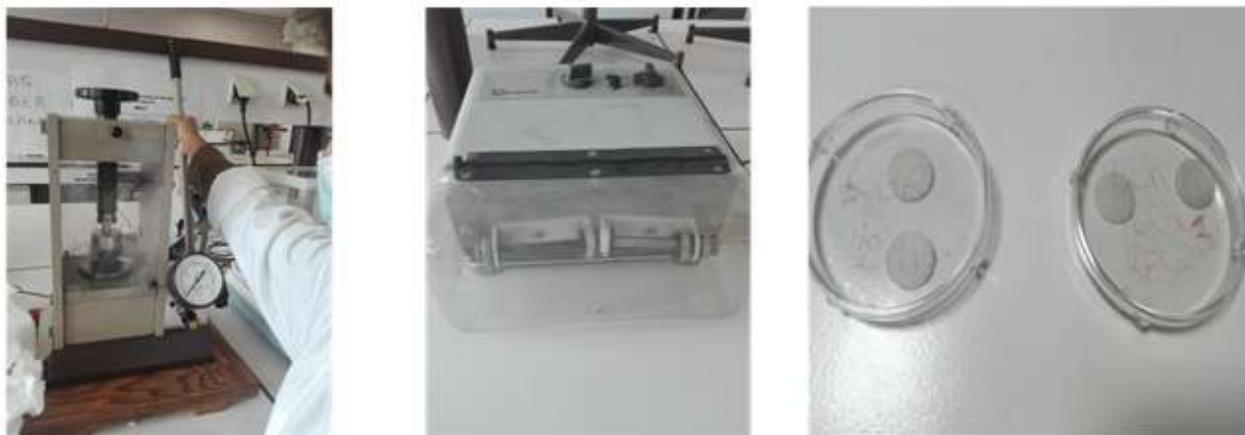


Figure 9: Specimen Preparation, MNEJJA, H, (GEMTEX Laboratory)

The second step is **FTIR spectrum measurement**: the FTIR spectrometer directs a beam of infrared light through the sample, recording the wavelengths absorbed by the chemical bonds. The next step focuses on **peak analysis**: the peaks in the FTIR spectrum are analyzed to identify the chemical bonds and functional groups present in the microcapsules.

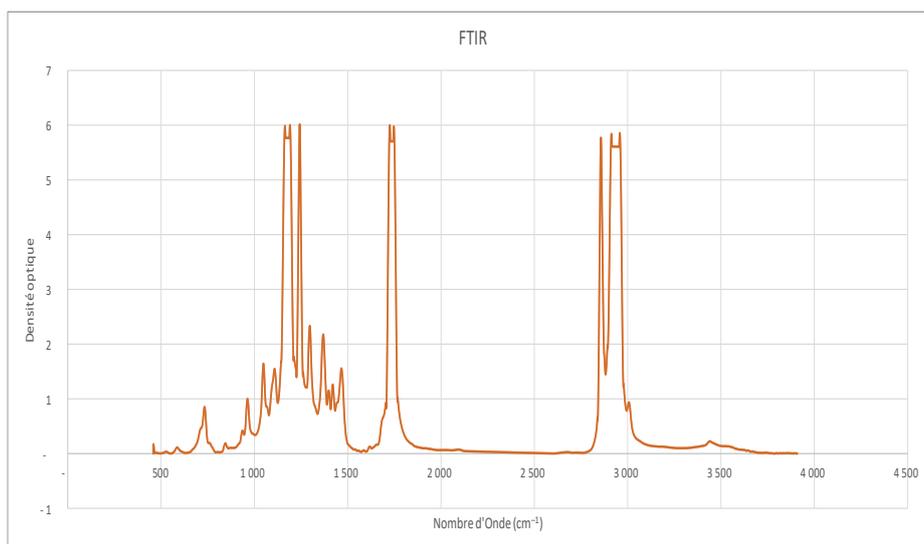


Figure 10: Infrared Spectroscopy Curve, MNEJJA, H, (GEMTEX Laboratory)

FTIR characterization allowed us to obtain information on the chemical composition of the microcapsules. We were able to confirm the presence of PCL and ethyl cellulose polymers, as well as other specific functional groups. This analysis played a crucial role in validating the successful encapsulation of the active compounds and the essential oil within the microcapsules. The results of the FTIR characterization further enhance our understanding of the microcapsules’ properties and their potential in various industrial and scientific applications.

Microcapsule Immobilization on the Textile Surface

As part of our experimental protocol, two distinct samples were prepared: **Solution B** (Figure 73) and **Solution A (Control)**.

Solution B consists of 1 g of MIKRAFIX as a catalyst and 4 g of MIKRACAT B as a crosslinking agent. This formulation allows the establishment of chemical bonds with the fibers, using the previously prepared microcapsules (MPH). The MPH microcapsules mainly contain potent essential oil, PCL (polycaprolactone), and ethyl acetate.



Figure 11: MIKRAFIX (catalyst) and MIKRACAT B (crosslinking agent) MNEJJA, H, (GEMTEX Laboratory)

On the other hand, Solution A (Control) was specifically designed for comparison with Solution B. It consists of lavender, known for its antimicrobial properties, which will be evaluated during the experiment. The formulation of Solution A includes 4 g of the binder Lurapret N5122 LIP combined with 1 g of the thickener Appretan® Thickener 2710 liq to increase the solution’s viscosity. Additionally, 10 g of previously prepared lavender microcapsules were added to confer specific antimicrobial properties to the solution.

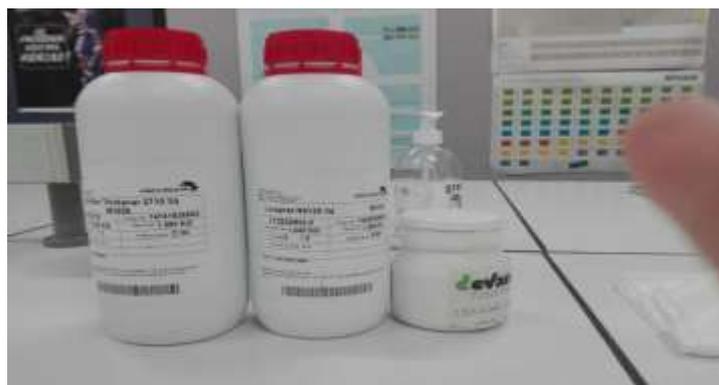


Figure 12: Binder “Lurapret N5122 LIP” and thickener “Appretan® Thickener 2710” MNEJJA,H, (GEMTEX Laboratory)

The following table presents our exploration of the capabilities of polyether binders and finishing additives for high-performance coating formulations.

BINDERS	PROCESSING ADDITIVES
<ul style="list-style-type: none"> • Polyether PU: <i>Lurapret® N5112 liq</i> • 35 % • Medium soft • High hydrolysis resistance • Low water absorption 	<ul style="list-style-type: none"> • Thickeners: Adjust the viscosity and rheological behavior of the formulations for the application system: <i>Appretan® Thickener 2710 liq</i> • Fully neutralized concentrated reverse emulsion

Our main objective was to compare these two solutions and analyze their respective performance on the fibers. Solution B is of particular interest due to its specific chemical bonds with the MPH microcapsules, which contain key components such as the potent essential oil and PCL.

In contrast, Solution A (Control) highlights the antimicrobial properties of lavender, providing a reference to evaluate the effectiveness of Solution B in this regard.

Overall, this experiment allows us to better understand the properties and advantages of each solution, particularly their interaction with fibers and microcapsules, as well as their potential in industrial applications such as textile manufacturing and antimicrobial materials.

Deposition of Microcapsules and Final Drying and Fixation

As part of our experimental protocol, the pre-prepared Control Solution and Solution B were applied to a scarf to evaluate their properties

For the Control Solution, the solution was poured onto the scarf multiple times to ensure even distribution. The scarf was then weighed precisely to determine the initial mass. After application, 60 % of the total mass was retained, representing the weight gain due to the presence of microcapsules in the Control Solution. For the next step, the scarf was placed in an oven preheated to 105 °C, followed by a water spray at 115 °C to fix the solution onto the fibers.

For Solution B, a similar procedure was followed. The solution was poured onto a separate scarf, and the initial mass of the impregnated scarf was measured. As with the Control Solution, 60 % of the total mass was retained, corresponding to the weight gain from the MPH microcapsules. However, unlike the Control Solution, the scarf was not subjected to high temperatures. The MPH microcapsules are made from PCL, a temperature-sensitive material that could melt if exposed to prolonged high heat. Therefore, the scarf impregnated with Solution B was air-dried to preserve the integrity of the microcapsules.



Figure 13: Steps of the Scarfing Technique: Fixation and Drying, MNEJJA, H, (GEMTEX Laboratory)

This experimental approach will allow us to evaluate the performance and properties of the two solutions applied to the fibers of the scarf. By comparing the results obtained for the Control Solution and Solution B, we can determine their respective effectiveness in terms of adhesion and stability of the microcapsules on the fibers, while taking into account the specific characteristics of the MPH microcapsules related to their sensitivity to high temperatures.

In conclusion, the diagram below presents a summary of the process, from the microcapsule preparation phase to the fixation of these microcapsules onto the textile.

RESULTS

Experimental Results

- Microscopic Analysis: Revealed a well-defined, homogeneous microcapsule size distribution (0–100 μm), with a substantial proportion between 0–20 μm . The PCL shell around essential oil droplets was clearly visible, confirming effective encapsulation.

- FTIR Spectroscopy: Validated chemical integrity, confirming the presence of PCL, ethyl cellulose, and characteristic functional groups of the essential oil, indicating that bioactive compounds remained stable.
- Textile Application: Solution B (microcapsule-based) retained ~60 % of its mass after air-drying, preserving microcapsule integrity, whereas Solution A (control) underwent thermal fixation. Treated textiles exhibited uniform coating, flexibility, and maintained sensory and olfactory properties.

Quantitative Results (General Public Survey)

- Common well-being issues: insomnia, dehydration, stretch marks, obesity, UV sensitivity.
- Interest in "cosmetotextiles": ~90 % expressed curiosity about textiles as a "second skin."
- Knowledge prior to survey: 68 % had little or no awareness of "cosmetotextiles."
- Preferences: comfort, skin health, psychological well-being, and aesthetic appeal.

Qualitative Results (Interviews with Vulnerable Individuals)

- Case 1 – Lamia (Xeroderma Pigmentosum): UV protection, lightweight and modern design, durability, cosmetic integration, social inclusion concerns.
- Case 2 – Rim (Anxiety & Stress): Calming/sensory textiles, integration of relaxing ingredients (e.g., lavender), improved psychological well-being.

Combined Analysis

User Group / Method	Key Findings	Needs / Preferences	Implications for Cosmetotextiles
General Public (Survey)	Insomnia, dehydration, stretch marks, obesity, UV sensitivity.	Comfort, skin health, psychological well-being, curiosity about "second skin."	Develop textiles enhancing comfort, cosmetic benefits, and public awareness.
Vulnerable Individuals (Interviews)	Lamia: UV sensitivity, social inclusion challenges. Rim: Anxiety, stress, sleep disturbance.	Lamia: UV protection, modern design, durable cosmetic integration. Rim: Calming, sensory-enhanced textiles.	Targeted design for physical, psychological, and sensory needs.
Experimental (Microcapsules)	Homogeneous encapsulation (0–100 μm), chemical stability, good textile adhesion.	Effective release of bioactive compounds, flexible and comfortable textiles.	Empirical support for developing safe, functional, and user-friendly cosmetotextiles.
Combined Insights	High interest across groups; multidimensional benefits desired.	Integrate aesthetic, functional, and psychological effects.	Supports human-centered design and laboratory validation for user satisfaction.

DISCUSSION: LINKING EXPERIMENTAL RESULTS TO HUMAN-CENTERED DESIGN

The integration of experimental, quantitative, and qualitative results provides strong support for a human-centered design (HCD) approach:

1. Empathic Understanding: Direct user input revealed both common and highly specific needs, allowing customization of "cosmetotextiles" for vulnerable users (UV-sensitive, anxiety-prone).
2. Multidimensional Product Design: Experimental validation confirmed that microcapsules maintain chemical stability and adhesion, ensuring functionality, comfort, and sensory appeal as required by users.

3. Iterative Feedback and Validation: Survey and interview insights guide laboratory testing, confirming that products meet user expectations for well-being, protection, and sensory experience.

The study demonstrates how user perspectives inform experimental design: microcapsule characteristics, textile application methods, and sensory properties are aligned with quantified needs and expressed preferences. This closing of the loop between design, experimentation, and user feedback exemplifies HCD principles in practice.

CONCLUSION

This study demonstrates the relevance of integrating direct user involvement with experimental validation in the development of cosmetotextiles. Quantitative surveys revealed general user needs and interest in functional and well-being-oriented textiles, while qualitative interviews provided insight into the specific requirements of vulnerable individuals, enabling the formulation of tailored design solutions. Laboratory experiments confirmed the stability of microcapsules, their effective adhesion to textile substrates, and the preservation of sensory properties, thereby validating the feasibility of user-informed textile designs. Overall, the findings highlight the necessity of a multidimensional and multisensory approach that combines aesthetic, functional, and psychological benefits, establishing a robust human-centered framework for cosmetotextiles oriented toward well-being, protection, and sensory comfort.



Figure 14: Integrated human-centered and experimental workflow illustrating the combination of user research (quantitative and qualitative), microcapsule formulation, textile application, and user-oriented validation in cosmetotextiles.

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