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Original Research

New Materials for Design: A Sensory and Perceptual Analysis of Transparent Wood

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Abstract: This research presents an analysis of Transparent Wood (TW), a material currently under development, focusing on its perceptual and sensory aspects, specifically through sight, hearing, and touch. The objective of this study is to examine TW's current perception to propose clear and effective communication strategies enhancing its adoption and acceptance before its market introduction. Advances in material innovation contribute to sustainability, performance, and the meaningfulness of new artifacts, yielding benefits not only in academia but also in the real-world contexts of businesses and end users. In this context, the research falls within the domain of Design for Materials, which intersects the fields of Design and Materials Science. The study uses a protocol drawn from the scientific literature for evaluating perceived quality through a sensory test administered to eighty participants, referred to as "material tasters." Data were collected during a two-hour session in which participants, provided with TW samples, performed three distinct actions for each selected sense, and selected four adjectives from a predefined list that they considered most appropriate. The collected data were subsequently analyzed for each sensory modality and across cross-sensory modalities, yielding guidelines to improve future communication strategies related to the perceived quality of TW. Results may be limited by the geographic homogeneity of participants and by preconceived notions of traditional wood and other transparent materials—aspects currently under further investigation. The proposed guidelines will be validated with designers and architects in upcoming focus groups, ensuring a broader and more diverse perspective on the material's potential applications.

Keywords: *Sensory Analysis, Transparent Wood, Innovative Materials, Design Material, Green Technologies*

Introduction and Research Context

Investing in research on new and innovative materials, along with sustainable technologies and their applications, is essential for driving progress across industries and impacting society and people's lives. Cutting-edge materials could revolutionize product performance, reduce environmental impact, and open new possibilities for design and engineering. These innovations, from biodegradable composites to smart materials with adaptive properties, are shaping a more sustainable and efficient future (Ashby 2016).

Beyond their technical properties (chemical, physical, or mechanical), the success of new materials also depends on how they are perceived and experienced. Testing materials from a sensorial perspective (considering factors such as texture, color, transparency, sound, and temperature) is crucial for predicting their acceptance and adoption. Studies show that human–material interaction significantly affects consumer choices and product satisfaction (Karana et al. 2014). Therefore, a material may be technically superior, but its real-world success depends on user interaction and perception. This intersection of material innovation and user experience explores how materials shape experiences, emotions, and behaviors, ensuring that technological progress aligns with human needs, expectations, and desires (Karana et al. 2009).

This research, initiated within the European co-funded AI-TranspWood project (2024–2026, project ID HORIZON-CL4-2023-RESILIENCE-01 101138191—GAP-101138191—AI-TRANSPWOOD), sought to examine a new material identified as Transparent Wood (TW) through a perceptual and sensory lens, exploring how its sensory and experiential qualities influence user interaction and material acceptance. TW is a composite made by treating natural wood to remove its lignin (a component that gives wood its color and opacity) and then infiltrating the delignified material with a polymer/biopolymer resin/bio resin whose refraction index perfectly matches that of the hosting material. This process retains the wood's structure (Chen and Hu 2021) while making it see-through. However, it is still being tested by research centers and universities and is not yet on the market. According to the innovation maturity of TW obtained by pre-treatment of wood and processing, the current TRL (Technology Readiness Level) is 3 (Experimental proof of concept), and the AI-TranspWood project aims to reach TRL 5 (Technology validated in relevant environment).

The so-called TW-based composite is a cutting-edge material emerged over the past decade as one of the most promising innovations in materials science (Pandit et al. 2025). With potential applications across various industrial sectors (including construction, automotive, electronics, furniture, and interior design), it could be a viable and sustainable alternative to traditional plastics and glass (Mariani and Malucelli 2022).

To fully unlock the potential of this material, an international consortium of thirteen partners—comprising five universities, eight research centers, and industrial collaborators—is engaged in a three-year Horizon Europe project titled "AI-TranspWood: AI-Driven Multiscale Methodology to Develop TW as a Sustainable Functional Material."

The AI-TranspWood project seeks to establish an AI-powered multiscale methodology for designing and manufacturing novel wood–based functional composites within the European Union's "Safe and Sustainable-by-Design" (SSbD) framework (European Commission. Joint Research Centre 2023). By integrating SSbD tools with the development of advanced TW materials, the project aims to enhance the innovation capacity of SMEs and industry, fostering the creation of next-generation sustainable products. This initiative could significantly boost Europe's position in the global production of TW-based composites.

A well-structured strategy to introduce this innovation to potential users is essential to effectively disseminate the knowledge generated by this research, communicate its findings, and engage stakeholders in adopting this new material. A research team from the *Politecnico di Torino*, composed of experts in materials science and product and communication design, plays a fundamental role in the investigations necessary for this purpose.

Theoretical Background

What Transparent Wood Is

The development of TW can be traced back to 1992 when Sigfried Fink successfully produced a translucent version of pine veneer of 1-mm thickness (Fink 1992). This was achieved by selectively removing lignin (a structural polymer responsible for wood's natural opacity and coloration) and subsequently infusing the resulting structure with a transparent polymer. This process enhanced the wood's optical transmittance, making it transparent. However, at that time, Fink's primary objective was to investigate the internal structure of wood rather than to pioneer a novel material with practical applications. Consequently, further research in this area was not pursued.

The concept of TW re-emerged in 2015 when two independent research teams, one at the University of Maryland, United States (Zhu et al. 2016) and another at KTH Royal Institute of Technology in Sweden (Li et al. 2016), revisited Fink's methodology. These teams explored TW's properties and potential applications, leading to significant advancements in its development, demonstrating the feasibility of this material for various technological and industrial applications, generating a new interest in the field.

Figure 1: Samples of Transparent Wood Produced by Latvijas Finieris Shown at the First Workshop of the AI-TranspWood Project Held in Turin in June 2025

Source: Photo by Tito Poles, 2025

Since then, research on TW has accelerated, with ongoing advancements in material processing and application-driven innovations (Kivikytö-Reponen et al. 2024). TW is being investigated for a wide range of high-tech applications today in optics and optoelectronics, with ongoing research focusing on advanced lighting systems (Zou et al. 2022). In architecture and design, this technology shows potential for smart screens and energy-efficient windows (De Ranieri 2016). Furniture designers are considering TW's potential for creating novel, aesthetic, and functional pieces, while researchers are exploring its application in flexible electronic devices for next-generation technologies (Wan et al. 2021). Additionally, TW is being studied as a sustainable alternative to glass and plastic in construction materials, and for lightweight yet durable automotive components (Mariani and Malucelli 2022). Its unique properties also make it an attractive choice for aesthetic and decorative applications in interior and architectural design (Mariani and Malucelli 2022). The TW market is expected to grow substantially, with its global value projected to rise from $88.4 million in 2021 to approximately $208.1 million by 2031, reflecting a compound annual growth rate (CAGR) of 9.0% (Allied Market Research 2022). The increasing demand for sustainable building materials is significantly contributing to this upward trend. TW stands out due to its advantages over traditional construction materials. It is a versatile, sustainable, and high-performance material, combining optical transparency, mechanical strength, impact resistance, and thermal insulation. Its ability to balance clarity and haze makes it an excellent alternative to plastic and glass in applications requiring diffused light, while its toughness and flexibility offer advantages over traditional brittle materials. Additionally, TW's low environmental impact and renewable nature further enhance its appeal for eco-friendly solutions (Mariani and Malucelli 2022; Chutturi et al. 2023). Notably, it can reduce CO_2 emissions by an estimated 10% to 15%, emphasizing its potential as an environmentally friendly alternative in the construction industry (Allied Market Research 2022).

TW's continued research and refinement highlight its potential to revolutionize several industries. It is a sustainable, lightweight, and durable alternative to conventional materials, making it a promising innovative material at the intersection of material science, sustainability, and design. However, for TW to be widely adopted, it is essential to clearly differentiate it from traditional materials available in the market.

Sensory Perception of Materials

TW can be considered as an emblematic case for exploring how users perceive materials beyond their physical composition. According to established concepts in material perception literature, TW can be described as a perceptually ambiguous material (Cheeseman et al. 2022), because users could struggle to classify it as either wood or plastic-based solely on sensory prompts. The material mimicry of TW explains this ambiguity (Bond et al. 1995), as the material visually resembles plastic due to its translucency while retaining tactile features reminiscent of natural wood. Such incongruities highlight the role of crossmodal correspondences (Motoki et al. 2023), where expectations created by one sense (e.g., vision) may not always align with information from another (e.g., touch or sound). This duality creates an ambiguous sensory identity that challenges conventional material classifications and is a common feature of other innovative composite materials, such as sustainable plastics (Del Curto et al. 2022), and DIY materials (Rognoli et al. 2015), to name a few well-known material families.

The sensory perception of materials has been a subject of growing interest within the Design field for over two decades. Since the early 2000s, perceptual qualities have been considered as important as technical performance, marking a shift in how materials are evaluated and selected (Ashby and Johnson 2014). Designers increasingly recognize that how a material looks, feels, and sounds can strongly influence user experience, emotional response, and perceived functionality, especially in the context of innovative or unfamiliar materials, where the perceptions could be strongly influenced by previous knowledge. Over the past decades, several qualitative frameworks have been developed to systematically explore this dimension of material perception (Karana et al. 2009; Lerma and De Giorgi 2011; Veelaert et al. 2020). One example is the Sensoaesthetic Design approach, which investigates how materials engage the senses and communicate symbolic or emotional meanings, incorporating multisensory integration using psychophysics (Miodownik 2007). Another well-established model is the material experience framework (Giaccardi and Karana 2015), which examines the user's experience of materials on four interconnected levels: sensorial, interpretative, affective, and performative. In more structured experimental contexts, Descriptive Sensory Analysis (Sakamoto and Watanabe 2017) assesses materials through predefined sensory vocabularies, collections of adjectives associated with visual, tactile, and auditory stimuli. This approach enables designers to compare materials, even at early stages of exploration systematically. Finally, the Material Driven Design (MDD) methodology (Karana et al. 2015) integrates qualitative sensory evaluation into its very first step: understanding the material (1), followed by creating a materials experience vision (2); manifesting materials experience patterns (3); and, finally, designing material or product concepts (4). This phase emphasizes technical and experiential characterization, often involving user interaction, the use of descriptive terms, and the construction of perceptual maps. In this context, the MDD methodology provides a framework that closely aligns with the development journey of TW. The relevant scenario within the MDD framework involves designing with a material proposal based on semi-developed or exploratory samples, where the design process plays a crucial role in further defining the material's properties and identifying meaningful applications.

These approaches use well-defined qualitative protocols that allow designers and researchers to generate valid, comparable insights across different materials. Such approaches bridge the gap between numerical data and human perception, highlighting how new and innovative materials are experienced in the real-world context.

The present research focuses specifically on the sensorial perception of TW, contributing to a better understanding of how it is experienced, and paving the way for its future integration into design practice.

Research Methodology

Sensory-Driven Communication for Transparent Wood

The research seeks to define the main perceptive attributes in order to develop practical communication guidelines that encourage stakeholders to promote innovative materials, such as TW-based composites, within the built environment application field, specifically emphasizing its perceived quality.

To achieve this, the study is structured around the central research question (Main RQ): How can communication strategies for TW be improved by leveraging its perceptual and sensory characteristics?

Sensory Vocabulary for the Expressive/Sensory Description of Materials

Among the methodologies mentioned before, there are well-established methods for analyzing qualitative sensory characteristics, complemented by standardized approaches designed to improve the consistency and effectiveness of the assessment process (Dal Palù et al. 2017). Among these, the sensory vocabulary stands out as a particularly effective tool. This method involves developing and applying a structured set of adjectives organized according to sensory modalities such as vision, audition, and touch (Sakamoto and Watanabe 2017; Houix et al. 2012). These carefully curated lexical items enable evaluators to articulate and categorize sensory perceptions more precisely. Sensory vocabularies enhance the reliability and comparability of qualitative sensory analyses across different contexts and evaluators by providing a common linguistic framework.

Experimental Protocol

The study utilizes an established protocol for assessing perceived quality through a sensory evaluation conducted with eighty voluntary participants from Italy evenly distributed by gender with an average age of 23 years, referred to as “material tasters.” The profile of the material testers corresponds to that of a junior designer, but with naïve knowledge concerning TW. Data collection occurred during a structured two-hour sensory session, where participants interacted with TW samples of 5-centimeter square (Figure 2).

Figure 2: Samples of Transparent Wood of 5-Centimeters Squared Used During the Data Collection

They performed three distinct actions identified in the literature for each selected sense: sight (Lerma et al. 2013), hearing from SoundBe methodology (Dal Palù et al. 2018), touch from Sensotact by Renault (Allione et al. 2012) and chose four adjectives from a predefined list from the vocabulary that best described their perception of the material. The gathered data were then analyzed through descriptive statistics within individual sensory modalities and across multiple senses to identify key insights. These findings serve as a foundation for refining future communication strategies to enhance TW's perceived quality and acceptance.

For this study, the authors selected twelve adjectives for the visual and tactile modalities according to Allione et al. (2012) and ten for the auditory modality according to Dal Palù et al. (2017), as shown in Table 1. It is worth noting that the adjective "transparent" was intentionally excluded from the list, as its inclusion would have been redundant and implicitly understood. Participants had to select four adjectives: three from the predefined list and, optionally, one of their choosing.

Table 1: Sensory Vocabulary Used

Sight	*Touch*	*Hearing*
Vivid	Warm	Dull
Intense	Cold	Irregular
Warm	Hard	Penetrating
Bright	Soft	Strident
Clear	Rough	Harsh
Sparkling	Smooth	High-pitched
Delicate	Slippery	Low

Mellow	Sticky	Mild
Faded	Shape memory	Deep
Dull	Fibrous	Subtle
Pale	Rigid	
Opaque	Flexible	

The adjectives were selected following the performance of a total of nine actions, three for each sensory modality, with each action having a predefined short duration. To ensure that participants recorded their initial sensory impressions, which occur after approximately forty milliseconds (Herzog et al. 2016), they were given thirty seconds to receive the stimulus and record their response without second thoughts. The actions were as follows:

Sight

1) S_A1_Paper: Place the sample on top of the printed sheet of paper and move it without detaching it from the sheet—30 seconds, 4 adjectives.
2) S_A2_Backlight: Place the sample in a backlight (first natural and then artificial)—30 seconds, 4 adjectives.
3) S_A3_Rotation: Rotate the sample to make it vertical, horizontal, oblique—30 seconds, 4 adjectives.

Hearing

1) H_A1_Tapping: Tap the sample with your knuckles, with a pen or a marker (in plastic like a Bic)—30 seconds, 4 adjectives.
2) H_A2_Waving: Wave the sample—30 seconds, 4 adjectives.
3) H_A3_Scratching: Scratch the sample with your fingernail—30 seconds, 4 adjectives.

Touch

1) T_A1_Thermal: Thermal perception: place your hand on the table for 10 seconds, then place it on the sample for 3 seconds—5 seconds, 4 adjectives.
2) T_A2_Finger: Run your finger over the sample in circular movements—30 seconds, 4 adjectives.
3) T_A3_Bending: Handle the sample, try to bend it—30 seconds, 4 adjectives.

All participants performed each action, following the given instructions and within the specified time frame. The data collection campaign occurred in a silent room under constant lighting conditions. Participants performed the actions individually and selected adjectives immediately after each action to avoid any confusion or overlap between them. After completing each action, participants recorded their chosen adjectives on a template sheet designed to facilitate structured and consistent data entry.

Findings

The data were collected anonymously, and preliminary results were obtained by creating a ranking based on the four most frequently selected adjectives for each action. From this ranking, a set of insights were derived and summarized in the following table.

Sight

Table 2: Sight: Top 4 Adjectives and Insights for the Sight

Action	*Top 4 Adjectives (No. of Votes)*	*Insights*
S_A1_Paper	39 Warm—35 Pale—33 Mellow—32 Faded	The TW gives the underlying paper a warm, yellowish tint. Its translucency creates a subtle, veiled effect. Overall, it comes across as a material lacking strong character.
S_A2_Backlight	33 Opaque—26 Mellow—24 Delicate 23 Faded/Pale	It is called TW, but it is translucent (only one person describes it as transparent). Its interaction with light gives it a neutral appearance.
S_A3_Rotation	30 Opaque—22 Dull—20 Pale—20 Faded	The rotation and angle of light do not create any notable effects.

The TW sample, despite its name, is perceived more as a translucent than a truly transparent material, with only a single participant described it as transparent. Its visual effect is characterized by a warm, yellowish tint that it imparts to underlying surfaces, creating a soft, veiled appearance. However, it lacks notable interaction with light; rotating the material or changing the illumination angle does not produce significant visual shifts. As a result, TW is generally seen as a neutral material with limited expressive qualities, offering subtlety rather than visual presence or strong character.

Hearing

Table 3: Hearing: Top 4 Adjectives and Insights for the Hearing

Action	*Top 4 Adjectives (No. of Votes)*	*Insights*
H_A1_Tapping	40 Mild—35 High pitched—35 Subtle—30 Dull	The sample is likely perceived as producing a high-pitched and dull sound, depending on the material used to beat it.
H_A2_Waving	39 Subtle—34 Dull—32 Low—26 Mild	Waving the sample produces little noise, likely because the sample does not flex much.
H_A3_Scratching	36 Irregular—27 Low—27 Subtle—24 Dull	The sample has a visible texture, which can be misleading since the surface is smooth and free of irregularities.

The TW sample produces minimal sound when waved, likely due to its rigidity, and emits a high-pitched yet dull sound when struck, depending on the striking material. Visually, it appears textured, but its surface is smooth, creating a sensory mismatch between sight and touch. This suggests that TW generates subtle auditory feedback and may convey conflicting sensory signals where visual cues do not align with tactile or acoustic experiences. Such discrepancies can influence users' perceptions and expectations of the material, which is important to consider in design and communication contexts.

Touch

Table 5: Touch: Top 4 Adjectives and Insights

Action	*Top 4 Adjectives (No. of Votes)*	*Insights*
T_A1_Thermal	34 Warm—24 Cold—19 Sticky—14 Hard/Fibrous	The sample feels more warm than cold.
T_A2_Finger	42 Fibrous—35 Slippery—28 Irregular—18 Sticky	The appearance can be deceptive; the sample is smooth and not fibrous.
T_A3_Bending	45 Flexible—22 Soft—19 Rigid—16 Hard	The sample is flexible up to its breaking point along the grain but remains rigid in the opposite direction.

The TW sample is perceived as warm to the touch. While it visually appears fibrous, the surface is smooth, indicating a disconnect between appearance and tactile sensation. Mechanically, it shows directional flexibility, bending along the grain but remaining rigid across it.

These observations highlight the material's complex sensory profile, where visual cues may mislead tactile expectations, and mechanical behavior varies with orientation. Such characteristics are crucial for applications where user interaction and material perception play a central role, as they may affect usability, perceived quality, and design suitability.

Cross Sensorial Assumptions

Following the sense-by-sense analysis, the research conducted a cross-sensory examination to explore potential insights emerging from synesthetic perception. TW samples are generally perceived as neutral and unobtrusive, conveying a subtle presence rather than a striking visual or tactile impression. Its muffled and understated acoustic response raises the question of whether TW possesses sound-absorbing properties, an aspect that merits further investigation.

TW is consistently described as warm, both in terms of visual impression and tactile sensation. The material's yellowish hue likely contributes to this multisensory perception of warmth. Interestingly, while its appearance and surface texture suggest delicacy, the relatively high-pitched sound it emits when tapped introduces a sensory dissonance, potentially challenging the expectation set by its visual and tactile cues.

Moreover, TW appears fibrous to both the eye and the touch; however, the surface is in fact, smooth. This contrast may indicate a form of tactile proxy, in which visual texture informs tactile expectation, creating a perceptual disconnect between anticipated and actual sensation.

Communication Guidelines for Transparent Wood

Following the sensory and perceptual experiments of TW samples and the qualitative analysis of the results, based on the assumptions made, the research identifies the following guidelines to improve the communication of TW:

1) Consideration should be given to the name: calling it "Transparent Wood" could create perceptual biases and/or unmet expectations. The material is more translucent and is perceived as more opaque than transparent.
2) TW generally presents itself as a material with "weak character," exuding a neutral quality. The communication strategy could either embrace TW's neutral, understated qualities as a versatile strength or highlight its innovative potential to appeal to a broader audience.

3) Communication strategies should be tailored to the specific application areas, with B2B sectors like electronics highlighting functionality and innovation, while B2C sectors such as furniture focus on design versatility, sensorial aspects, aesthetic appeal, and the material's potential to enhance consumer spaces.

Discussion and Conclusion

This research yields insights on two main levels: the first concerns the sensory perception of the new material (Allione et al. 2012) known as TW; the second addresses the communication strategy necessary to introduce such an innovative and still largely unknown material, both to professionals and the general public.

To date, this is the first study specifically focused on the perception of TW. Although material perception methodologies are well-established, no directly comparable data exist. This is mainly due to the fact that TW has only recently been brought to public and academic attention, primarily through the European research project AI-TranspWood. Current investigations are still mainly limited to its physical and chemical properties, with little emphasis on user experience or sensory analysis.

Therefore, the first level of the analysis presented in this study, focusing on how TW is perceived, will not only be valuable to project partners, particularly those involved in market exploitation and commercialization but also to researchers working on emerging materials that have not yet entered the market. The sensory insights gathered from each modality, as well as the results of the cross-sensory analysis, will support companies and project professionals interested in adopting TW in developing new products that better align with user expectations and experiences, according to the MDD methodology (Karana et al. 2015) and the material experience framework (Giaccardi and Karana 2015).

An important issue this research raised concerns the perception of TW as a perceptually ambiguous material (Cheeseman et al. 2022), a material that evokes sensory associations with both natural wood and transparent plastic.

The second level of results offers valuable insights for future efforts related to the communication and dissemination of TW. First, the name itself raises critical reconsideration: the current name may raise expectations that are ultimately unmet, as the material is, in fact, translucent rather than fully transparent. Therefore, relying heavily on this term in communication strategies may be misleading or ineffective.

Moreover, since TW tends to be perceived as a material with delicate presence and limited expressive character, it becomes essential for communication efforts to strengthen its identity. This can be achieved by carefully curating visual elements such as color palettes, textures, and patterns, that are consistent with the visual direction currently being developed within the AI-TranspWood project. A strong and cohesive communication strategy will be instrumental in shaping the material's perceived value and desirability.

The proposed guidelines will be further validated through upcoming focus groups involving project professionals, including designers, architects, and other industrial stakeholders. These sessions are intended to ensure a broader and more diverse perspective on the potential applications of TW, drawing from both creative and technical expertise, as well as to concur at creating meaning in the communication strategies development of the innovation (Bin Ali et al. 2025). To gather a variety of cultural and design sensibilities, focus groups will be conducted in both the Mediterranean region and the Scandinavian region, which represent the geographical boundaries of the project's partner institutions. This approach explores how regional contexts may influence material perception and application strategies.

The current study results may have been limited by the geographical homogeneity of participants and their preconceived associations with traditional wood and conventional transparent materials, such as glass or plastic. Furthermore, the present results represent a first set of outcomes generated by a perceived quality sensory session conducted on the first set on sample during the project. In fact, it can therefore be assumed that the production process has influenced the appearance of the produced TW sample. These biases could have subtly influenced the adjectives selected and the interpretations formed. Therefore, future research should seek to expand the participant base across different cultural and professional backgrounds to enhance the robustness and generalizability of the findings; finally, to gather "robust" data, it will be necessary to replicate the analyses once the production process has been developed at a more advanced TRL level—i.e., on an industrial scale.

Future studies are already planned to advance this research. To fully understand the unique sensory identity of TW, it will be important to conduct comparative analyses with its closest substitutes, namely traditional wood and plastics. Additionally, based on the findings of this study, a dedicated online survey is being planned to explore, among others, alternative naming strategies that more accurately reflect the material's properties and potential.

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that they, Eva Vanessa Bruno, Doriana Dal Palù, and Beatrice Lerma, are the sole authors of this article and take full responsibility for the content therein, as outlined in COPE recommendations.

Informed Consent

The authors have obtained informed consent from all participants.

Conflict of Interest

The authors declare that there is no conflict of interest.

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