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Paulo Eduardo Tonin * and Marinella Ferrara

Posted Date: 17 October 2025

doi: 10.20944/preprints202510.1361.v1

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Olfactory Attribution Circle (OAC): Designing Crossmodal Congruence Between Scent, Color, and Language

Paulo Eduardo Tonin [1,2,*] and Marinella Ferrara [1]

[1] Politecnico di Milano, Italy
[2] Universidade do Estado de Santa Catarina, Brazil
* Correspondence: paulotonin@gmail.com

Abstract

This article introduces the Olfactory Attribution Circle (OAC), a conceptual tool for integrating olfaction, color, and linguistic attributes in the design of multisensory atmospheres. Developed through a multi-method strategy, the research combined a systematic literature review, semi-structured interviews with academic and industry sources, a case study of *EveryHuman* (Algorithmic Perfumery), and AI-assisted exploration. The review revealed a lack of tools operationalizing olfactory design within the built environment. Interviews provided practice-based insights on inclusion, intensity calibration, and feasibility, while the case study demonstrated the potential and limitations of AI-driven personalization. AI was employed to generate mappings between 60 essences, bipolar semantic attributes, and chromatic codes, refined through authorial curation. Results highlight systematic crossmodal correspondences between scents, linguistic attributes, and chromatic values, underscoring the importance of crossmodal congruence in designing coherent sensory experiences. The OAC enables congruent, human-centered olfactory design, though cultural variability and semantic ambiguity limit universal application. The study positions the OAC as both a methodological contribution and a foundation for future empirical testing across diverse cultural contexts.

Keywords: olfactory design; built environments; atmospheres; linguistic attributes; crossmodal congruence

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1. Introduction

The design of sensory atmospheres in the built environment has increasingly attracted scholarly and professional attention, particularly in retail, hospitality, and cultural spaces [1–12]. While the visual dimension has long dominated design practice, olfaction has emerged as a critical yet underexplored sensory layer capable of shaping perception, emotion, and memory [4,5,13,14]. At the same time, artificial intelligence (AI) has begun to transform creative and design processes, offering new ways to explore semantic associations, generate correspondences across modalities, and test design hypotheses [15–18].

In the context of sensory design, AI provides not a replacement for human authorship, but a tool for expanding the creative search space and highlighting ambiguities that demand interpretation [15,17,18]. Despite the growing importance of smell in shaping user experience, the design of olfactory atmospheres remains fragmented, often relying on intuition, marketing trends, or isolated artistic explorations rather than structured methodologies. This limitation became evident when a systematic literature review was conducted to determine whether tools currently exist that guide olfactory design within the built environment.

Unlike narrative reviews, the systematic approach applies explicit inclusion and exclusion criteria, ensuring transparency and reproducibility. The review was performed using two research

 doi:10.20944/preprints202510.1361.v1

platforms—Scopus and Google Scholar—with keyword searches such as *olfactory*, *smell*, *design*, and *built environment*. The inclusion criteria focused on studies addressing sensory or specifically olfactory design –A branch of sensory design dedicated to the deliberate use of scent in influencing memory, affect, and spatial identity– within architecture and product design, with particular attention to research examining how scent and other sensory attributes shape user experience. Only peer-reviewed sources—journal articles, books, and conference proceedings—were considered. Exclusion criteria ruled out works unrelated to sensory or olfactory design, as well as non-peer-reviewed publications, anecdotal accounts, animal studies, investigations limited to virtual reality or digital interfaces, and studies outside the scope of human-centered design.

On Scopus, the search (2010–2025) initially yielded 43 documents. After screening, 14 articles were considered relevant, of which 5 were retained for review. These included key works such as Henshaw's *Designing with Smell* (2017) and Spence's *Senses of Place* (2020). On Google Scholar, 76 documents were retrieved, 17 shortlisted, and 6 retained. These included Barbara & Mikhail's *The Odor of Colors* (2021) and Sarstedt et al.'s work on multisensory design of retail environments (2024). Duplicates across both databases (e.g., Henshaw, Spence) confirmed the centrality of these sources but did not expand the methodological landscape. The results demonstrate that while significant research exists on the effects of ambient scent on perception, emotion, and well-being, no study proposes a concrete, systematic tool to guide olfactory design in practice. The literature emphasizes either experiential description or empirical measurement but does not bridge into actionable approaches for designers. Thus, a clear gap emerges despite the recognition of smell's influence and the growing discourse on multisensory design, there is no methodological tool that operationalizes olfactory design through crossmodal correspondences –Systematic associations between stimuli from different senses (e.g., colors and odors) that influence perception and behavior– with color and language [8–10,17,18,21–24].

In response, this article introduces the *Olfactory Attribution Circle (OAC)*, a conceptual tool developed through the integration of systematic literature, practice-based insights, and AI-assisted exploration. The study is guided by the research question: *Is it possible to develop a tool that can guide olfactory design through the systematic alignment of linguistic attributes and color correspondences, creating synesthetic relationships that inform multisensory experience?* Several secondary questions support this inquiry: (a) What role can artificial intelligence play in constructing and mediating such a tool?; (b) How congruent are the AI-generated correspondences with existing knowledge from psychology, color theory, perfumery, and crossmodal research?; (c) What opportunities and limitations emerge when comparing AI-driven mappings to expert insights and real-world applications?.

The built environment constitutes a critical arena for exploring these questions, since architectural spaces function not as neutral containers but as active mediators of identity and atmosphere. Through materials, spatial layouts, and lighting, they communicate multisensory information that engages smell, vision, and touch in concert [1–3]. Within this perspective, olfactory design cannot be treated as an isolated sensory layer; it must instead be understood as an integral component of architectural and experiential identity. Accordingly, the purpose of this article is not to empirically test the tool in practice, but to introduce and examine the OAC as a methodological approach that aligns olfaction, color, and semantic attributes—developed with the support of AI.

1.1. Methodological Approach

To address the research questions, the study adopted a multi-method strategy comprising five complementary phases: (1) a systematic literature review, (2) semi-structured interviews (Appendix A – Tables 1, 2), (3) a case study of EveryHuman (Algorithmic Perfumery), (4) an AI-assisted tool construction (Appendices B–C), and (5) an analytical cross-comparison (see Table 1). First, the systematic literature review provided theoretical grounding, identifying validated bipolar attributes and crossmodal patterns while revealing a persistent research gap. The review emphasized prior evidence of crossmodal correspondences—systematic associations between olfaction, color, and language—as well as the importance of crossmodal congruence in producing coherent and

 doi:10.20944/preprints202510.1361.v1

emotionally resonant multisensory experiences [25]. Second, semi-structured interviews were carried out with four representatives from academia and industry—a color specialist, an olfactory design practitioner, a fragrance-branding consultant, and a representative from the manufacturing sector—yielding practice-based insights into inclusion, intensity calibration, and feasibility [26].

Table 1. Overview of the Methodological Approach. Source: Author (2025).

Phase	Method	Output	Purpose/Insight
1	Systematic literature review	Theoretical foundation, identification of validated attributes	Reveal research gap and conceptual grounding
2	Semi-structured interviews	Practice-based insights	Identify inclusion, intensity and feasibility concerns
3	Case study – *EveryHuman*	Observation evidence of AI-mediated olfactory personalization	Evaluate potential and limits of AI in olfactory design
4	AI-assisted exploration	Mapping of essences-attributes-colors	Generate crossmodal correspondences
5	Analytical cross-comparison	Olfactory Attribution Circle (OAC)	Triangulate findings and refine tool

Third, a case study of EveryHuman (Algorithmic Perfumery) was used to investigate the intersection of olfactory design and artificial intelligence, highlighting both opportunities and limitations of computational approaches [27]. Fourth, the AI-assisted tool construction employed OpenAI's GPT-5 model to explore associations between 60 essences (provided by the author with common and scientific names and organized into olfactory families, based on Martone's *Grammatica dei Profumi* (2019), the twelve bipolar semantic attributes, and chromatic codes. GPT-5 was tasked with producing initial essence–attribute–color correspondences; these machine-generated outputs were subsequently structured by the author into a visual diagram and a consultation table (Appendices B–C), ensuring semantic coherence, chromatic accuracy, and functional usability [28].

Finally, an analytical cross-comparison triangulated evidence from the literature review, interviews, case study, and AI exploration to refine the Olfactory Attribution Circle (OAC). This triangulated design is consistent with Research-through-Design paradigms, in which knowledge is produced by iteratively generating artifacts and critically reflecting on their performance in relation to theory and practice. A key strength of the method is the explicit distinction between automatic generation (AI-assisted mapping) and human curation (authorial organization and visualization). A corresponding limitation—acknowledged as a natural avenue for future work—is the absence of an in-situ empirical validation of the OAC in multiple real-world projects and cultural contexts, which will be necessary to test generalizability and practical impact [29].

2. Literature Review

Designing with smell requires a multidisciplinary foundation that integrates history, semiotics, psychology, neuroscience, sensory design, and architecture. Perfumery has long employed taxonomies to classify fragrances, but these models rarely explain how olfaction interacts with other senses or how it functions as a semiotic system in spatial and cultural contexts. To situate the Olfactory Attribution Circle (OAC), this review examines three complementary strands: (1) the historical evolution of olfactory classifications, (2) semiotic approaches for structuring sensory meaning, and (3) empirical research on crossmodal correspondences between odor and color. Together, these strands provide the scaffolding for positioning the OAC as both a conceptual tool and a design methodology.

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2.1. Historical Evolution of Olfactory Classifications

Since antiquity, scholars have attempted to impose order on the elusive domain of smell. From Aristotle's natural groupings to Kant's dismissal of olfaction as the "poorest" of senses, philosophy often contributed to its marginalization [30,31]. In the nineteenth century, Piesse (1857) sought analogies with music, while in the twentieth century Henning's Olfactory Prism (1916) and Jellinek's (1951) psychological axes pursued geometric or affective orderings, though these proved fragile under scrutiny [32–35].

Within perfumery, classification assumed more enduring forms (see Figure 1): the Drom Fragrance Wheel (c. 1911) and Michael Edwards' Fragrance Wheel (1983) organized perfumes into coherent families such as Floral, Oriental, Woody, and Fresh, remaining widely used as communicative devices for consumers. Their clarity and usability explain their persistence, but their taxonomic and market-driven character limits their explanatory potential. They neither account for perceptual mechanisms nor for cultural and crossmodal dynamics. Contemporary initiatives, such as McLean's Urban Smellscape Aroma Wheel (2017), show how odors can be collaboratively mapped in cities, but they too depend on visual or metaphorical translations. These models thus provide historical baselines, essential for understanding the communicative legacy on which the OAC builds, while also clarifying the need for a tool that addresses design reasoning beyond mere classification [31, p.55-60].

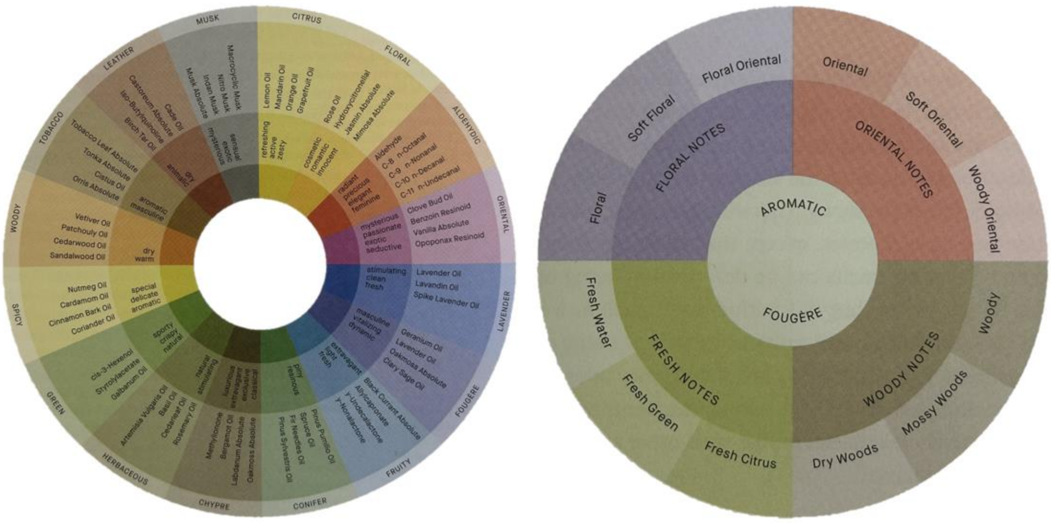

Figure 1. Left – Drom Fragrance Wheel (1911) and Right – Michael Edwards' Fragrance Wheel (1983). Source: Lupton and Lipps, 2018 (p. 58, 59).

2.2. Semiotic Approaches for Structuring Sensory Meaning

If taxonomies sought to stabilize smell, semiotic research reframed it as a language. Krippendorff's *Semantic Turn* (2006) is pivotal here: design is understood as a form of communication, and sensory descriptors function as semiotic units encoding perceptual, cultural, and affective meanings [36,37]. Classen, Howes, and Synnott (1994) demonstrated that odors act as cultural signs shaping social relations, while Pastorelli (2003, 2006) and Martone (2019) articulated grammars of perfume that resonate with this linguistic view [28,38–40]. Santos (2009) and Santaella (2018) further showed how product languages can be systematically structured [41,42]. Broader semiotic and cultural theories illustrate that both odors and colors carry layered symbolic codes [43–50].

Architecture and design research reinforced this perspective. Pallasmaa (2005) emphasized the phenomenology of multisensory atmospheres, while Henshaw et al. (2017) and Lupton & Lipps (2018) demonstrated the potential of smell as an active element in product and spatial experience [2,21,31]. Desmet and Hekkert (2007) linked emotional design to affective mappings between meaning and materiality, and Velasco and Spence (2019) extended this to multisensory coherence [51]. Within this trajectory, Boeri (2019) validated a system of twelve bipolar attributes—Delicate/Strong, Dynamic/Static, Fragile/Solid, Light/Heavy, Soft/Hard, Tidy/Messy—showing their inclusivity and neutrality in contrast to stereotypical commercial categories such as "masculine" or "feminine" [52,53]. Building on these precedents, the OAC operationalizes Krippendorff's linguistic view by structuring sensory meaning into a closed grammar of twelve attributes, ensuring coherence and interpretability while allowing for contextual and cultural adaptation [36].

2.3. Crossmodal Correspondences Between Odor and Color

Empirical research confirms that smell and vision are not perceived in isolation but interact systematically [54–75]. Gilbert, Martin, and Kemp (1996, 2008) identified stable hue–odor correspondences (e.g., citrus–yellow, floral–pink), while Kemp and Gilbert (1997) demonstrated that odor intensity aligns with color value, linking stronger odors to darker tones [54–56]. Morrot, Brochet, and Dubourdieu (2001) famously showed that the perceived aroma of wine can be altered by its color, while Schifferstein and Tanudjaja (2004) found consistent pairings of fruity aromas with bright warm colors and woody aromas with darker, desaturated hues [57,58]. Demattè, Sanabria, and Spence (2006) highlighted the mediating role of semantics, and Stevenson, Prescott, and Boakes (2012) distinguished perceptual, semantic, and hedonic pathways for congruence [59]. Herz (2004, 2007, 2016) further demonstrated the entanglement of odors, memory, and affect, underscoring the emotional dimension of crossmodal mappings [60–63]. Levitan et al. (2014) reviewed evidence across cultures, confirming both robustness and variability, while Spence (2011, 2020) emphasized applied relevance in branding, packaging, and retail design [8,9,24,64,65].

Color psychology reinforces these findings: lighter, less saturated hues tend to be perceived as delicate, calm, or fragile, while darker, saturated tones communicate solidity, heaviness, or strength [66–75]. Boeri (2019) confirmed the semantic stability of such associations in design education. Taken together, these results show that crossmodal congruence is not incidental but systematic: when odor and color are aligned, perception becomes clearer, affective responses are intensified, and memorability increases. Conversely, incongruence can generate noise or confusion in multisensory experiences [52,53]. At this point, the role of semantic attributes becomes crucial. By translating perceptual qualities into bipolar descriptors such as *Delicate/Strong, Fragile/Solid, Light/Heavy,* or *Soft/Hard*, designers gain a shared language for aligning odor and color choices with greater precision. These attributes act as a bridge between abstract identity and material execution, enabling congruence to be deliberately designed rather than left to chance. The literature thus converges on three key insights: (1) color and odor are semantically loaded, though culturally mediated; (2) their crossmodal correspondences are systematic and design-relevant; and (3) semantic attributes provide a validated approach for ensuring congruence in practice. What remains absent, however, is a methodology that integrates these strands into a tool for application in branding and spatial atmospheres.

3. Empirical Foundation: Interviews and Case Study

3.1. Semi-Structured Interviews: Academia and Industry

To complement the theoretical review, the study incorporated four semi-structured interviews (Appendix A) with professionals representing both academic and industrial perspectives on sensory and olfactory design. This methodological choice provided a balance between conceptual depth and practice-based knowledge. Each interviewee brought a distinct angle: a professor in sensory architecture and olfactory design with extensive research on atmospheres; a pharmacist-turned-fragrance designer leading a consultancy specialized in olfactory branding; an architect and color specialist with expertise in CMF (color, material, finish) design and university-level research; and a senior representative from the fragrance manufacturing sector, engaged in bridging artisanal perfumery with industrial production and regulation. The diversity of backgrounds created a multi-

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layered view of sensory design in the built environment, ranging from the dramaturgic sequencing of atmospheres to regulatory and supply-chain constraints, to the symbolic and narrative roles of color and scent.

A fundamental insight was that olfactory design cannot be reduced to the diffusion of added fragrances alone. Materials themselves—woods, leathers, textiles, metals, paints, and finishes—possess intrinsic odors that actively shape the atmosphere of a space. In this sense, materials act as sensory agents, carrying olfactory as well as tactile and visual information, and thus contributing directly to the experiential identity of the built environment. This resonates with phenomenological approaches to architecture, where atmospheres emerge from the interplay of matter, light, and sensory perception [1–3]. For the OAC tool, it reinforces the premise that olfaction must be integrated not as an external "plug-in," but as a layer inherently tied to materiality and crossmodal coherence. Another major theme was inclusivity. Respondents criticized the fragrance industry's reliance on stereotypes, such as florals being cast as "feminine," woody notes as "masculine," or fresh notes as "youthful." They welcomed the use of neutral bipolar semantic attributes—such as Delicate/Strong or Light/Heavy—that avoid gendered or generational bias, thus broadening participation and interpretive freedom.

Economic and operational feasibility also emerged as a concern. Consultants and manufacturers stressed that small and medium-sized enterprises often face barriers in implementing olfactory strategies, citing costs of diffusion and maintenance. However, accessible solutions such as programmable automatic diffusers controlled via mobile apps were highlighted as promising technologies for democratizing olfactory solutions. Closely tied to feasibility was the question of intensity control. All interviewees pointed out that diffusion must be carefully calibrated: overly intense aromas risk overwhelming or alienating users, while weak diffusion undermines effectiveness. This aligns with Malnar and Vodvarka's (2004) principle of sensory control, which emphasizes balance to prevent both overload and privation [1].

Sustainability was also highlighted as an increasingly sensorial expectation. Beyond regulatory standards, participants emphasized that sustainable practices—such as refillable packaging, natural materials, and visible craft processes—are themselves perceived as sensory cues of authenticity and care. This connects directly with the OAC's aim to align olfaction with the broader narrative and material culture of the built environment. Finally, participants converged on the strategic potential of olfactory design as a means of brand differentiation, memory encoding, and emotional resonance. Yet, a notable divergence appeared in relation to artificial intelligence. While some interviewees saw AI as a promising ally for creative exploration and systematizing correspondences, others questioned whether it could adequately capture the cultural nuances and subjective perceptions that are central to olfactory meaning.

In summary (see Table 2), the interviews revealed a set of convergences around the role of materials as olfactory agents, the value of neutral semantic attributes for inclusivity, the necessity of calibrated intensity, and the strategic potential of olfactory design. At the same time, divergences emerged regarding the role of artificial intelligence: while some participants saw AI as a promising ally for creative exploration and systematizing crossmodal correspondences, others expressed skepticism about its ability to capture cultural nuance and subjective interpretation. This divergence proved particularly relevant for the next stage of the study. To investigate the concrete possibilities and limitations of AI in olfactory design, we turned to a case study of *EveryHuman*'s Algorithmic Perfumery. Before presenting this case, the table below summarizes the main themes and insights from the interviews.

Table 2. Thematic synthesis of interview findings. Source: Author (2025).

Theme	Key Insight
Materials	Intrinsic odors of materials shape atmospheres.
Inclusivity	Semantic attributes preferred over gendered/age-based categories.

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Feasibility & SMEs	Barriers include cost and lack of design culture; need approaches and affordable technologies.
Intensity	Balance is critical: avoid overstimulation or imperceptibility.
AI Role	Potential for exploration vs. skepticism on cultural nuance.
Strategic Potential	Olfactory design as memory, identity, and differentiation tool.
Sustainability	Refill, reuse, authenticity, and crafted imperfection as sensorial values.

3.2. Case Study: EveryHuman's Algorithmic Perfumery

This case study investigates the Algorithmic Perfumery developed by *EveryHuman*, a project founded by Frederik Duerinck and Anahita Mekanik that integrates art, science, and technology to enable the creation of personalized fragrances through artificial intelligence. The Copenhagen unit, inaugurated in 2024, provided the setting for this study and served as a living laboratory for observing how computational systems mediate between individual attributes, crossmodal associations, and olfactory outcomes (see Figure 2). The methodology followed an observational approach with active participation, allowing the researcher to engage in the full user journey. This included completing the online questionnaire, experiencing the AI-driven generation of fragrances, interacting with the physical store environment and its technological interface, and documenting each stage through detailed notes and photographs [27]. Such an approach ensured firsthand understanding of both the human–machine interaction and the sensory outputs produced, situating the case within broader discussions of human-centered design in multisensory environments [4–6].

A distinctive feature of the process was the comprehensive questionnaire, structured into 22 sections covering demographic, lifestyle, and personality descriptors, as well as abstract associations such as the "Bouba/Kiki" test and self-perception along axes like "realist" or "dreamer." Particularly significant was the integration of an interactive color wheel, which enabled users to select from an expansive chromatic spectrum rather than being restricted to predefined swatches. This step underscored the importance of color in olfactory attribution: warm hues such as reds and oranges often aligned with gourmand or spicy accords, while cooler hues like blues and greens tended to correspond with aquatic or herbal compositions. These findings resonate with prior crossmodal research, which consistently demonstrates perceptual linkages between visual and olfactory modalities [7–9,58,65–70].

Figure 2. *Every Human*'s Algorithmic Perfumery in Copenhagen. Source: Author (2025).

Once the questionnaire was completed, the AI processed the data and produced three distinct fragrance options. Each option included a breakdown of top, heart, and base notes, a chromatic representation that reflected the inferred sensory identity, and semantic mappings that linked linguistic descriptors and personality traits to olfactory families. For instance, participants who described themselves as "energetic" were directed toward citrus and aldehydic accords; those who identified as "dreamers" or "artsy" were associated with floral–woody nuances; while individuals selecting "dark" as a defining attribute received resinous or smoky formulations. These mappings illustrated the underlying principle of attribution: the transformation of verbal and chromatic input into olfactory output. The experience culminated in the physical preparation of the perfume, where robotic installations blended the chosen formula with visible mechanical precision. The process was complemented by the personalization of labels and packaging, as well as the opportunity for iterative refinement. A dedicated "scent exploration table" allowed participants to test individual fragrance notes, compare them with the generated blends, and request adjustments. This stage emphasized the role of human agency: while AI generated the initial formulations, refinement required sensory judgment, negotiation, and cultural interpretation by both staff and users.

The study revealed several key insights. First, the system demonstrated a notable capacity to translate abstract attributes into coherent olfactory formulations, supporting the notion that semantic descriptors and chromatic choices can serve as reliable inputs for fragrance design. Second, the incorporation of color confirmed the importance of crossmodal congruence, reinforcing existing literature that highlights the systematic alignment of brightness, saturation, and hue with odor intensity, volatility, and weight. Third, the case underscored that AI cannot operate independently of human authorship. Human actors remained essential in calibrating intensity, fine-tuning accords, and ensuring cultural and contextual relevance. In terms of implications for the OAC tool, the *EveryHuman* case demonstrates that the combination of language attributes and chromatic cues offers a viable pathway for structuring olfactory design. It also shows that effective sensory environments require iterative refinement between computational systems and human interpretation, rather than automated generation alone. Moreover, the case highlights the importance of controlling intensity and dosage—a concern raised by interviewees and consistently noted in sensory design literature (Malnar & Vodvarka, 2004)—to ensure that fragrances enrich rather than overwhelm an atmosphere. Finally, the study affirms the position that AI functions as an augmentation tool: it broadens the creative search space and reveals patterns of correspondence, but the ultimate responsibility for coherence and cultural resonance rests with the designer.

4. Results

The divergences identified in the interviews—particularly regarding the role of artificial intelligence in olfactory design—combined with the insights from the *EveryHuman* case study and the extensive body of literature on crossmodal correspondences, color theory, semiotics, psychology, and perfumery, provided the foundation for developing the Olfactory Attribution Circle (OAC). The OAC emerged as a hybrid tool, in which AI-assisted exploration was systematically combined with authorial design decisions. This process was intended to test whether artificial intelligence could effectively support the attribution of aromas, colors, and linguistic descriptors in a coherent and congruent manner, while also recognizing its limitations in achieving visual precision and in accounting for cultural nuance. The results are therefore presented in two parts: first, the construction of the OAC with AI, and second, its proposed application as a step-by-step tool for olfactory design in the built environment.

4.1. Construction of the OAC

The development of the OAC began with the preparation of a dataset comprising 60 essences or essential oils, each identified by both their common and scientific names and classified into established olfactory families, including Floral, Fruity, Woody, Amber/Oriental, Aromatic, Citrus, and Musky. This taxonomy was carefully curated by the author, drawing on Martone (2019), in order to guarantee coherence with perfumery literature and ensure the reliability of the input provided to the AI [. The inclusion of scientific nomenclature served a dual purpose: it eliminated ambiguity that

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often arises from the cultural and semantic interpretation multiplicity of common names and it situated the dataset within a rigorous academic foundation [28].

To connect the dataset with semantic dimensions, the essences were mapped onto twelve bipolar attributes widely recognized in design and color research: Delicate/Strong, Dynamic/Static, Fragile/Solid, Light/Heavy, Soft/Hard, and Tidy/Messy [7,51–53]. These attributes were selected for their strong validation in the literature as well as their neutrality and inclusivity, offering descriptors that move away from gendered or generational stereotypes such as "masculine" versus "feminine" or "youthful" versus "mature." Instead, they establish a universal and accessible vocabulary, encouraging broader interpretive participation while ensuring semantic clarity. In this way, the attribute approach operated as a semantic bridge, linking abstract identity with the tangible articulation of olfactory, chromatic, and linguistic elements.

Based on these foundations, the AI was engaged in a step-by-step prompting procedure (see Table 3) designed by the author. The system was first provided with the dataset of 60 essences, each tagged with their olfactory family. Next, the twelve bipolar attributes were introduced, and the AI was instructed to distribute essences evenly across them, creating five essences per attribute. While the AI was able to generate plausible distributions, several duplications emerged—for instance, Rose was allocated simultaneously to both "Soft" and "Solid," while Pomegranate appeared under both "Soft" and "Messy." These duplications reflected the inherent semantic ambiguity of certain essences but also revealed the AI's difficulty in navigating polysemic cultural meanings. At this stage, no semantic choices were made by the author; instead, the process relied on iterative prompting, whereby the AI was repeatedly asked to refine its distribution until a balanced and duplication-free outcome was achieved.

Table 3. Step-by-step procedure for AI-assisted generation of the OAC. Source: Author (2025).

Step	Action	Purpose
1	Provide AI with dataset of 60 essences (common names, scientific names, olfactory families).	Ground the system in reliable taxonomy.
2	Introduce the 12 bipolar attributes and instruct AI to distribute essences equally (5 per attribute).	Create balance across the semantic approach.
3	Analyze outputs: resolve duplications (e.g., Rose allocated to both *Solid* and *Soft*; Pomegranate in *Soft* and *Messy*). Iterative refinement applied.	Ensure semantic clarity and uniqueness.
4	Request AI to associate each essence with a color (initially in NCS, later converted into RGB for digital applications).	Establish crossmodal correspondences aligned with chromatic coding.
5	Evaluate AI results for semantic coherence and cultural resonance; manually refine inconsistencies.	Guarantee conceptual and aesthetic accuracy.
6	Attempt to generate visual diagram (circle segmented into 12 equal parts, each with attribute, essences, and colors).	Test AI's capacity for visual representation.
7	Recognize limitations: AI was unable to segment the circle evenly or apply color codes consistently.	Identify scope and boundaries of AI assistance.
8	Author creates final consultation table and visual OAC diagram based on AI descriptions	Assert authorship and ensure usability.

Once a balanced distribution was achieved, the AI was tasked with associating each essence with a corresponding color, initially in NCS notation and later translated into RGB for digital representation. The outputs consistently echoed crossmodal correspondences reported in the literature, such as the alignment of citrus essences with bright, luminous hues and woody or resinous notes with darker, heavier tones [7,58]. The use of the Natural Color System (NCS) was particularly relevant, as it is a widely adopted standard in architecture, interior, and environmental design, enabling precise specification of perceptual dimensions such as hue, saturation, and brightness within built environments. The subsequent translation into RGB notation provided continuity with digital platforms, allowing the OAC to bridge physical spatial applications with computational and visualization tools. These results reinforced the validity of the AI's semantic reasoning while simultaneously confirming patterns already established by empirical research.

However, limitations quickly became evident. On the one hand, semantic ambiguity persisted as a recurring challenge: certain essences carried multiple interpretative possibilities, as exemplified by Rose oscillating between "Soft" and "Solid," or Labdanum, which could be interpreted as both "Heavy" and "Static." While such ambiguities can enrich discussion, they underscored the AI's limited ability to reconcile the cultural and semiotic complexity embedded in olfactory meaning. On the other hand, visual incoherence proved even more constraining. When prompted to generate the OAC diagram, the AI consistently failed to segment the circle into twelve equal parts or to apply the provided color codes faithfully. This revealed its incapacity to incorporate structured design principles into a coherent graphical output, highlighting the boundaries of its applicability.

Consequently, the final consultation table (Appendix B) and the visual OAC diagram (Appendix C) were produced directly by the author, given the AI's incapacity to generate a coherent visual representation. While the AI outputs served as raw material, they were not semantically altered: all correspondences between attributes, aromas, and colors were preserved exactly as generated by the system. The author's role was to reorganize these outputs into a usable design tool, defining the consultation table with the categories: a) Essential Oil; b) Scientific Name; c) Olfactive Family; d) Language Attribute; e) Meaning; f) Color (NCS Code); g) Color (RGB Code) and h) Color Description. This ensured clarity, transparency, and practical usability. In addition, the author created the visual OAC diagram itself, segmenting the circle into 60 equal parts, each corresponding to one essence, represented by its associated RGB color, and grouped according to the 12 bipolar language attributes (five essences per attribute).

Importantly, the circle was organized according to a structural logic in which each attribute's opposite occupied the diametrically opposite position on the diagram (e.g., Delicate directly opposed to Strong, Light opposite Heavy). Such geometric mirroring was intentionally adopted to enhance cognitive legibility and visual equilibrium, allowing users to immediately perceive contrasts and affinities across the sensory spectrum. By aligning opposites through spatial symmetry, the OAC facilitates comparative reasoning and supports the designer's capacity to evaluate congruence and tension between olfactory, chromatic, and linguistic dimensions. In this sense, while the AI functioned as a generative partner, surfacing patterns and ambiguities, the construction of the consultation tool and diagram required human authorship in terms of formatting, organization, and visualization—without intervening in the semantic content of the mappings and cross-relations made by the AI.

4.2. Application of the OAC

The Olfactory Attribution Circle (OAC) is proposed as a structured tool to support designers, architects, brand managers, and consultants in integrating olfaction into spatial and brand experiences. Its application is particularly relevant in contexts such as retail, hospitality, cultural exhibitions, and brand activations, where the built environment functions as a communicative medium and sensory atmospheres play a decisive role in shaping identity and memory. The OAC follows a methodology inspired by established design approaches, structured into four iterative phases: Investigate, Attribute, Designate, and Test (see Table 4) [76,77]. Each phase connects abstract identity to material decisions, ensuring that olfactory strategies are coherent, inclusive, and feasible.

Table 4. Summary of OAC's Phases and Actions. Source: Author (2025).

Phase	Key Question	Main Actions	Expected Outcome
Investigate	What atmosphere and identity are desired?	Ethnography, observation, user insights	Cultural and sensory identity map

doi:10.20944/preprints202510.1361.v1

Attribute	How is identity linguistically expressed?	Workshops, word clustering, OAC mapping	Selection of bipolar attributes
Designate	How can identity be materialized?	Olfactory composition, color palette, material selection	Sensory design strategy
Test	Does the experience communicate the intended identity?	User evaluation, affective measures	Validation and refinement

4.2.1. Investigate

The process begins with the definition of identity, which encompasses atmosphere, communicational intent, and target users. This identity is mapped through three interconnected layers: (1) Users, whose needs, perceptions, and emotional expectations must be understood; (2) Physical environment, which requires analysis of architectural features, spatial layout, materiality, lighting, and circulation; and (3) Products or services—or, in the case of ephemeral brand activations, the immersive experience itself. To capture these dimensions, the stage draws on ethnographic and observational techniques such as ethnography, observation and semi-structured interviews. Building on research into multisensory environments, it highlights that identity mapping must extend beyond material attributes to consider the cultural repertoires through which colors, aromas, and atmospheres are interpreted [4–9].

4.2.2. Attribute

In the second phase, descriptors of the intended identity are elicited through workshops or focus groups involving diverse stakeholders—designers, clients, brand managers, and architects. Participants are invited to freely generate words that describe the atmosphere, personality, or emotional tone they wish the space to convey. This first moment is intentionally open and intuitive, encouraging expressions that reflect both perceptual and affective impressions without imposing categorical limits. Once a broad vocabulary has been collected, a semantic clustering process is conducted to organize these words into relational groups. Through discussion and facilitation, participants identify affinities in tone, mood, and sensory connotation, grouping words that "speak the same emotional language." This participatory analysis gradually leads to the twelve bipolar attributes validated in design and color research (*Delicate/Strong*, *Dynamic/Static*, *Fragile/Solid*, *Light/Heavy*, *Soft/Hard*, and *Tidy/Messy*) [7,51–53].

For instance, words such as *calm*, *serene*, *fluid*, *poetic*, *translucent*, and *gentle* might naturally converge into the Delicate cluster. These expressions share associations with harmony, balance, and refinement, often corresponding in design terms to lighter color values, subtle transitions, and olfactory notes that evoke clarity or openness—such as watery or fresh floral accords. In contrast, words like *granular*, *structured*, *mechanical*, *dense*, *robust*, and *architectural* may gravitate toward the Hard cluster. They evoke ideas of resistance, tension, and persistence, aligning with darker chromatic palettes and heavier aromatic profiles, such as smoky, resinous, or mineral essences.

This stage is interpretive rather than algorithmic: clustering does not seek consensus but resonance. Participants collectively negotiate meanings and nuances, translating individual perceptions into shared semantic categories. The process also reinforces inclusivity, since the attributes operate as neutral conceptual poles—free from gendered, generational, or commercial connotations—and allow each group to project its own cultural and contextual interpretations. Once the clusters are finalized, the OAC diagram is introduced as a visual and cognitive mediator. Rather than prescribing solutions, it encourages reflection and dialogue: participants explore how the chosen attributes might be embodied through congruent combinations of color, material, and aroma. In doing so, the OAC becomes a bridge between abstract identity and sensory form, guiding the translation of linguistic intention into multisensory spatial experience.

4.2.3. Designate

The Designate phase focuses on material and sensory decisions, translating abstract attributes into concrete strategies. Fragrance composition is structured much like in perfumery, combining essences through different layers: top notes, with volatile accords such as citrus or herbs, introduce brightness and energy; heart notes, often florals or fruits, sustain the atmosphere; and base notes, typically woody or resinous, provide persistence and solidity. Materiality also plays an active role, as architectural materials can function as olfactory agents in themselves. Untreated woods such as cedar or oak, as well as leathers and textiles, contribute intrinsic odors that merge with added essences to form a global olfactory identity. The color palette is equally important, reflecting the selected attributes: pastels and high-value, low-saturation tones correspond to Delicate or Fragile, while darker and more saturated tones express Strong or Heavy. Finally, technological delivery ensures feasibility and control. Contemporary solutions such as programmable diffusers connected to mobile apps enable intelligent and economic dispersion of aromas throughout the day, preventing waste, maintaining consistency, and offering flexibility aligned with budgetary and operational constraints.

A critical aspect, emphasized by Malnar and Vodvarka (2004), is the control of sensory intensity. Overstimulation risks alienating users, while insufficient intensity makes the atmosphere imperceptible [1]. Designing olfactory experiences thus requires calibrating diffusion carefully, ensuring balance and subtlety. This phase also considers economic, human, and physical resources. Olfactory design must be feasible within the constraints of the project, aligning sensory ambitions with available budgets, maintenance capabilities, and spatial affordances. As Mozota (2006) highlights, design is not only a matter of creativity but also a matter of strategic integration into organizational and material realities [76].

4.2.4. Test

The Test phase represents the final stage of the process, dedicated to evaluating whether the sensory strategy effectively communicates the intended identity. This assessment goes beyond aesthetic appreciation to examine congruence and resonance: does the atmosphere accurately reflect the chosen attributes? Do users perceive coherence between aromas, colors, and brand identity? Does the experience generate memory, satisfaction, and value? To address these questions, a variety of tools may be employed, including experience diaries, post-experience interviews, affective evaluation scales such as SAM or PAD, and behavioral indicators like dwell time in retail environments. Research consistently demonstrates that crossmodal congruence enhances recognition, engagement, and even willingness to purchase [4–9].

Taken together, these four sequential phases demonstrate how the OAC operates as a methodological bridge between linguistic expression, chromatic perception, and olfactory design. By structuring sensory choices around validated semantic attributes and aligning them with available resources, technologies, and evaluation tools, the OAC provides a process that is inclusive—by avoiding stereotypes and enabling broader participation; strategic—by integrating creativity with economic and technological feasibility; and grounded—by drawing on established theories of design methodology and multisensory research. In this sense, the OAC serves simultaneously as a creative compass and a decision-making tool, guiding the development of multisensory atmospheres that are congruent, memorable, and emotionally resonant.

5. Discussion

The Olfactory Attribution Circle (OAC) demonstrates how crossmodal correspondences between language, color, and aroma can be systematically integrated into design processes. Its results reveal not only theoretical consistency but also strong alignment with expert insights and real-world practices, while simultaneously exposing the limitations of artificial intelligence in the field of sensorial design. The congruences observed in the OAC resonate with longstanding findings in

 doi:10.20944/preprints202510.1361.v1

design research. The alignment of *Delicate, Fragile, Light,* and *Soft* with pastel tones of high brightness and low saturation and with floral or fruity essences reflects systematic patterns documented in crossmodal studies. Boeri (2019) demonstrated in educational experiments that design students consistently associated attributes such as *Fragile* and *Soft* with light, pastel hues—technically defined as *high-value, low-chroma colors*—while darker, more saturated hues corresponded to attributes such as *Hard* and *Strong [52].* These findings echo Velasco and Spence (2019, 2020), who confirm that crossmodal congruence enhances coherence and memorability in multisensory environments [7–9]. Similarly, Schifferstein and Tanudjaja (2004) showed that fruity aromas align with bright, warm colors, while woody and resinous notes correspond to dark, desaturated hues. The OAC thus consolidates and visualizes these correspondences into a structured tool that bridges perceptual, semantic, and cultural dimensions [58].

From a phenomenological perspective, crossmodal congruence extends beyond cognitive or perceptual alignment and unfolds as an experiential condition that binds the senses into a unified field of awareness. Perception, as Merleau-Ponty (1945) and later Böhme (1993) observed, is not a summation of sensory inputs but an embodied synthesis

where vision, smell, and language co-constitute atmosphere. Within this unity, congruent

relations between scent and color generate what can be described as perceptual rightness—a pre-reflective sense of harmony that grounds emotional and spatial coherence [78,79]. When olfactory and visual stimuli resonate in tone, intensity, and semantic valence, they form an aesthetic continuum that stabilizes attention and enhances immersion. Conversely, incongruence introduces dissonance or tension, which, while potentially disruptive, can also be intentionally used to provoke curiosity or aesthetic friction. In this sense, congruence is not a constraint but a compositional parameter within an expanded sensory grammar. Aesthetically, crossmodal congruence can be understood as a principle of synesthetic composition, akin to musical harmony: a balance between sensory modalities that creates unity across difference. Following empirical evidence and phenomenological interpretation, Table 5 presents a synthesis on crossmodal congruence.

Table 5. Crossmodal Congruence Synthesis (Empirical/Phenomenological). Source: Author (2025).

Dimension	Empirical Evidence (Literature)	Phenomenological Interpretation	Design Implication
Odor-Color	Schifferstein & Tanudjaja (2004); Velasco et al. (2015)	Congruent hues reinforce perceptual clarity	Harmonize chromatic and olfactory values
Odor-Language	Krippendorf (2006); Boeri (2019)	Semantic attributes shape sensory meaning	Use bipolar descriptors for inclusivity
Odor-Memory	Herz (2016); Spence (2020)	Scents evoke embodied recall	Design for emotional resonance
Overall Congruence	Merleau-Ponty (1945); Böhme (1993)	Embodied unity and aesthetic coherence	Design atmospheres as unified fields

Through calibrated relations between chromatic value, odor weight, and linguistic tone, designers can orchestrate multisensory atmospheres that evoke affective resonance rather than mere decoration. Following Böhme's concept of Raumstimmung (1993) and Pallasmaa's phenomenology of atmospheres (2005), suchalignment transforms space into an active medium of feeling—an environment that is not only seen or smelled but felt as coherent [2,78]. In this view, crossmodal congruence functions as a form of aesthetic intentionality: it reflects the designer's capacity to choreograph sensory relations that embody meaning, emotion, and care. The OAC thus does not only operationalize sensory data but also extends the scope of design ethics toward phenomenological sensitivity—where material, chromatic, and olfactory elements converge in shaping atmospheres.

Yet, analysis revealed tensions and interpretive absences that highlight the need for human discernment in applying the OAC. Notably, the AI did not assign any essences to neutral or "non-colour" categories such as grays—tones frequently employed in architectural and interior contexts to temper or harmonize sensory atmospheres. This omission points to a blind spot in AI reasoning, as these "non-colours" are critical in modulating the intensity of chromatic and olfactory experiences. Similarly, certain allocations appeared less harmonious within the circular logic—for instance, *Vanilla* positioned under *Heavy* or *Pomegranate* aligned with *Soft.* These exceptions disrupt the otherwise balanced visual rhythm of the circle but simultaneously underscore the richness and complexity of olfactory semiotics. They also signal the need for interpretive agency: designers must refine, contextualize, and, when necessary, recalibrate the OAC mappings to align with project-specific meanings. Attributes such as *Messy* and *Tidy* also emerged as semantically ambiguous, reflecting culturally relative notions of order and chaos. Unlike more physically grounded pairs (*Light*/*Heavy*, *Delicate*/*Strong*), these abstract dimensions resist universal translation, requiring contextual sensitivity and critical reflection from users of the tool. Thus, the OAC should never be interpreted as a prescriptive taxonomy but rather as a structured departure point—a tool designed to stimulate reasoning, iteration, and cultural adaptation rather than dictate fixed sensory correspondences.

The interviews reinforced and expanded these insights by grounding them in practice. Experts emphasized that materials themselves act as *inherent sensory carriers*. Woods, leathers, textiles, and metals emit distinct odors that interact with added essences, becoming integral to the olfactory identity of a space. This observation aligns with the Designate phase of the OAC, where the global aroma should be conceived as a *layered architecture* integrating both designed fragrances and material emissions. As one interviewee emphasized, the scent of cedar in an interior, for instance, can be as defining as an added perfume—confirming that materiality has agency in sensory composition. Inclusivity also emerged as a central theme. Experts applauded the choice of neutral bipolar attributes, contrasting them with gendered or generational stereotypes common in marketing (e.g., "masculine" woods, "feminine" florals). The OAC's linguistic neutrality thus promotes cultural adaptability and fosters participation across age, gender, and background—an ethical as well as aesthetic advance in sensory design.

A recurring technical concern among all professionals was intensity control. Overly concentrated aromas risk alienating users, while insufficient diffusion results in imperceptibility. This aligns with Malnar and Vodvarka's (2004) notion of *sensory control*, emphasizing the need to modulate stimuli to avoid both overload and deprivation. The Designate phase explicitly addresses this by encouraging the use of smart diffusion technologies—such as programmable scent dispensers or app-connected nebulizers—that release balanced doses throughout the day [1]. These devices not only ensure consistency and comfort but also enhance sustainability by reducing waste and optimizing the use of volatile compounds. Sustainability and provenance, in fact, constitute an essential extension of the OAC discussion. Many natural essences—such as sandalwood, oud, or ambergris—carry environmental and ethical implications related to sourcing, extraction, and biodiversity impact. Future applications of the OAC must therefore integrate sustainability criteria at the design stage, privileging ethically sourced, renewable, or synthetic alternatives verified by certification bodies (e.g., IFRA, FSC, Ecocert). This ethical dimension links directly to the experts' insistence that *olfactory design must not only create atmosphere but also express responsibility*. Just as visual materials are now chosen for low embodied carbon, olfactory materials should be evaluated for their ecological footprint and supply-chain transparency.

At the same time, divergences emerged regarding the role of AI. While some professionals saw it as a powerful enabler for creativity, efficiency, and mass customization, others questioned its ability to capture cultural nuance and emotional subtlety. The study's results affirm both positions: the AI was remarkably consistent in aligning citrus essences with luminous colors and woody ones with darker tones—findings coherent with the literature—but it faltered in semantic disambiguation and failed entirely in generating the visual diagram. Despite receiving precise chromatic codes and segmentation parameters, it could not produce a coherent circular structure. These limitations

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required the author to manually organize the information, creating the consultation table and diagram that now define the OAC. In this sense, AI served not as a designer but as a creative sparring partner, expanding the search space while reaffirming the indispensability of human interpretation and design sensibility.

The validity of the OAC's conceptual model is further supported by real-world cases that exemplify congruent sensorial design. In Dolce & Gabbana's exhibition *Dal Cuore alle Mani* (From the Heart to the Hands) in Milan, Rose was selected as the central essence for its embodiment of Italian craftsmanship—delicate yet strong, deeply rooted in Mediterranean culture. Within the OAC's tool, Rose aligns with the attribute *Solid*, expressing tradition, mastery, and endurance—qualities mirrored in both the exhibition's narrative and material language. Similarly, Aesop's *The Second Skin* (Milan's Fuorisalone, 2025) demonstrated the agency of materials as olfactory and tactile communicators. Cedarwood, a key ingredient in Aesop's products, permeated the architectural installation both as matter and aroma, allowing visitors to experience its texture, scent, and symbolic depth simultaneously. In this setting, materiality itself became an active agent of meaning, confirming that matter in sensory design is communicative, not passive (see Figure 4).

Figure 4. Aesop's "The Second Skin" at Milan's Design Week 2025. Source: Author (2025).

By synthesizing evidence from the literature, expert interviews, and case study observation, the OAC emerges as a methodological and human-centered tool for translating semantic attributes into coherent chromatic and olfactory systems. It bridges theoretical knowledge and practical constraints, integrating sustainability, inclusivity, and feasibility. The following hypothetical applications illustrate its potential range: A fashion and accessories brand characterized by *Fragile* and *Delicate* might select pastel tones—soft pinks, violets, and yellows of high brightness and low saturation—paired with floral essences, producing an atmosphere of refinement and subtlety. Conversely, a sports car showroom anchored in *Strong* and *Solid* would gravitate toward darker, high-chroma colors and woody or resinous notes.

These examples demonstrate the OAC's operational power: it translates abstract language attributes into sensory decisions that unify color, aroma, and material presence. It also underscores the interpretive flexibility of the tool—its ability to inform, not dictate, design practice—while demanding human discernment to maintain cultural sensitivity, ethical responsibility, and aesthetic harmony. Ultimately, the OAC positions itself as a bridge between artificial intelligence and human authorship, between sensory coherence and cultural complexity, and between creative exploration and environmental consciousness. It does not claim to deliver absolute truths but offers a systematic, reflexive, and ethically aware approach to crafting atmospheres that are coherent, memorable, and sustainable within the built environment.

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7. Conclusion

This research set out to investigate whether olfactory design can be systematically oriented by linguistic attributes and chromatic associations, establishing synesthetic relations between language, color, and scent. The answer is affirmative: the Olfactory Attribution Circle (OAC) demonstrates that such relations can be structured into a coherent, replicable, and inclusive tool for multisensory branding and environmental design.

The study's contributions can be summarized in six key outcomes (see Table 6): (1) A structured methodology: the OAC proposes a four-phase process—Investigate, Attribute, Designate, Test—grounded in design research traditions, enabling designers to move systematically from abstract identity to material and sensory decisions [76,77]; (2) Inclusive semantic attributes: by clustering descriptors into twelve bipolar attributes, the tool avoids stereotyped divisions such as masculine/feminine or young/mature, thereby promoting inclusivity and broad participation [53]; (3) Systematic congruences: the results confirmed consistent mappings, with pastel, high-value, low-saturation tones aligning with delicate florals and fruits, while dark, saturated hues corresponded to woody and resinous notes, consolidating prior crossmodal research [54–75]; (4) AI as a creative partner: artificial intelligence enriched the exploratory process by generating associations between essences, attributes, and colors, yet revealed limitations in resolving semantic ambiguities and producing visual diagrams. The final OAC diagram and consultation table were thus curated by the author, underscoring the indispensable role of human sensibility in design; (5) Importance of balance and intensity: both interviews and literature highlighted that olfactory design depends not only on selecting appropriate essences but also on calibrating their intensity and diffusion. Technologies such as programmable diffusers can help achieve this balance, ensuring that atmospheres remain perceptible yet subtle.

Extensive evidence in the literature emphasizes that without crossmodal congruence, multisensory combinations often fail to generate positive outcomes. Incongruent sensory pairings can produce confusion, cognitive dissonance, and reduced engagement. By contrast, congruent multisensory experiences are consistently associated with higher satisfaction, stronger memorability, and enhanced influence on cognitive and behavioral processes. They also contribute to brand equity and market distinctiveness, reinforcing the role of sensory design as a strategic asset. This underscores the importance of approaches like the OAC, which seek to structure sensory choices around validated correspondences rather than arbitrary associations. Future research should therefore address three main directions: (1) Cross-cultural validation: testing whether the proposed associations remain stable or shift across different cultural environments; (2) Architectural applications: exploring how the OAC can be integrated into real projects, ranging from retail and hospitality to exhibitions and workplaces; (3) Longitudinal impact: investigating how olfactory–chromatic congruence influences cognitive and behavioral responses such as memory, well-being, and brand attachment over time.

Taken together, these outcomes show that the OAC is both a creative compass and a strategic tool, aligning sensory decisions with brand identity, spatial constraints, and user experience. However, the research also revealed limitations. AI's inability to produce coherent visual diagrams reflects the current immaturity of computational tools for sensorial design. Moreover, while the OAC provides conceptual clarity, its practical application across diverse cultural contexts remains untested. Odor–color correspondences are not universal but mediated by cultural repertoires, suggesting that the tool must be adapted and validated in situ. In conclusion, the OAC advances the field of multisensory design by bridging theory, practice, and technology. It confirms that aligning aromas, attributes, and colors enhances coherence, deepens emotional resonance, and fosters inclusivity. By balancing AI's computational possibilities with human creativity and critical judgment, the OAC offers a path toward designing atmospheres that are not only functional but also meaningful, memorable, and profoundly human-centered. Importantly, the tool should not be understood as a universal model, but rather as an initial proposition—an open methodological

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orientation to be refined, challenged, and expanded. Its greatest potential lies in the fact that the logic applied to attribute–aroma–color relations can be systematically extended to other sensory domains.

Attributes such as *soft* and *hard* can guide the selection of materials and the tactile qualities they communicate; descriptors like *fragile* and *delicate* can inform the choice of musical programming, associating them with slower tempos, softer dynamics, or higher pitches; and flavors may be tested in relation to olfactory and chromatic dimensions, generating congruence between what is seen, smelled, and tasted. In this way, the OAC provides a methodological orientation for building fully crossmodal experiences in which touch, sound, and taste are not treated as isolated layers but as integrated components of a coherent sensorial narrative. Rather than an endpoint, the OAC should be seen as a foundation for further inquiry—a methodological platform capable of guiding research protocols, informing design processes, and fostering evidence-based innovation in multisensory branding and environmental design. Its value lies less in delivering definitive answers than in inviting exploration, offering designers and researchers a structured yet adaptable path toward the creation of congruent, inclusive, and human-centered multisensory environments.

Table 6. Key Outcomes of the Research. Source: Author (2025).

Outcome	Description
Structured Methodology	Proposes a four-phase process—Investigate, Attribute, Designate, Test.
Inclusive Semantic Attributes	Avoids stereotyped divisions, promoting inclusivity and broad participation.
Systematic Congruence	Confirms consistent mapping across attributes, scents and colors.
AI: Creative Partner	Reveals AI possibilities and limitations as a creative partner for designers
Importance of Balance and Intensity	Evidences the importance of calibrating intensity and diffusion when designing for Smell

Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
CMF	Color, Material and Finish
GPT	Generative Pre-trained Transformer
NCS	Natural Colour System
OAC	Olfactory Attribution Circle
RGB	Red, Green and Blue
SME	Small and Medium Enterprise

Appendix A

Table A1. Semi-structured interview – Academia. Source: Authors (2025),.

nº	Question
1	Could you tell me a bit about your professional or academic background and your involvement in research or work that, in some way, considers the sensory aspects of spaces and products and their perceptual effects on people?
2	How do you see the role of sensory stimuli, with a focus on olfactory stimuli, in experience design within built environments, such as retail spaces and exhibition spaces? What do you think are the benefits that solutions involving olfactory stimuli can bring to both people and businesses?

 doi:10.20944/preprints202510.1361.v1

3	Which senses do you consider to be most explored in sensory design nowadays? Are there any, in your opinion, that are still underutilized?
4	Could you share examples of innovative solutions for each of the senses in physical environments?
5	Which companies or initiatives do you know that stand out for creating solutions for commercial and exhibition spaces?
6	What new technologies do you believe have the greatest potential to transform the field of olfactory design in built environments?
7	How can regenerative and sustainable design practices be integrated into the development of olfactory solutions in built environments? What precautions should professionals take to ensure that the solutions adopted are aware?
8	What are the main methodological challenges that arise when implementing effective olfactory design strategies in SMEs?
9	Is there a recommended approach or methodology for defining and selecting olfactory solutions to be adopted in a project? What would be the first step in this process?
10	How do you see the future of Sensory Branding and Experience Design in built environments in the coming years?

Table A2. Semi-structured interview – Industry. Source: Authors (2025).

nº	Question
1	Could you tell me a bit about the history of the company and how it started getting involved in the development of olfactory solutions for people or built environments?
2	What are the main challenges faced in integrating olfactory solutions into different types of spaces and sectors?
3	How does the company develop olfactory solutions? What technologies and methodologies do you use?
4	Does the company collaborate with designers, architects, and marketing professionals to implement olfactory solutions?
5	What are the main emerging trends and innovations in the field of sensory experiences?
6	What benefits does the integration of your olfactory solutions offer to the user? Is there a process to measure the impact (effectiveness) of these benefits?
7	Does the company integrate sustainable and regenerative practices in the development of olfactory solutions? Which ones?
8	Does the company customize olfactory solutions for different types of brands and people? Is there a process that guides this customization?
9	How do you see the adoption of olfactory experiences by SMEs (small and medium enterprises)? What do you think are the main obstacles in implementing sensory solutions for SMEs?
10	Is there a possibility of making customized olfactory solutions more accessible and scalable for SMEs? What kind of tools or resources would be necessary?

Appendix B

doi:10.20944/preprints202510.1361.v1

Table A3. Consulting Table – OAC. Source: Authors (2025).

Essential Oil	Scientific Name	Olfactive Family	Language Attribute	Meaning	Color (NCS Code)	Color (RGB Code)	Color Description
Freesia	*Freesia Refracta, Freesia Hybrida*	Floral	Delicate	Romantic softness, ephemeral charm	S1030-R10B	244, 194, 194	Pale Pink
Lilac	*Syringa Vulgaris*	Floral	Delicate	Spring fragility, gentle bloom	S1040-R30B	222, 200, 222	Light Lilac
Mimosa	*Acacia Dealbata*	Floral	Delicate	Warmth of sunlight, tender brightness	S0550-Y10R	255, 230, 135	Soft Yellow
Orange Blossom	*Citrus Aurantium Var. Amara*	Floral	Delicate	Innocent purity, luminous freshness	S0502-Y	255, 255, 240	White Yellow
Violet	*Viola Odorata*	Floral	Delicate	Nostalgic fragility, shy beauty	S2020-R50B	200, 162, 200	Lilac Pastel
Lemon	*Citrus Limonum Risso*	Esperidata	Dynamic	Sparkling vitality, radiant clarity	S0570-Y	255, 236, 61	Bright Lemon Yellow
Mandarin	*Citrus Reticulata*	Citrus	Dynamic	Joyful energy, playful freshness	S0580-Y50R	255, 152, 51	Orange
Mint	*Mentha Spicata e Mentha Piperita*	Aromatic	Dynamic	Cool action, refreshing sharpness	S1050-B50G	0, 204, 153	Bright Green
Rosemary	*Rosmarinus Officinalis*	Aromatic	Dynamic	Mental clarity, herbal crispness	S2060-G10Y	102, 153, 51	Silver Green
Bergamot	*Citrus Aurantium L. Bergamia*	Citrus	Dynamic	Bright zest, lively balance	S0560-G70Y	204, 255, 102	Yellow-Green
Cherry Tree	*Prunus Genus*	Fruity	Fragile	Ephemeral bloom, fleeting beauty	S1030-R20B	255, 182, 193	Pastel Pink
Helichrysum	*Helichrysum Italicum, Angustifolium*	Aromatic	Fragile	Precious fragility, golden warmth	S1030-Y20R	235, 208, 123	Light Gold
Jasmine	*Jasminum Officinalis, Jasminum Grandiflorum*	Floral	Fragile	Seductive delicacy, fragile intensity	S0505-R90B	245, 245, 255	White Blue Hue
Lavender	*Lavandula Officinalis, Lavandula Angustifolia, Lavandula Hybrida*	Aromatica	Fragile	Vulnerable calm, tender serenity	S2030-R60B	181, 126, 220	Lavender Lilac
Frangipani	*Plumeria*	Floral	Fragile	Tropical fragility, sensual sweetness	S0550-Y40R	255, 204, 153	Soft Apricot
Amyris	*Amyris Balsamifera*	Woody	Hard	Dry rigidity, austere presence	S4010-Y50R	153, 102, 51	Wood Grey-Brown
Eucalyptus	*Eucalyptus Sp.*	Aromatic	Hard	Cutting freshness, metallic edge	S3020-B50G	102, 153, 153	Blue-Green
Thyme	*Thymus Vulgaris*	Aromatic	Hard	Sharp herbality, strict intensity	S6030-G10Y	51, 102, 0	Dark Green
Robinia	*Robinia Pseudoacacia*	Floral	Hard	Rugged wildness, structured bloom	S6030-G30Y	51, 102, 51	Brownish Green
White Fir	*Abies Alba, Abies Balsamea*	Woody	Hard	Resinous firmness, alpine strength	S5020-G10Y	0, 102, 51	Pine Green
Almond Tree	*Prunus Amygdalus Var. Amara*	Fruity	Heavy	Dense sweetness, rustic weight	S3020-Y20R	123, 82, 41	Warm Brown
Liquidambar	*Liquidambar Orientalis, Liquidambar Styraciflua, Liquidambar Form*	Oriental Amber	Heavy	Resinous chaos, deep warmth	S5040-Y80R	153, 51, 51	Red-Brown
Opoponax	*Commiphora Erythracea Var. Glabrescens*	Oriental Amber	Heavy	Resinous weight, mystical depth	S6020-Y30R	102, 76, 51	Dark Amber
Vanilla	*Vanilla Planifolia*	Oriental Amber	Heavy	Sweet density, enveloping comfort	S1010-Y	255, 240, 200	Cream Beige
Benzoin	*Styrax Tonkinensis, Styrax Benjoin*	Oriental Amber	Heavy	Balsamic heaviness, soothing warmth	S3040-Y20R	141, 86, 51	Golden Brown
Cedar	*Citrus Medica L.*	Citrus	Light	Crisp brightness, zesty clarity	S2050-G80Y	204, 255, 153	Yellow-Green
Ambrette	*Hbiscus Abelomoschus Moschatus*	Musky	Light	Radiant musk, airy warmth	S1510-Y90R	255, 229, 204	Warm Nude
Angelica	*Angelica Archangelica*	Aromatic	Light	Subtle spirituality, herbal lightness	S1030-G10Y	204, 255, 204	Soft Green
Gardenia	*Gardenia Jasminoides, Gardenia Grandiflora*	Floral	Light	Pure luminosity, creamy clarity	S0502-G50Y	255, 255, 245	Yellow White
Neroli	*Citrus Aurantium Var. Amara*	Floreale	Light	Solar freshness, refined purity	S0505-G60Y	240, 255, 240	Pale Greenish White
Artemisia	*Artemisia Vulgaris, Artemisia Alba*	Aromatic	Messy	Bitter wildness, tangled herbality	S5020-G50Y	102, 153, 102	Grey Green
Tonka Bean	*Coumarouna Odorata, Dipteryx Odorata*	Oriental Amber	Messy	Excessive sweetness, gourmand chaos	S3010-Y30R	153, 102, 51	Cream Brown
Myrtle	*Myrtus Communis*	Aromatic	Messy	Dense green chaos, herbal disorder	S5030-G10Y	51, 102, 51	Dark Herbal Green
Star Anice	*Illicium Verum*	Aromatic	Messy	Exotic intensity, playful disorder	S3050-R30B	102, 0, 102	Deep Purple
Ylang-Ylang	*Cananga Odoratum*	Floral	Messy	Exuberant sensuality, lush disorder	S1070-Y10R	234, 173, 0	Golden Yellow
Osmanthus	*Osmanthus Fragrans, Olfa Fragans, Osmanthus Heterophyllus*	Floral	Soft	Honeyed softness, velvety sweetness	S0540-Y30R	255, 204, 153	Apricot Orange
Fig	*Ficus Carica*	Fruity	Soft	Creamy sweetness, gentle indulgence	S3030-R40B	153, 102, 153	Green Purple
Magnolia	*Magnolia Grandiflora, Magnolia Stellata*	Floral	Soft	Creamy floral tenderness, gentle elegar	S0505-Y80R	255, 248, 240	Cream White
Peach Tree	*Prunus Persica*	Fruity	Soft	Velvety tenderness, juicy softness	S1040-Y90R	255, 182, 120	Soft Peach
Pomegranate	*Piunica Granatum*	Fruity	Soft	Juicy affection, tender richness	S2070-R	204, 0, 51	Orange Pink
Cistus Labdanum	*Cistus Ladaniferus L., Cistus Creticus*	Oriental Amber	Solid	Dramatic resin, symbolic firmness	S4050-Y90R	136, 0, 0	Dark Red
Cypriol	*Cyperus Scariosus, Cyperius Scariosus*	Woody	Solid	Robust earthiness, dense strength	S7020-Y30R	102, 51, 0	Dark Earth Brown
Frankincense	*Boswelia Sp*	Woody	Solid	Sacred solidity, ritual power	S3040-Y20R	153, 102, 51	Golden Amber
Guaiacwood	*Bulnesia Sarmienti, Guaiacum Officinalis*	Woody	Solid	Dense woody stability, smoky root	S7502-Y	51, 51, 51	Charcoal Grey
Rose	*Rosa Damascena, Rosa Centifolia*	Floral	Solid	Symbolic strength, timeless presence	S1580-R	153, 0, 51	Crimson Red
Cypress	*Cupressus Sempervirens*	Woody	Static	Vertical austerity, meditative stillness	S7020-G30Y	0, 76, 38	Deep Green
Cedarwood	*Cedrus Atlantica, Juniperus Virginiana, Juniperus Mexicana*	Woody	Static	Timeless stability, classic grounding	S5020-Y30R	153, 102, 51	Dark Beige
Myrrh	*Commiphora Myrrha*	Oriental Amber	Static	Ritual immobility, sacred heaviness	S4040-Y30R	153, 51, 0	Deep Amber
Oakwood	*Quercus Robur, Evernia Prunasti*	Woody	Static	Tradition, stable rootedness	S6020-Y30R	102, 51, 0	Earth Brown
Olive Tree	*Olea Europaea*	Fruity	Static	Ancestral wisdom, grounded heritage	S6010-G70Y	102, 102, 51	Olive Green
Oud	*Aquilaria*	Woody	Strong	Mystical depth, intense mystery	S8502-Y	38, 28, 20	Black Brown
Patchouli	*Pagostemon Cablin*	Woody	Strong	Earthy power, sensual richness	S7010-Y50R	102, 51, 0	Dark Brown
Rosewood	*Aniba Rosaedora*	Woody	Strong	Noble strength, refined depth	S5040-R10B	102, 0, 51	Burgundy
Sandalwood	*Santalum Album, Santalum Spicatum*	Woody	Strong	Spiritual solidity, creamy depth	S3030-Y30R	153, 102, 51	Amber Brown
Vetiver	*Vetiveria Zizanioides*	Woody	Strong	Rooted grounding, earthy intensity	S6010-G10Y	51, 102, 51	Forest Green
Bitter Orange	*Citrus Aurantium Var. Amara*	Citrus	Tidy	Crisp order, structured freshness	S0560-Y30R	255, 183, 76	Golden Orange
Sweet Orange	*Citrus Aurantium Var. Dulcis Citrus Sinesia*	Citrus	Tidy	Vibrant clarity, playful balance	S0570-Y30R	255, 204, 102	Bright Orange
Medlar	*Mespilus Germanica*	Fruity	Tidy	Grounded rusticity, subtle sweetness	S3040-Y20R	206, 157, 108	Rustic Beige
Linden	*Tilia Sp.*	Floral	Tidy	Gentle order, calm elegance	S0510-G90Y	204, 255, 204	Soft Pale Green
Santolina	*Santolina Chamaecyparissus*	Aromatic	Tidy	Herbal neatness, organized green	S2020-G70Y	204, 255, 153	Pale Yellow-Green

 doi:10.20944/preprints202510.1361.v1

Appendix C

Figure A1. Visual Diagram – OAC. Source: Authors (2025).

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