

Research on Tactile Experience Based on Expectation Effects and Material Perception

Zhuan Zhou

Zhongkai University of Agriculture and Engineering, Guangzhou, Guangdong, China

Abstract: In recent years, research on human sensory experiences has received widespread attention in design, with tactile experience being an important component of these sensory experiences. The tactile feedback that humans can perceive mainly includes vibration, texture, temperature, and pressure. On one hand, in real experiential design, using the differences between tactile and visual experiences has become an important strategy to create a sense of surprise. On the other hand, tactile experience is closely related to the material of the product itself, with designers focusing on the physical properties, emotional characteristics, and implicit traits of materials when making material choices. This paper will conduct an in-depth exploration of tactile experiences from the perspectives of visual-tactile differences under expectation effects and various material characteristics, providing important references for designers in product design.

Keywords: Sensory Experiences; Tactile; Material Selection; Material Perception.

1. Introduction

In product experiences, touch serves as a vital channel through which users perceive functionality, form, and service, profoundly influencing the emotional and cultural depth of their interactions. In recent years, market competition has intensified, with similar products increasingly narrowing their differences in terms of appearance and materials, leading to a growing trend of product homogenization. As users are continually exposed to uniformly designed products, their sensory sensitivity toward such offerings has gradually diminished—particularly affecting the tactile experience, which has become noticeably weaker. Meanwhile, materials, as one of the key elements driving product differentiation, have also converged, further eroding the richness of users' sensory perceptions. Compared to other senses, touch offers an unparalleled sense of authenticity and immediacy when it comes to perceiving material qualities.

Thus, against the backdrop of both product homogenization and evolving user experience expectations, the value of tactile engagement is becoming ever more prominent. This article examines recent domestic and international research on product tactile experiences, summarizing existing achievements and identifying current limitations, while also outlining potential directions for future studies. The aim is to provide valuable insights that can guide deeper exploration in this field.

2. Tactile Experience

Tactile sensation is the perception generated by the skin when exposed to external stimuli such as temperature, humidity, pressure, or vibration—resulting in sensations like warmth, coolness, stickiness, smoothness, hardness, and even pain. These tactile experiences can further evoke emotional responses, such as joy or disappointment. Meanwhile, tactile experience refers to the process through which users form an overall emotional understanding of a product by consciously engaging with its tactile qualities.

Currently, research on product tactile experiences has yet to develop a systematic theoretical framework, with most

findings still stuck in the exploratory and application phases of fragmented models. Existing studies primarily focus on two key perspectives: First, starting from user expectations, researchers analyze behavioral patterns at each stage of the tactile experience to build a corresponding user psychology model. Second, the focus shifts to product materials, beginning with an analysis of material properties and manufacturing processes, followed by sensory experiments that measure users' emotional responses during touch. These insights are then integrated with specific usage contexts to establish a clear link between "physical attributes" and "psychological perception." In summary, research into product tactile experiences demands that designers not only deeply understand users' tactile behaviors and psychological responses but also precisely grasp the physical characteristics of materials—ultimately achieving an organic integration of both aspects.

This article first presents a theoretical model of tactile experience based on user expectations and its practical applications. Next, it traces the evolution of material design and selection, highlighting the significant value of materials research in shaping product tactile experiences—and then delves deeper into specific discussions from two perspectives: research types and hierarchical content. Finally, building on existing research findings, the article outlines promising future directions and emerging trends in this field.

3. Expectation Effect in Tactile Experience

Existing research exploring the principles of product tactile experiences has already identified "user expectations" as a key area of focus, encompassing three main aspects: the nature of these expectations, relevant theoretical models, and their application to tactile experiences.

3.1. The Essence of Expectation Effect

When interacting with a product, users often rely on their existing perceptions, experiences, and cognitive frameworks to predict their future experience, thereby generating "expectations" about the product. These expectations can

significantly influence how users actually perceive and experience the product afterward—a phenomenon known as the "Expectation Effect" [1].

3.2. Theoretical Models

3.2.1. Expectation Disconfirmation Theory

Tolman[2] identified three sources of expectation: past experience, relevant inferences, and current stimuli. The Expectation Disconfirmation Theory further suggests that an individual's level of familiarity is a key factor influencing how expectations are formed: for familiar objects or situations, expectations primarily stem from past experiences; however, for unfamiliar items, expectations are more likely to arise from related inferences—and these expectations tend to carry greater uncertainty[3]. In other words, when encountering relatively new or unfamiliar stimuli, users develop tactile expectations that are inherently more uncertain.

That's precisely why uncertain expectations tend to capture users' attention more effectively than predictable ones. In product design, deliberately introducing elements of novelty—whether in terms of features, aesthetics, or materials—can create a sense of anticipation, encouraging users to explore further and develop a deeper interest in the product.

3.2.2. Affective Expectation Model

Wilson[4] defines "affective expectation" as an individual's emotional prediction in response to a specific situation or stimulus. The Affective Expectation Model, meanwhile, delves deeper into the underlying mechanisms driving emotional shifts: it is based on the premise that there is a discrepancy between expectations and actual experiences. When individuals become aware of this gap, a "contrast" effect emerges, amplifying the difference between their expectations and reality. Conversely, if the discrepancy goes unnoticed, an "assimilation" effect occurs, narrowing the gap instead. Research further suggests that when individuals have previously encountered stimuli inconsistent with their expectations, they are more likely to experience a contrast effect in subsequent encounters. Today, leveraging this inherent inconsistency between expectations and perception has become a key strategy in emotional design, enabling designers to proactively influence and regulate users' emotions.

3.3. Applications

Research on the application of expectation theory in tactile experiences primarily focuses on two key areas: first, the visual expectation effect, which explores how visual texture influences tactile perception mechanisms; and second, visual-tactile mismatch, which centers on the "surprise" sensation triggered by this inconsistency and its impact on users' emotional responses.

In tactile experiences, users often transition seamlessly from visual to tactile sensations. When "observing," visual information unconsciously activates a "mental touch" rooted in tactile memory—this process is initially shaped by past experiences, which in turn influence subsequent real-world tactile perceptions, ultimately creating a complete expectation effect. At the application level, Yanagisawa [5] leveraged this visual expectation effect, using a semi-lens experiment to identify high-quality visual-tactile combination samples, providing valuable insights for designing new materials. Meanwhile, this phenomenon into a deliberate design strategy, integrating it into an emotional design framework to guide

designers in effectively harnessing the expectation effect.

Because visual textures are highly telegraphic, they often trigger illusory visual perceptions—specifically, discrepancies between users' visual predictions and their actual tactile sensations. Such cognitive conflicts tend to capture users' attention and evoke an emotional "sense of wonder." In product design, deliberately introducing inconsistencies between visual and tactile experiences has become a key creative strategy. A deeper understanding of the underlying mechanisms behind this sense of wonder can help designers craft more effectively and deliver truly awe-inspiring user experiences.

From a typological perspective, wonder can be categorized into "Hidden Novelty" and "Visible Novelty". Hidden novelty manifests when users initially perceive a product as familiar, but upon actually touching it, they discover that its textural features don't match their expectations, creating an unexpected cognitive contrast. Such moments of wonder can evoke delightful surprises—or, if perception is misleading, even lead to disappointment. In contrast, visible novelty occurs when users encounter a product they've never experienced before, prompting them to rely on past experiences to make tactile guesses. This exploratory process itself is enough to spark ongoing curiosity in the user.

Therefore, in design practice, designers tend to use hidden surprises when iterating and improving products, creating an unexpected effect of 'seemingly familiar but actually unfamiliar'. Meanwhile, when developing entirely new products, designers often opt for visible novelty, introducing sensory characteristics that users have never encountered before, thereby igniting their innate desire to explore and discover.

The expectation Effect triggered by visual-tactile inconsistency is not constant. Initially, the mismatch directly elicits surprise; however, with prolonged use, users gradually develop specific tactile memories and preferences, which in turn shape their subsequent cognitive judgments. This process unfolds iteratively, continually refining both tactile memory and user preferences over time. Notably, the once-surprising experience tends to become habituated as time passes, causing users to adapt to it—meaning that similar stimuli can no longer reach the perceptual threshold required to evoke that same sense of wonder. Thus, time emerges as a critical factor that shapes and ultimately diminishes the level of user surprise.

4. Material Perception

When functionality and aesthetics struggle to create a competitive edge, materials have become the key factor determining the success of product design. They not only reflect the designer's meticulous craftsmanship but also serve as the tactile channel through which users perceive the deeper meaning behind the product. For designers, understanding material properties and empathizing with users' emotional responses is essential for refining the overall tactile experience. "material-driven design" [7], material experience [8-9] all underscore the critical role that material research plays in shaping modern product design. Looking back at designers' evolving priorities in material selection across different eras, we can clearly observe a distinct evolutionary trajectory. In the last century, design decisions primarily focused on the manufacturing attributes of materials—such as workability, physical properties, and production efficiency—as well as their economic aspects. However, entering the 21st

century, designers began placing significant emphasis not only on these practical attributes but also on the aesthetic appeal of materials, their sensory qualities, and the implicit meanings they convey. For instance, Karana [10] systematically explored the sensory characteristics of materials—including visual, tactile, olfactory, auditory, and gustatory experiences—as well as their implicit features, such as perception, value, emotion, and semantics. Meanwhile, Nagai [11] further highlighted that "perceptual characteristics" represent the most fundamental dimension among these implicit traits. Thus, it becomes evident that, with advancing technology and shifting societal values, the focus of product material design has gradually shifted—from a previous emphasis on functionality and cost-effectiveness toward a deeper commitment to enhancing users' perceptual experiences. The following sections will explore this topic further, examining both the research approaches and the hierarchical framework of material tactile experiences.

4.1. Types of Material Tactile Experience Design Research

The tactile material experience refers to the user's comprehensive perception of material properties through a multisensory channel centered on touch. Based on the types of perceptual modalities employed in representative studies conducted over the past decade, both domestically and internationally, these can be categorized into two main research directions: first, studies focusing on material experiences based on a single tactile modality, which emphasize uncovering the implicit characteristics and emotional attributes inherent in materials themselves; and second, research exploring cross-modal interactions in material perception, with a particular focus on how touch collaborates—or contrasts—with other senses, such as vision and hearing, in shaping our understanding of materials.

4.1.1. Material Tactile Experience in the Tactile Modality

The primary advantage of single-haptic modality research lies in its ability to eliminate interference from other senses, allowing participants to perceive material surface textures with heightened sensitivity. This approach focuses on implicit features such as concept associations and semantic mappings that are uniquely triggered by the tactile channel alone. For instance, Nagai [12] explored deep-level impressions evoked by materials by constructing a conceptual network, aiming to decode users' tactile cognitive patterns; meanwhile, Lindberg [13] worked on establishing connections between wood textures and specific semantic labels, with the goal of aligning design intentions precisely with the most appropriate materials.

4.1.2. Cross-modal Material Tactile Experience

The material experience of users in real-world scenarios is typically a multi-sensory process. In cross-modal research, Chihiro [14] notes that for the same material, perceptions from different sensory modalities often align, though the underlying weights influencing these perceptions can vary—for instance, if tactile feedback identifies a stone as hard, visual and auditory cues usually also point toward a similar conclusion. However, the extent to which each modality contributes to the final emotional judgment differs. Wastiels, in studies exploring these weight differences, reached a similar conclusion, finding that color has a more pronounced impact on the perception of warmth in stone compared to its roughness.

In summary, over the past decade, research on material tactile experiences—whether focusing on unimodal or cross-modal approaches—has consistently aimed to establish a systematic link between the objective physical properties of materials and users' subjective perceptions and emotional responses.

4.2. Material Tactile Experience

To systematically analyze the intrinsic structure of tactile experiences, scholars Chen et al. [15] proposed a top-down, hierarchical model that progresses from ambiguity to clarity, encompassing three key levels: affect and emotion, tactile perception, and the physical properties of materials. Meanwhile, some researchers have simplified the framework by focusing their investigations on just two of these levels.

At the emotional and affective level, the choice of emotion-describing vocabulary heavily depends on the specific research subject and the questions being explored. For instance, when studying domestic wall cladding materials, "warmth" emerges as a central emotional indicator, aligning with the emotional semantics associated with "home." In contrast, when examining gift packaging boxes, words like "excitement," "joy," "naturalness," and "liking" are selected to capture the emotional responses evoked by "gifts." Meanwhile, in studies focusing on textiles such as fabrics and denim jeans, "comfort" becomes the key dimension for expressing users' emotional experiences. Thus, at the emotional and affective level, researchers must first identify the implicit characteristics embedded within the product—such as perceptions, values, associations, emotions, and semantic meanings—and then carefully choose corresponding emotion-related terms to accurately describe these feelings.

At the perceptual dimension level, existing literature provides limited explanations for the theoretical rationale behind selecting specific perceptual dimensions, nor does it clearly establish an inherent link between these dimensions and particular research subjects. Zhuangzhou [16] offers a general summary on this topic, noting that tactile texture is primarily composed of three fundamental perceptual dimensions—rough/smooth, soft/hard, and cold/warm—which collectively capture the vast majority of information involved in tactile perception. Additionally, within the rough/smooth dimension, two further subdimensions can be identified: dry/wet and sticky/slippery.

At the level of material physical properties, different materials focus on distinct physical parameters, which commonly include surface roughness, coefficient of friction, temperature, thermal conductivity, specific heat capacity, and density. Most of these properties can be measured directly or indirectly using specialized instruments.

After identifying the research attributes at each level, researchers typically combine the methods of sensory engineering with sensory evaluation experiments to collect user perception data. The subsequent data analysis is conducted in two main directions: First, dimensionality reduction is applied within each level—using techniques such as principal component analysis, factor analysis, or multidimensional scaling—to eliminate multicollinearity among variables and ensure their relative independence. Second, relationships are established across different levels, often through correlation or regression analyses. By following these approaches, researchers ultimately construct a hierarchical mapping between "emotion—perception—

attributes," thereby transforming the initially ambiguous tactile experiences into clear, structured insights.

In summary, the complexity of materials determines the diversity of emotions they evoke, while the same material can also elicit subtle emotional variations depending on its product form, semantic context, and usage scenario. Currently, constructing a hierarchical relationship model has emerged as an effective approach for analyzing tactile experiences associated with materials. In practical research, the selection of specific content at each level should be guided by a comprehensive assessment that takes into account the particular research question, the target audience, and the actual application context.

5. Discussion

5.1. Summary

In Sections 2 and 3, we conducted a literature review of the tactile experience from two perspectives: user expectations and material design. The first perspective focuses on the intrinsic link between touch and vision, highlighting how previous tactile experiences are integrated in the brain as visual representations, thereby shaping visual expectations for subsequent tactile perceptions. When these expectations clash with actual sensory input, it leads to Discovering users' surprising experiences. These studies place "people" at the core, often relying on psychological experiments to gather perceptual data from users during tactile interactions. By doing so, they uncover how internal factors like cognition, experience, and personal preferences influence tactile perception, providing a solid theoretical foundation for optimizing material textures to enhance user experiences.

In contrast, the latter approach focuses on "objects," systematically examining the differences in material experiences across both single-tactile modalities and cross-modal contexts. It establishes a hierarchical research framework linking "physical properties—perceptual dimensions—user emotions," where sensory experiments are used to measure emotional responses and their correlations with specific material attributes. This approach clarifies the mapping mechanism between materials and emotions, ultimately offering practical guidance for material selection and design.

Overall, while the two types of studies fall into different research domains, they also share certain limitations stemming from their distinct perspectives. For instance, when evaluating tactile experiences related to material properties, assessing only the inherent quality of a product's texture is insufficient—it should also take into account users' expectations. Even if a product doesn't stand out in terms of objective attributes, if it manages to exceed user expectations and deliver a delightful surprise, the degree of that surprise can serve as a crucial indicator for gauging user experience. Meanwhile, in studies focused on users' tactile expectations toward products, insights gained from material research can be integrated to pinpoint exactly which specific physical attributes trigger feelings of delight or wonder. This approach not only clarifies the often-vague concept of "surprise" but also translates it into concrete, actionable design parameters, empowering designers to systematically enhance the overall tactile quality of their products.

5.2. Development Trends

As an interdisciplinary field intersecting industrial design,

psychology, and materials science, research on product tactile experiences is still in its early stages, both domestically and internationally. In China, related studies remain relatively limited, while even internationally, the history of such research is not extensive—meaning a comprehensive theoretical framework has yet to emerge. However, as users increasingly demand emotionally engaging material experiences and advancements in materials science continue to accelerate, the research trends in this area are expected to evolve in the following directions:

5.2.1. Precise Collection of User-Subjective Data

In tactile experience research, accurately and reliably capturing users' emotions, feelings, and perceptual data is crucial for influencing material selection and design outcomes. Currently, the process largely relies on traditional methods such as sensory experiments and questionnaire-based scales, which can introduce certain levels of subjective bias. Looking ahead, we could integrate physiological signal-measurement technologies—such as electroencephalography (EEG) and facial expression analysis—to objectively record and validate users' internal responses during tactile interactions, thereby enhancing the reliability and interpretability of the collected data.

5.2.2. Development of New Materials Focused on User Experience

Currently, research on the relationship between material's objective properties and users' subjective perceptions often remains at the level of correlational phenomena. Yet, one of the fundamental goals of tactile experience design is precisely to tailor material attributes—or even develop entirely new materials—to align with users' emotional and functional needs. Moving forward, efforts should focus on building a systematic database that links user perceptions directly to material characteristics. By leveraging advancements in materials science and technology, we can pave the way for truly user-centered material design and innovative applications.

6. Closing Remarks

The ambiguity of the product's tactile experience stems from the complex properties of materials combined with differences in users' subjective experiences. This paper employs sensory experiments and the methodology of sensory ergonomics to establish a mapping between users' psychological perceptions and material attributes, aiming to bridge this cognitive gap and guide material design and selection. By examining both user behavior and material characteristics, the study systematically reviews the current state and achievements in tactile expectations and material research, while also outlining promising directions for future research in this field.

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