IFSCC 2025 full paper (IFSCC2025-1584)

Revolutionizing Skincare: Biometric-Emotion Driven 3D Printing for Personalized Beauty Solutions

Sara Bom [1], Pedro Pinto [1,2]*, Helena Margarida Ribeiro [1] and Joana Marto [1]

[1] Research Institute for Medicines (iMed.ULisboa), Faculty of Pharmacy, Universidade de Lisboa, Portugal; [2] PhD Trials, Avenida Maria Helena Vieira da Silva, nº 24 A – 1750-182, Lisboa, Portugal

* Presenter

1. Introduction

The cosmetics industry is undergoing a significant transformation as it increasingly embraces the integration of technology-driven personalized skincare solutions. This shift not only aligns with evolving consumer preferences for customized products but also enhances operational efficiency and supports ongoing innovation within the sector (Bhosale et al., 2023; Snekha et al., 2023; Ustymenko, 2023).

In this dynamic landscape, the concept of personalizing beauty has gained significant traction, particularly within the skincare market. This approach provides a compelling alternative to conventional one-treatment/size-fits-all products, which often fail to address the uniqueness of each individual consumer (Bom et al., 2021).

Recent advancements in various technologies, including virtual reality (VR), augmented reality (AR), artificial intelligence (AI), digitalization, and 3D printing (3DP), have significantly expanded the possibilities for creating tailored skincare solutions that meet personal preferences and requirements (Amornvit & Sanohkan, 2019; Chandel & Gain, 2024; Elder et al., 2024; Mangtani et al., 2020). Despite the diversity in these approaches, they share a unified goal: to address the unique needs of each customer while fulfilling their desire for effective and personalized beautification options.

Among the array of emerging technologies facilitating this trend, 3DP has emerged as a particularly versatile and innovative solution. Its ability to rapidly customize skincare products allows for a responsive approach to individual consumer needs and preferences (Goyanes et al., 2016; Pech & Vrchota, 2022).

This study seeks to investigate the personalization of both structural and aesthetic features of 3D-printed skincare eye patches. The products were tailored to align with the beautification needs and preferences of each volunteer participant. To enhance the degree of customization, a biometric-emotion driven methodology was utilized. Additionally, a biometric sensory analysis was conducted to compare the 3D-printed products developed in this study with conventional market patches, evaluating consumer acceptability through emotional response evaluation.

2. Materials and Methods

Hydrogel preparation: A gelatin-based hydrogel with printable properties was used as a model formulation. This ink was prepared in a water bath (Nahita International, UK) at 55 ˚C under discontinuous stirring for 1 hour, prior to printing. Color and fragrance were added to the ink after formulation development, considering each volunteer's preference (see personalization step 1).

Ethics - *In vivo* studies: The *in vivo* studies were approved by the Ethics Committee of PhD Trials® (http://phdtrials.com/, Opinion No. 005/2012, issued on 15 June 2012). All procedures were conducted at the PhD Trials® facilities in compliance with the principles outlined in the Declaration of Helsinki and in accordance with the regulatory frameworks established by Agence Française de Securité Sanitaire des Produits de Santé (AFSSAPS). Prior to enrolment, all participants provided written informed consent and completed an authorization form permitting the use and publication of their images.

Personalization steps:

1. First, a personalization survey was sent to each of the volunteers included (n = 10; age range 24-32), to understand their skincare goals and needs, and fragrance and color preferences.
2. Following, AEVA-HE² (Eotech, France) was employed as a 3D scanner for further drawing and extraction of the patch area.
3. Afterwards, the patch area was sliced (Simply3D) and printed using an extrusion-based 3DP approach (Allevi2, Allevi, USA).

Emotional analysis: A biometric sensory analysis was also carried out to validate the 3D-printed patches' acceptability, employing a facial action classification system (FACS) performed on Afets (PhD Trials). During this study, the volunteers also applied a non-3D-printed market option (Reference) for comparison purposes. The analysis measured emotional valence based on pleasantness. Emotions like joy are classified as positive valence, while emotions such as disgust fall under negative valence (Kauschke et al., 2019).

3. Results

To validate the developed biometric-emotion driven digitalization approach, a proof of concept was carried out by selecting volunteers with standard skincare habits. The personalization questionnaire revealed that the primary concern for the volunteers participating in the study pertained to skin hydration, enhancing the appearance and ensuring aesthetic satisfaction. In terms of color, pink, blue, yellow and light shades prevailed, while fragrance choices fell into the categories of fresh, fruity, sweet and froral (**Figure 1a**).

Following, the anatomical-fitted patches were accuractely designed using advanced 3D scanning technology, ensuring precise adherence to the unique contours of the periorbital and midfacial regions of each volunteer (**Figure 1b**). In addition, a moisturizing compound was integrated into the formulation to align with the skincare goals previously identified by the participants. To further enhance personalization, the color and fragrance was also customized to their individual preferences (**Figure 1c**).

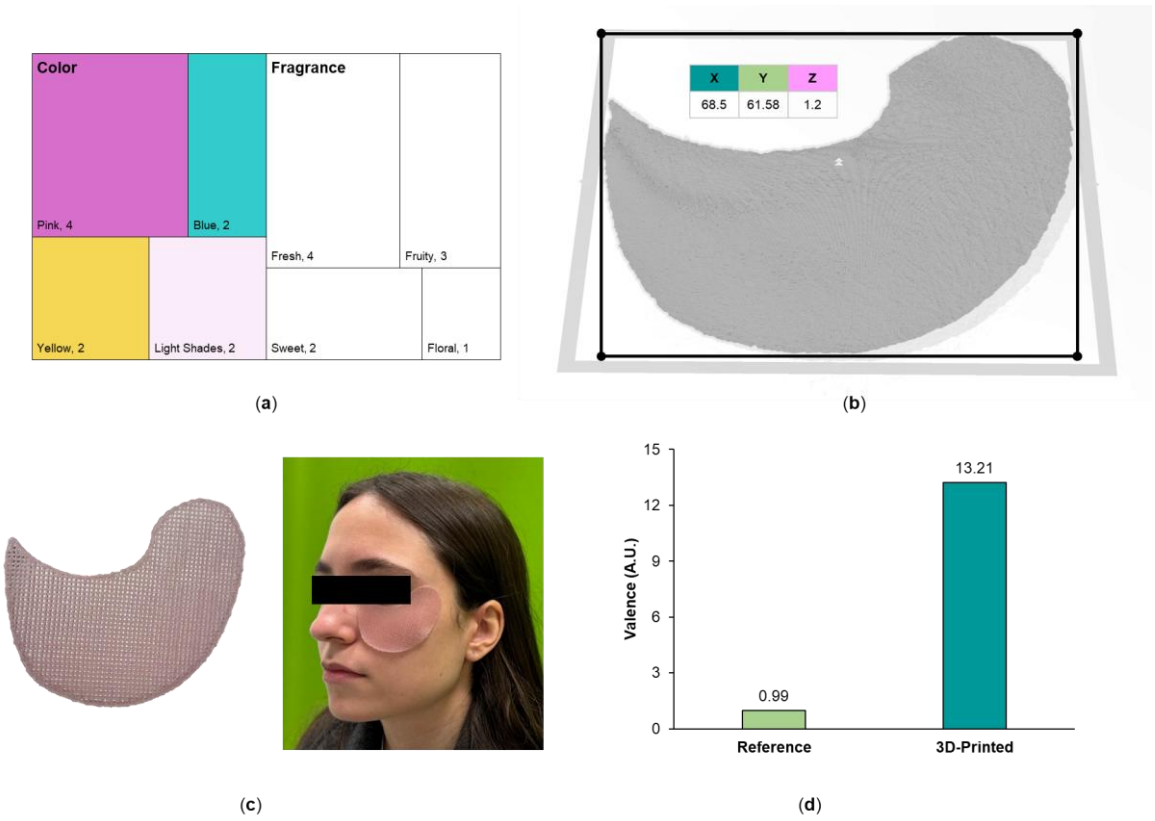

Figure 1. Biometric-Emotion Driven 3D Printing for Personalized Beauty Solutions. (a) Color and fragrance preferences. (b) Design and printing features of the gelatin-based eye patches: From 3D scanning to size/shaped-fitted patches. (c) Example of a 3D-printed personalized patch, with the color selected by the volunteer. (d) Emotional response evaluation (Reference vs. 3D-Printed), employing a facial action classification system (FACS) – Valence.

The biometric sensory analysis conducted revealed clear emotional responses from participants, particularly those of joy and disgust. These emotions were systematically converted into valence values to facilitate a more precise interpretation of the emotional spectrum. As illustrated in **Figure 1d**, participants demonstrated a higher level of acceptance for the personalized 3D-printed product, reflected in a notable increase in the valence value. This indicates a strong positive emotional response and a favorable perception of the product's design and attributes. Moreover, the results suggests that personalization in product design can foster deeper emotional engagement among users.

4. Discussion

While advanced technologies such as 3DP, hold transformative potential for the cosmetics industry, there is still a notable lack of scientific studies exploring this potential. Aside from a

few pioneering works, carried out by Goaynes *et al.* (Goyanes et al., 2016) and Manousi *et al.* (Manousi et al., 2024), the intersection between additive manufacturing and cosmetic science remains largely underexplored. The current pace of technological advancement highlights an urgent need for further interdisciplinary research that can support the integration of such innovations into personalized cosmetic solutions.

This study endeavors to address this critical gap by exploring different cosmetic personalization approaches, focusing particularly on the novel application of 3D-printed patches. An innovative aspect of this investigation is the incorporation of consumer perspectives, which provides valuable insights into their expectations, desires, and responses to personalized cosmetic offerings. Engaging potential users through qualitative feedback is essential for understanding their needs and preferences, thereby informing more effective product development.

Furthermore, the emotional analysis conducted yields critical data regarding user engagement and acceptance. This analysis transcends traditional measures of technical feasibility, encompassing emotional and experiential dimensions that significantly contribute to user satisfaction. Findings from this research underscore the relevance to design products that not only excel in performance but also foster emotional resonance with consumers. Factors such as aesthetic appeal, and user-friendliness play integral roles in shaping emotional responses, which in turn can significantly impact perceived product efficacy and overall consumer satisfaction. In this context, the implementation of co-creation strategies that actively involve consumers in the developmental process emerges as essential. Such participatory approaches promote a user-centered design framework, enhancing the likelihood that resulting products will be both functionally effective and emotionally captivating.

Moreover, the application of qualitative methodologies, such as FACS, proves to be an essential tool for elucidating the subtle nuances in consumer perceptions that are often neglected by purely quantitative approaches. This comprehensive methodological framework supports a more nuanced understanding of product performance in real-world contexts and strengthens the foundational knowledge necessary for future innovations in the domain of personalized cosmetic technologies. Ultimately, fostering this interdisciplinary dialogue may catalyze a paradigm shift toward a more consumer-centric approach in the cosmetics industry.

5. Conclusion

Overall, this study underscores the relevance of integrating biometric and emotion-driven technologies to the 3DP process, representing a considerable step forward in personalizing beauty. The ability to customize patches by tailoring parameters such as size, shape, color, fragrance, and bioactive compounds not only demonstrates the versatility of this approach but also elevates the innovation towards modern skincare science, paving the way for more personalized and effective solutions that ensure consumer satisfaction.

References

Amornvit, P., & Sanohkan, S. (2019). The accuracy of digital face scans obtained from 3D scanners: An in vitro study. *International Journal of Environmental Research and Public Health*, *16*(24), 1–13. https://doi.org/10.3390/ijerph16245061

Bhosale, U., Gaddam, S., Koutam, H., Sapre, P., Nallan, C., & Syed, S. M. (2023). Empowering consumers: The evolving paradigm of customization in personal care products. *Current Cosmetic Science*, *02*, 1–7. https://doi.org/10.2174/0126667797265268231011103859

Bom, S., Martins, A. M., Ribeiro, H. M., & Marto, J. (2021). Diving into 3D (bio)printing: A revolutionary tool to customize the production of drug and cell-based systems for skin delivery. *International Journal of Pharmaceutics*, *605*, 1–20. https://doi.org/10.1016/j.ijpharm.2021.120794

Chandel, A., & Gain, N. (2024). A review on digital transformation: cosmetic industry. *International Journal of Innovations in Science Engineering and Management*, *3*, 26–30.

Elder, A., Cappelli, M. O. D., Ring, C., & Saedi, N. (2024). Artificial intelligence in cosmetic dermatology: An update on current trends. *Clinics in Dermatology*, *42*(3), 216–220. https://doi.org/10.1016/j.clindermatol.2023.12.015

Goyanes, A., Det-Amornrat, U., Wang, J., Basit, A. W., & Gaisford, S. (2016). 3D scanning and 3D printing as innovative technologies for fabricating personalized topical drug delivery systems. *Journal of Controlled Release*, *234*, 41–48. https://doi.org/10.1016/j.jconrel.2016.05.034

Kauschke, C., Bahn, D., Vesker, M., & Schwarzer, G. (2019). Review: The role of emotional valence for the processing of facial and verbal stimuli - positivity or negativity bias? *Frontiers in Psychology*, *10*, 1–15. https://doi.org/10.3389/fpsyg.2019.01654

Mangtani, N., Bajpai, N., Sahasrabudhe, S., & Wasule, D. (2020). Importance of artificial intelligence and augment reality in cosmetic and beauty industry post COVID 19. *World Journal of Pharmaceutical Research*, *9*(8), 2296–2308. https://doi.org/10.20959/wjpr20208-18280

Manousi, E., Chatzitaki, A. T., Vakirlis, E., Karavasili, C., & Fatouros, D. G. (2024). Development and in vivo evaluation of 3D printed hydrogel patches for personalized cosmetic use based on skin type. *Journal of Drug Delivery Science and Technology*, *92*, 1–9. https://doi.org/10.1016/j.jddst.2023.105306

Pech, M., & Vrchota, J. (2022). The product customization process in relation to industry 4.0 and digitalization. *Processes*, *10*(3), 1–30. https://doi.org/10.3390/pr10030539

Snekha, S., Chandrasekar A Sanjana, M., Krishnan, J., Ranjith, R., & Vijayakumar, K. (2023). Cosmetic products customisation and customer segmentation. *Proceedings of the 2nd IEEE International Conference on Advances in Computing, Communication and Applied Informatics, ACCAI 2023*, 1–11. https://doi.org/10.1109/ACCAI58221.2023.10200286

Ustymenko, R. (2023). Trends and innovations in cosmetic marketing. *Economics & Education*, *8*(3), 12–17. https://doi.org/10.30525/2500-946x/2023-3-2