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Sense of Order: The Effects of Machine Aesthetic on Biomaterials Favourability

Fadzli Irwan Bahrudin[a], Liew Yong Kian[b], Khalilah Zakariya[a], Nuraini Daud[c], Park Dong-Myung[d]
a) Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia, Kuala Lumpur, Malaysia
b) School of Media, Arts and Design, Asia Pacific University of Technology and Innovation, Kuala Lumpur, Malaysia
c) Faculty of Artificial Intelligence, Malaysia University of Technology, Kuala Lumpur, Malaysia
d) Division of Design, Incheon National University, Seoul, South Korea

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Abstract: Designers are increasingly creating materials from renewable and recycled sources to support a circular economy, aiming to mitigate the adverse effects of linear production and consumption. These materials are considered sustainable alternatives to non-renewable materials, such as fossil fuel-based plastics. While users may be drawn to the sustainability narrative and "biography" of such materials, the highly natural appearance of biomaterials can sometimes evoke unappealing user responses. This study examines how "machine aesthetics"—visible signs of production like graphical embossment and engraving—impact user perceptions of biomaterials. The research explores how surface alterations influence emotional responses and underlying appraisals by comparing reactions to biomaterial samples with a high degree of naturalness against those with embossed and engraved surfaces. Findings reveal that machine aesthetics evoke a sense of order, contributing to favourable responses and minimising other negative evaluations of the material aspects. Although users value biomaterials for their natural origins, structured human-imposed aesthetics satisfy a desire for aesthetic coherence and control. This finding suggests that people appreciate sustainable materials' natural imperfections when presented within a framework of manageability and familiarity.

Designers' Pursuit of Sustainable Materials

Designers constantly seek ways to improve living standards. Initially, materiality knowledge was limited to specific fields, but the 'democratisation of knowledge' has spread expertise across disciplines (Biccum, 2024), sparking a renewed interest in Do-It-Yourself practices (Ayala-Garcia et al., 2024; Parisi et al., 2017; Rognoli & Parisi, 2016) and sustainable materials and design (Faludi et al., 2020; Rognoli & Parisi, 2016).

The movement signifies a revival of holistic product-making practices, where designers engage deeply with material origins before transforming them into functional products. This reciprocal relationship allows the product maker and the material to influence and guide each other (Spencer, 2021). Such hands-on interaction fosters a meaningful connection with materials, enhancing the ability to create innovative and functional designs (Pedgley et al., 2021).

This approach echoes the fundamentals of traditional craftsmanship, where artisans master materials with finesse (de Groot et al., 2023), carefully transforming them into functional or decorative items imbued with care and affection (Fuchs et al., 2015). Their motivations were often tied to cultural and heritage preservation rather than explicit sustainability goals (Hasanah et al., 2023).

Designers' current pursuit of sustainable materials aligns with the principles of the circular economy, emphasizing resource sustainability and lifecycle efficiency (Djassemi, 2009). The materials explored offer various benefits, including reduced environmental impact, improved aesthetics, and enhanced user experience (Thundathil et al., 2023).

In addition to the traditional, hands-on, and intuitive approaches commonly employed in 'designerly' material development processes, the Material Driven Design (MDD) framework offers a structured methodology to guide designers in creating innovative material applications. It fosters a deeper understanding of a material's characteristics, behaviours, and experiential qualities (Karana et al., 2015). Additionally, frameworks like Material Driven Textile Design (MDTD) help designers explore and understand the scientific aspects of material creation (Ribul et al., 2021).

The explored materials include unconventional sources like agricultural waste fibres and living organisms such as bacteria and fungi (Bahrudin et al., 2017; Garcia et al., 2017). These innovations signal a shift toward integrating biological systems into material design, where organisms become production co-creators. Additionally, materials within this spectrum hold significant potential for biomimicry applications, such as self-cleaning properties and ultra-lightweight structures (Popescu et al., 2024) Designers play a pivotal role in directing and shaping these living systems to achieve desired material characteristics, as seen in the bio fabrication projects by Susanne Lee (Jewell, 2023), Zena Holloway (Mitra, 2023), and Mycotech Lab (Gultom & Welly, 2023). Materials derived from living organisms are still in their early stages, yet they add to the growing diversity of sustainable material innovations (Bahrudin et al., 2017).

User- Sustainable Material Appraisals

New materials entering the market face significant challenges compared to existing ones in user evaluations. Even plastic, now ubiquitous, was initially met with scepticism, requiring a lengthy gestation period before its successful acceptance (Cordier et al., 2024; Newport, 1997; Shashoua, 2012; Suggit, 1997).

Generally, user material appraisal is a complex and multifaceted process heavily influenced by an individual's experiences, cultural background, gender, age, and memories associated with existing materials (Karana et al., 2013). These factors shape users' emotional responses when encountering new sustainable materials, impacting their overall evaluation and perception of material quality(Gifford et al., 2000).

Research into user-material interactions has identified several themes that influence material appraisal, encompassing physical and non-physical properties. Key themes include sensorial, technical, expressive semantic, use, manufacturing, emotional, and associative description (Karana, 2006).Bahrudin & Aurisicchio (2018) introduced the concept of systemic appraisal, emphasising the perceptual evaluation of materials across their entire lifecycle, including origin, production, use, and end-of-life considerations.

Users often depend on sensorial properties to form initial impressions of unfamiliar materials, drawing comparisons to known materials based on past experiences (Ortíz Nicolás, 2014). In the absence of familiarity, easily observable cues—such as visual appearance and tactile feel—serve as key quality indicators, as they are the most accessible and quickly processed forms of information (Vermeir, 2020).

Therefore, designers must understand how materials' visual and tactile characteristics influence user perception and experience (Haug, 2019). For instance, biomaterials may successfully mimic the texture of leather, yet their unfamiliarity can trigger doubts about functionality, potentially affecting user comfort and confidence (Bahrudin & Aurisicchio, 2018; Ram & Sheth, 1989). Historically, early plastics were designed to imitate familiar materials like ivory and wood to ease user acceptance.

User evaluations of sustainable materials become more complex when biographical narratives are introduced, adding layers to the appraisal process. For instance, some users initially rejected plastic due to its association with impurities from beneath the earth (Meikle, 1997). As the material's background becomes more transparent, the evaluation process grows more intricate. For example, "This material is made of used ground coffee powder from cafes in London" highlights key aspects of its lifecycle, including its origin and provenance (Bahrudin, 2019). Users will then evaluate the narratives based on prior knowledge and specific concerns. The cup from coffee waste might seem like an effective repurposing strategy. However, concerns about transporting waste from distant regions could complicate perceptions of sustainability, leading to varied judgments. (Camilleri et al., 2023; Catlin et al., 2017).

Adding complexity to material appraisals, the concept of "sustainable" is culturally nuanced, and the evaluation is context-specific. For instance, in Japan, local terms such as "material for lifecycle design" and "material of higher efficiency" are used to describe specific aspects of sustainability, reflecting variations of sustainable practices (Halada & Yamamoto, 2001). In Malaysia, the formal jargon *lestari* (see Mohd Salleh, 2012) is often employed to denote sustainability, though these terms may lack everyday familiarity and emotional resonance. These linguistic and conceptual variations underscore the influence of cultural and regional contexts, shaping diverse perceptions of sustainable materials.

Despite sustainability assessments, the origin of material can evoke diverse emotional responses and evaluations, influenced by cultural significance and symbolic meaning (Chávez et al., 2015). For instance, a study on products made from coffee waste fibres revealed that Arab respondents associated coffee with heritage and cultural lifestyle, favouring its application in furniture, while Malaysian respondents perceived coffee as an edible plant, preferring its use in food-related products (Ismail, 2024).

To address these challenges, designers must craft narratives that resonate with users' psychological and social contexts, enhancing the desirability of sustainable materials. By understanding the narratives of the materials they work with, designers can make more informed decisions and better communicate the sustainability credentials of their designs to users (Kesteren et al., 2007; Rognoli et al., 2022).

Biophilic Design and Human-Nature Relationship

Sustainable materials often feature distinct surface qualities, such as the unbleached natural brown of recycled tetra-pak packaging (Ma, 2018). By preserving these natural characteristics, designers emphasise authenticity and foster a sense of connection to nature. Research highlights that bio-based and bio-fabricated materials offer unique experiential qualities, adding aesthetic value through new sensory experiences and cultivating empathy for the natural environment (Sayuti & Kristensen, 2020).

The biophilic design principles aim to integrate natural elements into everyday living, enhancing well-being and encouraging environmental stewardship (Salonen et al., 2022). By incorporating natural textures, organic forms, or sustainable materials, designers can evoke feelings of calm, well-being, and harmony (Branca et al., 2024; Wolfs, 2015). It enhances the quality of life for modern society, which faces the adverse effects of urbanisation (Xia et al., 2024). It taps into humans' innate desire to connect with nature, which can be linked to a higher level of Maslow's hierarchy of needs (Maslow, 1954; Yalch & Brunel, 1996).

However, since the early modern era, humans have often sought to control nature. French-style gardens, known as *Jardins à la française*, gained prominence for their meticulous organisation, geometric precision, and symmetry (Yoon, 1994). Ornamental pruning, also known as topiary art, sculpts greenery into precise shapes, creating a structured visual harmony that evokes order and control. A well-maintained lawn, a symbol of aristocratic ownership, demands significant labour (Harris et al., 2013) and establishes a controlled boundary, reinforcing a sense of autonomy (Ignatieva et al., 2020).

Similarly, although the Asian and Japanese gardens embrace more naturalistic forms, shaping nature following its natural tendencies (Saitō, 2017), imperfections, irregularities, and transient qualities of materials are celebrated in the concept of *wabi-sabi* (Kongot & Matz, 2021; Siyi & Ayob, 2024; Venzo, 2019), the aesthetic concept incorporates a balance between natural beauty and the deliberate exertion of human control. The *karesansui*, or Japanese rock gardens, exhibit a deliberate structural pattern (Van Tonder et al., 2003), conforming to human ideals of form and proportion.

In contemporary society, people have become accustomed to the high standards of machine production, which consistently delivers precise, uniform, and high-quality outputs (Liebl & Roy, 2003; Markoff, 2012). As highlighted by Akbar et al. (2020), humans exhibit a strong preference for control and predictability, often opting for controlled environments over the uncertainties of nature. Plastics, with their durability and versatility, offer a sense of control, allowing individuals to experience the aesthetic qualities of natural materials without their inherent vulnerabilities, such as erosion or decay. Hence, artificial substitutes, such as plastic-wood composite flooring or PVC stone walls, are frequently employed for convenience. (Tabassum & Park, 2024; Zhong et al., 2022).

Advancing the Uptake of Sustainable Materials

When engaging with sustainable materials, users encounter a complex interplay of cognitive and emotional responses. Research indicates that the visual and tactile properties of materials—such as texture, colour, and perceived naturalness—play a crucial role in shaping user perceptions of value, aesthetics, and overall desirability (Dhakal et al., 2017; Thundathil et al., 2023). While emphasising the natural qualities of a material can draw attention to its sustainability, user acceptance is not guaranteed; it is often mediated by perceptions of quality, functionality, and visual appeal (Magnier & Crié, 2015; Magnier & Schoormans, 2015; Overvliet et al., 2014).

Users generally regard naturalness as a desirable attribute, influenced by both practical benefits and personal values (Li & Chapman, 2012). Materials that retain visual cues of their original state are often more readily judged as natural and environmentally friendly (Zhang et al., 2023). Users continue to embrace the natural appearance of building materials, even when they are aware that the materials are artificial (Zhang et al., 2023). Acceptance of material attributes like sensory appeal and perceived naturalness can strengthen emotional attachment, ultimately encouraging longer product usage and extending its lifespan (Haines-Gadd et al., 2018).

However, Karana (2012) highlights the inherent tension in biomaterials, where attributes associated with naturalness and high quality frequently conflict rather than align. A natural material may be made plain-looking to ensure easier acceptance, though this can diminish its perceived sustainability value. Conversely, materials that retain distinctive natural appearances might enhance eco-friendly appeal but face scepticism regarding durability. In such cases, strengthening the material's narrative can improve perceptions of its functional qualities (Bahrudin, 2019). But, such dynamics are rarely straightforward. Material acceptance is also shaped by familiarity with surface qualities and alignment with the material's sustainability narrative. Therefore, thoughtful messaging and intentional design strategies are essential to navigating these nuanced evaluations and fostering greater user acceptance of sustainable products (Houf et al., 2024).

To what extent can sustainable materials retain their natural surface characteristics while still being deemed desirable and practical by users? This critical balance between material authenticity and user preference is fertile for further exploration.

Method

This qualitative research explores users' affective responses and underlying appraisals of three Kombucha bacterial cellulose-based material samples. The study was conducted in two phases. The study's first phase involved fifteen university students (aged 19-20) from six countries recruited through convenience sampling. Their age and educational background likely indicate biospheric and altruistic behaviour (Balundė et al., 2020). The second phase was conducted with ten young adult executives (aged 25-35) from various backgrounds in an urban setting. The participants' diverse backgrounds offered a rich understanding of the material samples. The same data collection procedures were used in both phases.

Participants examined three 10cm x 10cm Kombucha-based bio-composite samples. The three samples, A, B, and C, varied in surface texture: A was highly natural, B had laser-hatched patterns, and C had an embossed texture (See Figure 1). Samples A and B are kombucha-based materials reinforced with plant fibres. However, Sample B features engraved geometric patterns, intentionally contrasting with the highly natural appearance of the material. Sample C, without plant fibres, had a moulded surface with small, uniform embossments. All three samples were unbleached and undyed, retaining a natural brown colour.

A list of emotion cards was given to induce participants' affective responses, aiming for explicit, accurate appraisals and expressions (Table 1). The material samples were accompanied by a brief description: "This sustainable material is made from natural fibres and microorganisms. It's a biodegradable, eco-friendly alternative to single-use plastics, suitable for packaging and leather goods". This description provides basic information without explicitly mentioning bacterial cellulose, which could potentially bias participants' perceptions.

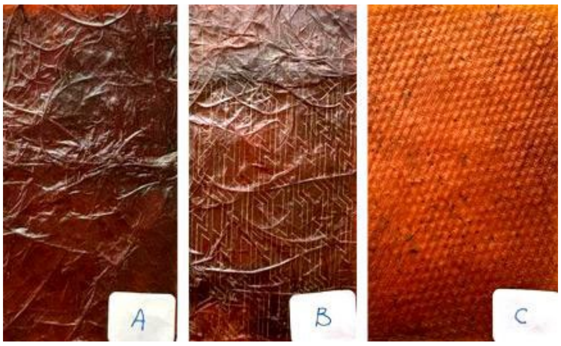

Figure 1. Close-up pictures of the material samples.

Positive Emotion	Negative Emotion
Joy	Irritation
Pleasant	Unpleasant
Satisfaction	Dissatisfaction
Pride	Shame
Admiration	Anger
Curious	Anxiety
Hope	Fear
Impressed	Unimpressed
Love	Dislike
Admire	Disgust
Enthusiastic	Disinterested
Peaceful	Uneasy
Happy	Discomfort
Easy	Doubt
Contentment	Reserved
Respect	Insecure
Surprise	Confused

Table 1 List of Emotions (synthesised from Desmet, 2003; Ebe & Umemuro, 2015).

Each participant was individually presented with the three material samples. They were encouraged to closely examine each sample and express their feelings using the emotion list. Participants were asked open-ended questions to trigger free expression of their thoughts. Each session lasted about thirty minutes.

The interview data—consisting of audio recordings and field notes, including notable non-verbal expressions—were coded and analysed using NVivo software (Figure 2). Each participant's responses were examined as a network of interconnected emotions and underlying reasons. Emotions were often expressed before or after the accompanying rationale, with some instances showing multiple reasons linked to a single emotional response.

Figure 2. Data coding and analysis using Nvivo.

Appraisal Theme	Terms and phrases used in the interview
Sensorial	Color, hair texture, bumpy texture, herbal tea smell, dry longan smell, smooth surface, transparent, translucency, fiber texture, geometry texture
Associative	Like-leaves, like-dry leaves, like-leather, like-fabric, like cool fever patch, like-plastic, like-dry longan
Manufacturing Process	Hatching process, engraving pattern, pattern making process
Expressive Semantic	Natural, luxury, futuristic, beautiful
Use	For bag, for recycled paper wrapper, for craft usage, for lighting design
Systemic	Natural material, environmentally friendly, eco material
Technical	Durable, strong, flexible

Table 2 Material appraisal themes (Bahrudin, 2019b; Karana, 2009) and examples of phrases in the appraisals.

The analysis aims to determine whether the appraisals for material Samples B and C are more favourable than Sample A, particularly concerning sensory experience, as influenced by the 'machine aesthetic'. The data were analysed using thematic analysis to identify recurring patterns. Specifically, the process involved three steps: first, all emotions were classified into positive and negative categories (Table 1). Second, the underlying reasons for each emotion were categorised based on material appraisal themes (Bahrudin, 2019b; Karana, 2009) (Table 2). Third, to gain deeper insights into the appraisals, participants' expressions were further examined to identify key issues or encapsulated appraisal components (Demir et al., 2009) (Table 3). The emotional-reasoning networks were visually mapped, with black lines indicating connections from Phase 1 and red lines representing those from Phase 2 (Figures 4, 5, and 7).

Appraisal components	Descriptions	Examples of positive and negative emotions
Motive consistency	The fundamental question is: 'To what extent does this situation correspond with my motivations?'	**Joy (Irritation)** - elicited when a the situation is appraised as consistent (conflicting) with one want.
Intrinsic pleasantness	The intrinsic pleasantness component pertains to the sensory appeal of an object. The corresponding question is: 'To what degree does this object possess sensory appeal?'	**Pleasant (Unpleasant)** - expressed due to affection (disliking) towards particular sensorial properties.
Expectation confirmation	This is about whether things turned out the way we thought they would. Our expectations can be anything from guessing how a new gadget will work to knowing what a button does on our phone.	**Satisfaction (Dissatisfaction)** - expressed when the outcomes of an event confirms (violates) one's expectations.
Agency	This component explores the issue of responsibility for a given situation. Potential attributions include self, others, and situational factors.	**Pride (Shame)** - elicited when one believes that he or she caused a pleasing (disturbing) event. Thus, he or she attributes the outcome to his effort and skill.
Standard conformance	This component asks, 'Does this situation align with social norms and expectations?' A situation can be seen as breaking, meeting, or exceeding these standards.	**Admiration (Anger)** - evoked when a situation is appraised as surpassing (violating) a standard.
Coping potential	This component examines one's perceived capacity to address and mitigate harmful elements of a situation. A sense of agency can lead to overt attempts to influence the situation.	**Anger** - involves high coping potential, manifested in the form of aggressive behaviour towards the person or the object that is responsible for the unpleasant situation, in an attempt to change the unpleasant aspects of the situation or restore social respect. **Anxiety** - involves low coping potential, meaning that one appraises oneself as having little control or power to change the situation, which results in moving away from the situation.
Certainty	This component pertains to the degree of confidence associated with an event. The question is: 'To what extent am I certain about this event?'	**Hope (Fear)** - evoked when one thinks that something pleasing (disturbing) may happen in the future but is unsure about it.

Table 3 The seven appraisal components, descriptions, and emotions (Demir et al., 2009).

Results

Participants in Phase 1 and Phase 2 generally showed consistent and coherent responses. Although some minor differences were noted, these seemed to result from random individual expression rather than any dominant divergence in perception. They demonstrated an active interest in participating in the study, as it involved the evaluation of novel materials. Their feedback initially focused on assessing the sensorial properties of the samples and associated them with familiar materials (Figure 3). Therefore, the predominant material appraisal themes identified for the three samples are "sensorial" and "associative". As participants interacted with the materials and experienced their flexibility, many remarked that "it is like leather."

Figure 3. The participants held the material samples up to the light to observe their translucency attributes.

As illustrated in Figures 4 and 5, Samples A and B elicited predominantly negative appraisals. In contrast, Sample C received more positive feedback than Samples A and B. Sample A, with its high naturalness, elicited more negative responses. This might be due to the tension between the material's natural qualities and industry standards for product finishes. Only for Sample B did participants express positive appraisals of its sustainability, suggesting a general acceptance of the material as a plastic alternative.

Across all sample appraisals, interesting relationships exist between the various appraisal components and emotional responses. For example, the "sensorial" and "associative" themes consistently appear to underpin positive emotions like "pleasant" and "curious". Meanwhile, "motive consistency" and "manufacturing process" seem to contribute to more negative responses like "confused" and "unimpressed." Additionally, the "coping potential" component, which represents the user's perceived ability to handle or manipulate the material, appears to be a key driver in the negative responses for sample A and B.

For Sample A, most participants primarily evaluated the colour and texture of the samples (sensorial) and expressed adverse reactions (intrinsic pleasantness) to their surface qualities. Participants also criticised the material's appearance by associating it with mundane materials (associative) and highlighting its perceived lack of a high-quality finish, as expected by conventional standards (standard conformance). For example, a participant expressed, "The material is coarse, the fibrous texture is uncomfortable to the touch, ….unlike the smooth feel of plastic or leather. ".

Some participants expressed apprehension about using the material, driven by concerns about its aesthetic appeal and functionality, which are closely linked to their perceived ability to manage such situations (coping potential). Other less prominent appraisal components are 'motive consistency', 'agency' and 'expectation confirmation'.

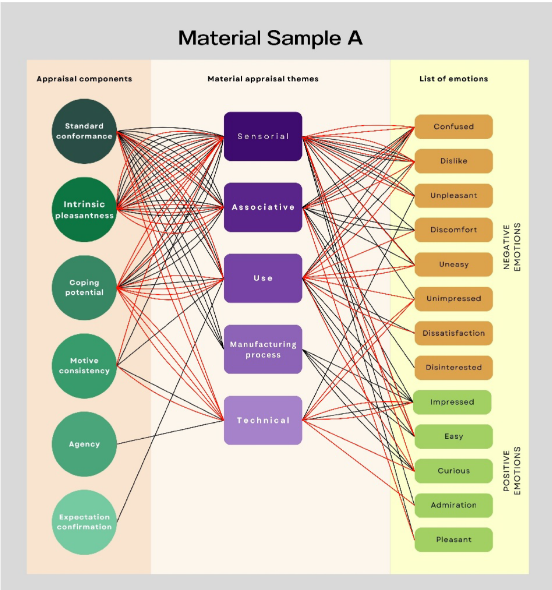

Figure 4. Network of Appraisals for Material A

Figure 5 shows the participants' responses to Sample B. The sample elicited slightly fewer negative emotional reactions than Sample A. Like Sample A; the central appraisal theme is on the material 'sensorial' properties and linked to 'intrinsic pleasantness' and 'coping potential'. For example, a participant said, "The material feels smoother and less textured,…I like the softness, … can use it as a leather bag".

The issue of 'Standard Conformance' did not emerge in the appraisal of Sample B, likely because participants recognised it as having characteristics similar to those of Sample A. Instead of reiterating the same appraisals, participants raised new concerns such as 'Expressive Semantic' and 'Systemic.'

The subtle surface treatment appeared to have an impact on the overall perception. Some participants preferred the more controlled texture of Sample B. One participant commented, "Sample B looks cleaner, with a less random texture and a futuristic, geometric pattern." Nevertheless, several negative appraisals emerged as participants expressed discomfort and confusion with the combination of the structured geometric pattern overlaying the natural, organic fibre arrangement on the sample surfaces (see Figure 6).

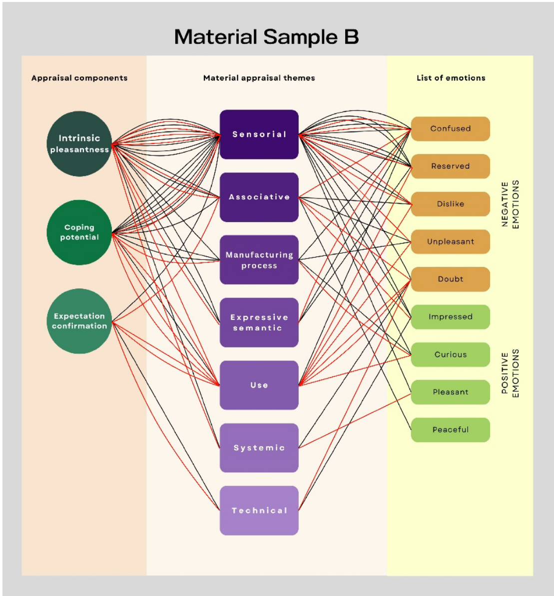

Figure 5. Network of Appraisals for Material B

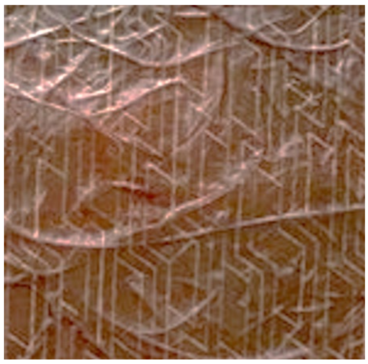

Figure 6. Subtle geometric pattern engraving on material sample B.

For Sample C, positive emotions dominated the participants' appraisals (Figure 7). The positively evaluated themes included

'Sensorial', 'Technical', 'Associative', 'Use', and 'Manufacturing Process'. Some participants associate it with luxury packaging materials and appreciate its symmetrical geometric texture. One participant noted, "The textured pattern on the material C gives it a leather-like and plastic-like feel, making it seem durable'. Other participants associated the translucency attribute of the sample with potential applications such as curtains and lampshades.

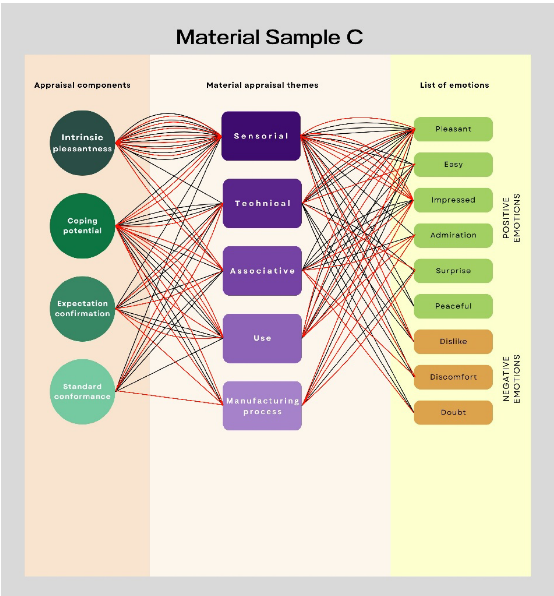

Figure 7. Network of Appraisals for Material C

Only the materials 'Sensorial', 'Technical' and 'Associative' properties minorly trigger negative emotions. Despite their overall positive reception, some participants expressed dislike or discomfort with the subtle, random freckle pattern on Sample C (Figure 8). A participant described, "The material's random dots, scattered across its surface, may be visually distracting and detract from its overall appearance."

Figure 8. Subtle natural random black freckles in material sample C.

Findings and Discussions

Sample C was generally preferred over Samples A and B. This finding suggests that a material's surface qualities strongly influence users' perception of sustainable materials from unconventional origins. When a material's surface appears natural, users often associate it with familiar materials, impacting their overall impression.

Over the high level of naturalness surface qualities, participants preferred a more plain with uniform surface treatment (machine aesthetics). Even within a design characterised by a high degree of order, unexpected natural elements can disrupt the appraisals and evoke mixed emotional responses. It is important to note that the participants in this study consist of tertiary-level students and young adult executives from urban settings. Their diverse experiences with natural materials may lead to findings that differ from those of suburban residents, who are likely more familiar with materials exhibiting natural characteristics.

The findings of this study emphasize the need for careful design consideration when working with natural fibre composites and biomaterials to balance their inherent natural qualities with user expectations. Drawing attention to a material's origin, such as incorporating visible coconut fibres, can spark curiosity and foster emotional attachment by highlighting its unique tactile and visual properties. However, focusing solely on raw naturalness may lead to perceptions of inferiority or reduced durability.

To counter this, enhancing biomaterials with machine aesthetics—such as embossed patterns or structured surface treatments—can signal intentional craftsmanship and processing. Perhaps mimicking existing, established materials may be a good strategy for easing user acceptance. For example, recycled plastics with colourful specks and irregular textures are often well-received, as users associate these features with familiar materials like terrazzo.

Furthermore, designers can apply machine-trace elements at the product level—through details like moulding marks, stitching, or architectural construction—to introduce structured accents that reinforce durability, quality, and reliability. These design choices, much like decisions about product form or colour, combine creative intuition with strategic reasoning, considering aesthetics, functionality, target users, and material narratives.

These findings provide valuable theoretical insights into how designers can enhance the sensorial experience of sustainable materials from unconventional sources. They build upon frameworks like the Material Driven Design (MDD) framework (Karana et al., 2015), with particular emphasis on the tinkering phase to explore the material's technical and sensorial properties and expand the understanding of its experiential potential. Materials that exhibit distinct natural characteristics can be further enhanced through careful surface manipulation, tailored specifically to their intended use. While the technical properties of these materials are best analysed using engineering methods and procedures, their aesthetic appeal and visual elements can be significantly elevated through the expertise of fine artists and graphic designers (Alahira et al., 2024).

By adopting an interdisciplinary approach, it is possible to develop innovative and sustainable materials and products that connect with consumers on both practical and emotional levels. This approach helps bridge the gap between the material's origin and user expectations, ensuring that natural aesthetics are balanced with perceptions of durability and quality. By applying these strategies, designers improve material appraisal, foster emotional connection, and elevate the overall material experience, supporting product longevity and encouraging more sustainable consumption.

Conclusions

Shaping materials to meet user preferences is essential in craftsmanship and product design. Sustainable biomaterials pose unique challenges due to their natural origins and surface qualities. While storytelling about a material's origin is important, balancing natural appeal with user aesthetic ideals is crucial. This study shows that while high naturalness can be perceived negatively, materials with lower naturalness and more visual coherence are often preferred. This preference likely reflects modern users' familiarity with machine-made precision.

The relationship between a material's biography and its sensory qualities is crucial and warrants further research. Understanding how users from different cultural background perceive and interact with these elements will help designers create functional and emotionally engaging materials. By balancing natural appeal with user preferences, sustainable materials can be developed into functional solutions that meet practical needs and instil user confidence in their durability. This, in turn, fosters product longevity, helping to reduce waste and support more sustainable consumption practices.

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