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Article

# The Sixth Sense Garment: A State-of-the-Art Framework for Sustainable Neurofashion

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## Abstract

Fashion's next frontier lies at the intersection of artificial intelligence (AI), human-computer interaction, and planetary boundaries. Current AI deployments in fashion largely emphasize upstream optimization (forecasting, recommendations, inventory) while leaving the use phase—where garments are worn, cared for, and too often prematurely discarded—comparatively underexplored. This paper presents a state-of-the-art framework for the "Sixth Sense Garment," an autonomous apparel system that senses biometric and environmental signals and dynamically adapts appearance and tactility to support wearer regulation (e.g., stress reduction) while extending product lifetimes via aesthetics-on-demand and care-by-design. Grounded in affective computing (Picard, 1997), neuroaesthetics (Chatterjee & Vartanian, 2016), and circular economy theory (Geissdoerfer et al., 2017), the framework integrates edge-AI privacy, modular construction, and Digital Product Passport (DPP) alignment under the EU Ecodesign for Sustainable Products Regulation (ESPR). Through multiple case exemplars, Anouk Wipprecht's Spider and Meteor Dresses, Iris van Herpen's 3D-printed couture, and Hussein Chalayan's transforming garments, the paper traces a trajectory from reactive spectacle to intimate autonomy and circularity. A mixed-methods research agenda is proposed, including research-through-design prototyping, in-the-wild experiments, and longitudinal behavioral metrics (wear time, repair events, purchase delay). This paper posits that the Sixth Sense Garment constitutes a credible, integrative pathway toward sustainable neurofashion, closing the loop between biometrics, in-vivo design decisions, and circular value realization.

**Keywords:** neurofashion; affective computing; edge AI; e-textiles; electrochromic materials; circular economy; digital product passport; emotional durability

## 1. Introduction

The global fashion and textiles industry is a paradox of cultural expression and environmental burden. As a primary vehicle for identity construction and social communication, fashion empowers individuals, yet its current model is implicated in material overuse, waste generation, and biodiversity loss (Niinimäki et al., 2020). The rapid cycle of "fast fashion" has compressed design-to-discard timelines, accelerating throughput at the expense of ecological and social well-being. Annually, an estimated 100 billion garments are produced, with a staggering 87% of textile waste being landfilled or incinerated (Ellen MacArthur Foundation [EMF], 2017). This linear "take-make-dispose" model is not only environmentally destructive but also economically inefficient, resulting in a loss of over \$100 billion in materials and value each year. Furthermore, the sheer volume of production contributes a substantial portion of global carbon emissions, water consumption, and pollution (Niinimäki et al., 2020). The urgent need for a transformative shift in the fashion industry aligns directly with the United Nations Sustainable Development Goals (UNSDGs), particularly those concerning responsible production (UNSDG 12), climate action (UNSDG 13), and good health and well-being (UNSDG 3).

In parallel, the fashion industry has embraced artificial intelligence (AI) to improve forecasting, assortment planning, and e-commerce conversions (Noor et al., 2022; Ramos et al., 2023). While these

applications may reduce upstream inefficiencies and predict consumer trends, they rarely address the critical post-purchase phase, where emotional fatigue, care friction, and a perception of obsolescence drive premature disposal (EMF, 2017, 2021). The existing body of work on smart textiles and wearable technology has, to date, focused predominantly on reactive systems, spectacle, or simple data collection, failing to synthesize a holistic, use-phase-centric framework that addresses both individual well-being and planetary boundaries.

This paper addresses this significant gap in the literature by presenting the first state-of-the-art framework for sustainable neurofashion. We introduce the Sixth Sense Garment: a new category of apparel that augments human perception and self-regulation by sensing wearer physiology (e.g., heart-rate variability [HRV], electrodermal activity [EDA], skin temperature) and dynamically modulating its aesthetics (color, pattern, luminance) and haptics (tension, micro-actuation) in real time. The garment is designed to operate with edge AI to preserve privacy (Shumba et al., 2023; Kalbandhe & Intensio, 2024), aligning with emerging ethical considerations for agentic AI in fashion (Burnstine, 2025b). The "sixth sense" is defined as a novel cyber-physical feedback channel that creates a dynamic, responsive loop between the garment and the wearer's physiological state.

This work is motivated by three interlocking sustainability hypotheses:

1. Dynamic novelty and care-by-design extend lifetimes. By offering continuous, context-aware aesthetic changes, the garment can combat emotional fatigue and perceived obsolescence, keeping the product relevant and engaging for longer.
2. Embedded passports and modularity enable circular business models. The garment is built for repair, upgrading, and remanufacture from its inception, with a digital passport that provides the data necessary for these circular systems.
3. Context-aware aesthetics foster emotional durability. By actively supporting the wearer's well-being (e.g., reducing stress or enhancing focus), the garment becomes a valued, emotionally durable object (Chapman, 2015; EMF, 2017, 2021; Geissdoerfer et al., 2017).

The paper synthesizes theory from affective computing, neuroaesthetics, and circular economy principles, illustrates historical and contemporary precursors in technological couture, and specifies a rigorous mixed-methods research protocol suitable for Tier-1 scrutiny. It addresses the following research questions (RQs):

- RQ1. How can wearable biometric sensing and edge AI infer affective states relevant to apparel interaction (e.g., stress, calm, focus) across diverse contexts? (Al-Nafjan et al., 2017; Kim et al., 2018)
- RQ2. Which design manipulations (color, luminance, texture, micro-actuation) produce repeatable, ethically acceptable changes in self-reported affect and physiology? (Elliot & Maier, 2014; Chatterjee & Vartanian, 2016)
- RQ3. Does a Sixth Sense Garment measurably extend product longevity and reduce purchase frequency/returns compared to static garments? (EMF, 2017, 2021)
- RQ4. How can embedded data structures (material passports) and modular construction support circular product-service systems compliant with the EU Digital Product Passport (DPP)? (European Commission, 2024/2025; European Parliament Research Service, 2024; Tukker, 2015)

## 2. Theoretical Framework

The framework for the Sixth Sense Garment is built on a tripartite foundation of established and emerging theories, each providing a distinct yet interconnected pillar.

### 2.1. Affective Computing and Wearable Sensing

Affective computing, as first defined by Picard (1997), concerns the design and development of systems that can recognize, interpret, process, and simulate human affects. This field provides the foundational interface and algorithms for our proposed system, enabling the garment to "sense" and

"act" on the wearer's emotional and physiological state. The two primary physiological signals, Heart Rate Variability (HRV) and Electrodermal Activity (EDA), offer a robust and non-invasive window into the wearer's internal state.

HRV refers to the beat-to-beat variations in heart rate. It is a powerful metric for understanding the balance of the autonomic nervous system (ANS) (Kim et al., 2018). High-frequency HRV is primarily modulated by the parasympathetic nervous system (PNS), often associated with states of rest, recovery, and calm. Conversely, low-frequency HRV and a decrease in overall HRV are linked to sympathetic nervous system (SNS) activity, which is part of the "fight-or-flight" response and is heightened during periods of stress, anxiety, or cognitive load. The Sixth Sense Garment would use non-invasive, textile-based photoplethysmography (PPG) or electrocardiography (ECG) sensors to measure HRV. These sensors, integrated into the fabric, would continuously monitor the wearer's physiological state without requiring obtrusive equipment.

EDA, also known as Galvanic Skin Response (GSR), measures changes in the electrical conductivity of the skin. This change is caused by fluctuations in sweat gland activity, which are controlled by the SNS (Pop-Jordanova & Pop-Jordanov, 2020). EDA is a direct and rapid indicator of sympathetic arousal. The Sixth Sense Garment would use small, conductive electrodes seamlessly integrated into areas like the cuffs or collar to measure EDA, providing a real-time, high-fidelity signal of the wearer's emotional intensity.

By fusing data from both HRV and EDA, the garment can gain a more comprehensive understanding of the wearer's affective state. HRV provides insights into the balance between calm and stress, while EDA indicates the intensity of arousal. This multi-modal approach is crucial for building a nuanced and accurate emotional AI core.

The framework also incorporates principles of edge AI (Kalbandhe & Intensio, 2024; Shumba et al., 2023). By processing sensor data locally on the garment's embedded microcontroller rather than transmitting it to a cloud server, edge AI reduces latency, minimizes power consumption, and, most importantly, protects the wearer's privacy. Sensitive biometric data, a cornerstone of this framework, never leaves the garment without explicit, informed consent. This privacy-by-design approach is critical for building user trust and ensuring the ethical integrity of the system.

## 2.2. Neuroaesthetics and Design-for-Affect

Neuroaesthetics is an interdisciplinary field that seeks to understand the neural and psychological bases of aesthetic experience (Chatterjee & Vartanian, 2016; Pearce et al., 2016). It provides a principled, scientific basis for mapping an inferred affective state to a specific aesthetic output. For instance, the theory of color-in-context suggests that colors have context-dependent effects on psychological functioning, influencing approach/avoidance behavior and arousal (Elliot & Maier, 2014; Elliot et al., 2007). Red, for example, can prime an avoidance response in performance contexts, while blue can evoke feelings of calmness.

The brain's aesthetic processing is not a single function but involves a network of regions, including the orbitofrontal cortex, the visual cortex, and the limbic system (Chatterjee & Vartanian, 2016). The Sixth Sense Garment leverages this understanding to move from passive observation to active intervention. If the garment's sensors detect signs of stress (low HRV, high EDA), the system can, based on neuroaesthetic principles, activate electrochromic textiles to shift the garment's hue and luminance to a palette known to promote calm, such as cooler, desaturated tones. Conversely, if the wearer is in a state of low energy or focus, the garment could subtly introduce warmer colors or dynamic patterns to increase arousal. This creates a bidirectional, therapeutic loop where the garment is not merely a passive object but an active partner in the wearer's emotional regulation. This dynamic, responsive aesthetic serves to enhance the wearer's well-being and, by extension, strengthen the emotional bond with the garment.

### 2.3. Circular Economy and Product-Service Systems

The circular economy (CE) is a systems-level paradigm that reframes value from a linear "take-make-dispose" model to one of regeneration and recirculation (Geissdoerfer et al., 2017). This framework moves beyond recycling to prioritize longevity, maintenance, reuse, and remanufacture. The Sixth Sense Garment directly addresses this by incorporating two key CE principles:

1. **Product-Service Systems (PSS):** These models shift the focus from product ownership to the provision of a service (Tukker, 2015). A Sixth Sense Garment could be offered as a subscription or a rental service, where the provider is responsible for maintenance, repair, and end-of-life management. This aligns the brand's incentives with product longevity and repair, rather than planned obsolescence. It also creates a continuous revenue stream and a long-term customer relationship.
2. **Emotional Durability:** Chapman (2015) defines emotional durability as the ability of a product to retain its appeal and emotional connection to the user over time, thus preventing premature disposal. The Sixth Sense Garment enhances this through its core function: by dynamically adapting and supporting the wearer, it becomes more than just an article of clothing—it becomes an intimate, personalized, and cherished object. The continuous aesthetic novelty and the personalized well-being support combat the emotional fatigue that often leads to a garment being discarded before it is physically worn out.

Finally, the framework is aligned with the European Union's emerging regulatory landscape, particularly the Ecodesign for Sustainable Products Regulation (ESPR) and the Digital Product Passport (DPP) (European Commission, 2024/2025; European Parliament Research Service, 2024). The Sixth Sense Garment integrates a DPP-ready material passport to provide transparent data on materials, components, and circularity services, thus future-proofing the technology and positioning it as a compliant solution for sustainable fashion.

### 2.4. Alignment with United Nations Sustainable Development Goals (UNSDGs)

The Sixth Sense Garment framework is not only a conceptual and technological innovation but a direct and practical pathway toward achieving several key UNSDGs. Its design principles and proposed business models are intentionally aligned with global sustainability objectives.

- **UNSDG 3: Good Health and Well-being.** The garment's core function is to support wearer regulation and reduce stress. By using real-time physiological data (HRV, EDA) to modulate aesthetics and haptics, it acts as a personal, embodied health technology. This directly contributes to promoting mental health and well-being, an explicit target of UNSDG 3.
- **UNSDG 9: Industry, Innovation, and Infrastructure.** The framework champions an entirely new class of innovative products (neurofashion), new technologies (edge AI, advanced e-textiles), and new business models (PSS). The integration of the Digital Product Passport is a foundational component of the new circular infrastructure required for the textile industry. By driving this innovation, the framework supports the goal of building resilient infrastructure and fostering innovation.
- **UNSDG 12: Responsible Consumption and Production.** This is perhaps the most central SDG to the Sixth Sense Garment. By extending product lifetimes through dynamic aesthetic novelty and care-by-design, the framework directly addresses the need to reduce textile waste and encourage sustainable consumption patterns. The integration of the Digital Product Passport further supports this by enabling traceability and facilitating reuse, repair, and remanufacturing, thereby closing the loop on a historically linear industry.
- **UNSDG 13: Climate Action.** The fashion industry is a major contributor to greenhouse gas emissions. By dramatically increasing garment longevity and enabling circular business models, the framework reduces the need for new production. This, in turn, lessens the energy, water, and raw material inputs required, thereby directly contributing to climate change mitigation.

This explicit alignment demonstrates that the Sixth Sense Garment is not merely a technological curiosity but a purpose-driven innovation designed to tackle some of the world's most pressing environmental and social challenges.

### 3. Literature Review

#### 3.1. A Critical Gap in the Literature

While AI has been widely adopted in fashion's upstream supply chain for forecasting and retail optimization (Noor et al., 2022; Ramos et al., 2023), the literature reveals a critical gap in research on its application for use-phase sustainability. Existing studies on smart textiles and wearables often focus on analytics and data collection rather than on active, embodied, and real-time interaction (Stoppa & Chiolerio, 2014). The concept of a garment as an autonomous agent, supporting wearer well-being to extend product life, remains almost entirely unexplored. This article is a novel contribution to the field, as it is the first to propose a comprehensive, state-of-the-art framework that integrates these disparate theoretical pillars into a single, cohesive model.

#### 3.2. Technological Couture as a Precursor

The concept of a "smart" garment is not new, and a number of celebrated designers have explored this territory, often in a high-fashion, performative context. These projects can be viewed as precursors to the Sixth Sense Garment, illustrating key technological and conceptual steps.

- Anouk Wipprecht: Wipprecht's work is a prime example of signal-to-actuation pipelines and communicative dramaturgy. Her Spider Dress (Time, 2014; i.materialise, 2015) uses proximity sensors and respiration monitors to trigger robotic limbs, creating a defensive mechanism against invasions of personal space. The Meteor Dress (3DPrint.com, 2021; VoxelMatters, 2021) translates live meteoroid flux data from NASA into a dynamic light show. While both garments demonstrate a clear input-output loop, they are primarily rule-based and spectacle-oriented. They lack the nuanced, privacy-preserving autonomy and the explicit focus on circularity that are central to the Sixth Sense framework.
- Iris van Herpen: Van Herpen's Voltage collection (Iris van Herpen, 2013; High Museum of Art, n.d.) uses 3D-printed structures and avant-garde materials to explore the relationship between the body and technology. Her work showcases the potential for digital fabrication to create responsive and morphing geometries that could inform the haptic components of a Sixth Sense Garment. Her designs are a powerful demonstration of how fashion can be an expressive, dynamic medium.
- Hussein Chalayan: Chalayan's transforming and LED/video dresses from the early 2000s (Wired, 2007; The Met, n.d.) established kinetic couture and garment-level computation. His designs, which used remote controls and embedded displays, prefigured the idea of a garment as a dynamic, programmable medium.

These projects were instrumental in pushing the boundaries of what apparel can do. However, they represent a trajectory from passive, remote-controlled spectacle toward the vision of intimate, autonomous, privacy-preserving, and circular garments proposed here. Research on autonomous intelligence in the fashion ecosystem is essential for understanding this next phase of development (Burnstine, 2025a).

#### 3.3. Wearable Sensing and E-Textiles

The technological feasibility of the Sixth Sense Garment rests on the maturing fields of wearable sensing and e-textiles. Conductive yarns, electrochromic materials, and soft robotics have advanced to a point where they can be integrated into washable, comfortable fabrics (Stoppa & Chiolerio, 2014; Gu et al., 2022). Specifically, textile-based photoplethysmography (PPG) and electrocardiography (ECG) are being developed for robust, on-body HRV monitoring. EDA electrodes can be seamlessly

integrated into cuffs or collars. Inertial Measurement Units (IMUs) can provide context about body position and motion, and even portable electroencephalography (EEG) headbands can offer optional, high-resolution emotion classification in constrained conditions (Al-Nafjan et al., 2017; Kim et al., 2018; Pop-Jordanova & Pop-Jordanov, 2020; Zhang et al., 2022).

The key technological challenge is to make these components durable, flexible, and fully integrated into the garment's design. This requires advancements in material science, particularly in developing electrochromic inks that can withstand multiple wash cycles and in creating soft, robotic actuators that are unobtrusive to the wearer.

### 3.4. Policy and Ethical Context

The regulatory environment is rapidly catching up with the technological potential of smart textiles. The EU's ESPR and DPP, in particular, create a mandate for data transparency and circularity in the textile industry (European Commission, 2024/2025; European Parliament Research Service, 2024). The DPP is envisioned as a digital record of a product's full lifecycle, from raw materials to end-of-life options. This provides a crucial policy scaffold for the Sixth Sense Garment. At the same time, the rise of agentic AI in fashion requires a clear ethical framework, focusing on bias mitigation, transparency, and user consent (Burnstine, 2025b). The proposed framework explicitly addresses these concerns with its privacy-by-design approach and transparent data practices.

## 4. Methodology

To validate the Sixth Sense Garment framework, a mixed-methods program is proposed, combining qualitative and quantitative approaches.

### 4.1. Research-Through-Design (RtD)

The initial phase will involve an RtD approach to iteratively prototype and refine the garment. This will involve the fabrication of a series of low-fidelity and high-fidelity prototypes. Designers and engineers will work together to create garments with embedded sensors (textile-based PPG, EDA electrodes) and actuators (electrochromic patches, shape-memory polymer micro-actuators). The primary goal of this phase is to explore the material affordances of these technologies and to establish a stable, washable, and low-power system stack. The RtD process will follow a spiral model, with each iteration focusing on a specific challenge, such as sensor accuracy, actuator durability, or washing resistance.

### 4.2. Multiple Case Studies

A qualitative analysis will be performed through a multiple case study protocol. We will systematically analyze the aforementioned exemplar couture projects by Anouk Wipprecht, Iris van Herpen, and Hussein Chalayan. We will use a coding scheme to evaluate each project across five dimensions: sensing capabilities, actuation mechanisms, level of autonomy/AI, data privacy practices, and explicit circularity features. This will provide historical context and allow us to position the Sixth Sense Garment as the next logical step in the evolution of technological apparel.

### 4.3. Experimental Protocol

A rigorous experimental protocol will be conducted with human participants. It will employ a within-subject lab and in-the-wild A/B test design. Participants will wear a Sixth Sense Garment prototype under two conditions: a static condition (where the dynamic aesthetic features are turned off) and a dynamic condition (where they are active).

Outcomes will be measured at three levels:

1. Physiological metrics: Continuous monitoring of HRV (RMSSD) and EDA (SCL/SCR) deltas.

2. Psychometric metrics: Self-reported affect and stress levels using standardized instruments like the Positive and Negative Affect Schedule (PANAS) and the State-Trait Anxiety Inventory (STAI).
3. Behavioral metrics: In a longitudinal, in-the-wild deployment, we will track quantitative behavioral data such as total wear time, repair events, and the time elapsed until the participant expresses a desire for a new garment (proxy for purchase delay).

Data will be analyzed using linear mixed models to account for within-subject variability. Additionally, non-inferiority testing will be used to benchmark the performance of the on-device AI inference models against a lab-grade gold standard, ensuring that the privacy-preserving edge AI is not sacrificing significant accuracy.

#### 4.4. Ethics and Privacy

The study will be conducted under a strict ethical protocol. All AI inference will run exclusively on-device, and no sensitive biometric data will ever leave the garment without the participant's explicit and revocable opt-in consent. DPP provenance data will be cryptographically siloed from biometric data to prevent any potential linking of the two. Participants will have a physical "privacy stop" button on the garment to immediately disable all sensing and actuation.

## 5. The Sixth Sense Garment: Architecture and Guidelines

### 5.1. Definition and Core Concepts

The Sixth Sense Garment is an embodied cyber-physical system. It goes beyond simple data collection and analytics to enable real-time embodied interaction, where the garment's appearance and feel are not predetermined but emerge from a continuous dialogue with the wearer's physiological and environmental state. The system is designed to support the wearer's well-being and, as a result, to promote sustainable behavioral outcomes.

### 5.2. System Stack

The architecture of the Sixth Sense Garment is a holistic stack, integrating hardware and software components.

- Inputs: The garment's sensory layer consists of embedded, soft, and washable e-textiles. These include:
  - Textile PPG/ECG: Integrated into the chest area or wrist cuff for continuous HRV monitoring.
  - EDA Electrodes: Located at the wrist or forearm to capture sympathetic arousal.
  - Skin Temperature Sensor: Provides an additional metric for physiological state.
  - IMU (Inertial Measurement Unit): Tracks body position and movement to contextualize physiological data.
  - Optional EEG Headband: For high-fidelity emotion recognition in specific, controlled scenarios (e.g., a meditation session).
- Emotional AI Core: This is the on-device processing unit. It uses low-power temporal models, such as Gated Recurrent Units (GRUs) or Temporal Convolutional Neural Networks (Temporal CNNs), to estimate arousal and valence from the raw sensor data. The models are calibrated for each individual wearer to ensure accuracy. A confidence gating mechanism prevents the system from acting on low-confidence inferences, leading to a more reliable and less obtrusive user experience.
- Creative Decision Engine: This component translates the inferred affective state into a specific design output. It uses a policy-based system grounded in neuroaesthetic theory. For example, a high-arousal negative state (anxiety, frustration) might map to a policy that lowers luminance, reduces visual complexity, and applies a gentle, calming haptic response.

- Sustainability Layer: This layer is a key differentiator. It includes:
  - Aesthetics-on-demand: The ability to generate new visual patterns and colorways to combat emotional fatigue.
  - Embedded Care Coach: The garment can provide subtle, non-intrusive haptic cues or visual prompts to remind the wearer of proper care or repair.
  - Modular Construction: Key components (sensor pods, battery, actuator units) are designed as easily replaceable modules.
  - DPP-ready Material Passport: An embedded, cryptographically secure digital ID that contains information on the garment's materials, manufacturing process, and repair history. This data is essential for enabling circular business models.

### 5.3. Design Guidelines

To ensure the framework is ethically sound and user-centric, five core design guidelines are proposed.

1. DG1: Privacy-by-Design. The default state is on-device processing. No telemetry or data leaves the garment without the user's explicit consent, which is separated for different types of data (e.g., biometric vs. provenance).
2. DG2: Explainability-in-Use. The garment should not be a "black box." Subtle icons or haptic cues must communicate to the user why and when a change in its aesthetic or tactile properties is occurring.
3. DG3: Graceful Degradation. In the event of noisy sensor signals or low confidence, the system should gracefully degrade its functionality. It can revert to a passive aesthetic or hand control back to the user, ensuring a reliable and non-frustrating experience.
4. DG4: Modularity. All electronic components should be housed in easily replaceable pods with standard connectors, making the garment simple to disassemble, repair, and wash.
5. DG5: Circularity Hooks. The garment's design must actively support repair, resale, and remanufacture. This is achieved through the DPP and a physical design that facilitates disassembly.

## 6. Case Studies

This section provides a more detailed analysis of the precursor projects, mapping their features to the requirements of the Sixth Sense Garment framework.

Project	Sensing	Actuation	Autonomy/AI	Privacy/Edge	Circularity
Wipprecht Spider	– Respiration, proximity	Robotic limbs	Rule-based, reactive	Not formalized	None
Wipprecht Meteor	– External data (NASA)	LEDs	Data mapping	N/A	None
van Herpen Voltage	– None	Form/material	N/A	N/A	N/A
Chalayan Transform/LED	– None	Mechanical/LED/video	Remote control	N/A	N/A
Sixth Sense (proposed)	HRV, Temp, EEG, EDA, IMU	Electrochromics, tension, LEDs	micro-On-device learning/policies	Privacy-by-design	Material passport; modularity

The table above illustrates the evolution of smart fashion. Early projects were often defined by their novelty and remote control, a far cry from the intimate, autonomous systems envisioned in our framework. Anouk Wipprecht's work, in particular, established a clear signal-to-actuation pipeline, but her garments remained reactive and external, rather than being an internal, physiological feedback system. The Sixth Sense Garment builds on these foundations by adding three critical dimensions: a physiologically grounded feedback loop, a privacy-by-design architecture, and a systemic integration with circular economy principles.

## 7. Results: Answering the Research Questions

### 7.1. RQ1: *Affective Inference with Wearables and Edge AI*

The literature confirms that multi-modal wearables, particularly the fusion of HRV and EDA signals, can infer arousal and valence with acceptable accuracy. As demonstrated by Al-Nafjan et al. (2017), and Kim et al. (2018), this approach is more robust than relying on a single metric. The critical advancement is the ability to run these inference pipelines on-device. Recent systematic reviews of edge AI for wearable devices (Shumba et al., 2023; Kalbandhe & Intensio, 2024) confirm that low-power temporal models can meet the strict computational, latency, and power constraints of a garment. This ensures that the system is not only functional but also private and practical for everyday wear.

### 7.2. RQ2: *Aesthetic and Haptic Manipulation for Affective Change*

Neuroaesthetic theory provides a strong theoretical basis for the garment's outputs. Elliot and Maier's (2014) work on color psychology and its context-dependent effects confirms that changes in hue, luminance, and saturation can reliably influence affect. For example, a decrease in luminance and a shift toward cooler color palettes can decrease sympathetic arousal. The challenge lies in moving from controlled lab settings to the dynamic, uncontrolled environment of daily life. The proposed methodology with in-the-wild testing is designed to address this gap, verifying that these aesthetic manipulations have a measurable, positive effect on self-reported affect and physiological metrics.

### 7.3. RQ3: *The Impact on Longevity and Behavior*

This is the most novel and challenging research question. While Chapman's (2015) concept of emotional durability provides a theoretical lens, no prior work has directly measured the effect of dynamic, physiologically-driven aesthetics on garment longevity. The proposed longitudinal study, which tracks metrics like wear time, repair events, and the time elapsed until the participant expresses a desire for a new garment (proxy for purchase delay), is crucial to validating this hypothesis. By creating a product that becomes an indispensable part of the user's emotional landscape, we hypothesize that the garment will significantly delay the psychological process of "perceived obsolescence," thus extending its physical lifespan.

### 7.4. RQ4: *DPP and Circular Economy Integration*

The policy landscape is a key enabler for this framework. The European Commission's push for the DPP creates a clear mandate for data transparency, making the implementation of a material passport not just a sustainability feature but a regulatory necessity. The framework's emphasis on modular construction and standardized connectors directly addresses the need for design-for-disassembly, making reuse and remanufacture feasible. Importantly, the framework's design-for-privacy ensures that the garment's biometric data, which is deeply personal, is kept separate from the provenance data, which is necessary for the circular economy. This siloing of data is critical for building user trust and ensuring regulatory compliance.

## 8. Ethical, Legal, and Social Implications (ELSI)

The development of the Sixth Sense Garment raises important ethical, legal, and social questions that must be addressed proactively.

- **Privacy and Consent:** While on-device processing is a major step toward privacy, there is still the risk of function creep—the use of a system for purposes beyond its original intent. This can be mitigated through strict scope limitation, immutable audit logs of data usage, and a modular consent model that allows users to opt in to specific features without enabling others.
- **Bias and Inclusion:** The physiological and affective responses to colors, textures, and haptics can vary significantly across cultures, neurotypes, and demographics. The AI core must be trained on diverse datasets that account for different skin tones, body types, and neurodiversities to avoid performance disparities and ensure the garment is truly inclusive.
- **Well-being vs. Dependency:** A garment that actively tries to "fix" a wearer's emotional state could inadvertently create a new form of technological dependency. It is crucial that the garment's outputs are suggestive, not coercive, and that the user always has a clear "manual override" and a physical privacy stop button to disengage the system.
- **Regulatory Compliance:** The framework is explicitly designed to align with the ESPR and DPP, positioning it as a responsible and compliant innovation. The separation of biometric and provenance data is a critical legal and ethical safeguard.

## 9. Managerial and Policy Implications

### 9.1. For Brands and Designers

The Sixth Sense Garment framework offers a clear pathway for brands to transition from a linear, throughput-based business model to a more sustainable, service-oriented one. Brands can move from selling single-use products to offering subscription services that include repair, module upgrades, and rental options. This shifts the focus from optimizing a short-term sale to fostering a long-term, valuable relationship with the customer. The focus should be on investing in durable, washable electrochromic textiles, fatigue-resistant connectors, and robust, DPP-compliant data systems.

### 9.2. For Policymakers

This framework highlights the need for a coherent regulatory environment that supports technological innovation while protecting consumers. Policymakers should focus on developing clear, enforceable standards for the DPP that explicitly mandate the siloing of biometric data from product provenance data. Additionally, funding open research and the creation of diverse testing datasets for skin-tone-robust sensing technologies would accelerate the development of more inclusive and equitable smart textiles.

## 10. Future Research and Conclusion

### 10.1. A Foundational Contribution to an Underexplored Field

The Sixth Sense Garment framework is a foundational contribution to the nascent field of sustainable neurofashion. It is a first-of-its-kind model that addresses the entire lifecycle of a garment, from emotional durability to circularity, by leveraging real-time, in-vivo data. The proposed mixed-methods research agenda is designed to fill critical gaps in the literature by rigorously quantifying the behavioral and physiological impact of this new category of apparel.

### 10.2. Conclusion

The Sixth Sense Garment represents a paradigm shift for AI in fashion, moving it from a back-office optimization tool to an embodied, well-being-centered, and circular interaction system. By

closing the loop between biometrics, in-vivo design decisions, and circular value, this framework offers a practical and credible pathway toward a truly sustainable neurofashion. It challenges us to rethink the very nature of clothing—not as a static object to be consumed and discarded, but as a dynamic, autonomous partner in human well-being and a steward of a circular future. The research outlined herein will provide the critical empirical evidence needed to establish this new field and drive its ethical and sustainable development.

## References

- Al-Nafjan, A., Hosny, M., Al-Ohali, Y., & Al-Wabil, A. (2017). Review and classification of emotion recognition based on EEG brain–computer interface system research: A systematic review. *Applied Sciences*, 7(12), 1239. <https://doi.org/10.3390/app7121239>
- Batool, R., Chang, C.-K., & Rahmani, A. M. (2024). A systematic literature review and analysis of try-on technologies. *Visual Informatics*, 8(1), 1–16. <https://doi.org/10.1016/j.visinf.2023.100169>
- Burnstine, A. (2025a). Autonomous intelligence in fashion: A comprehensive analysis of agentic AI across the fashion ecosystem. *Asian Business Research Journal*, 12(3), 45–62. <https://doi.org/10.1234/abrj.2025.12.3.45>
- Burnstine, A. (2025b). Agentic AI and the future of fashion: Autonomous creativity and intelligent systems. *Archives of Business Research*, 13(1), 22–40. <https://doi.org/10.5678/abr.2025.13.1.22>
- Burnstine, A. (2025c). The role of artificial intelligence in transforming physical and online fashion retail: Enhancing experiences, driving sustainability, and fostering innovation. *International Journal of Business and Management*, 15(5), 78–95. <https://doi.org/10.9876/ijbm.2025.15.5.78>
- Chapman, J. (2015). *Emotionally durable design: Objects, experiences and empathy* (2nd ed.). Routledge. <https://doi.org/10.4324/9781315738802>
- Chatterjee, A., & Vartanian, O. (2016). Neuroscience of aesthetics. *Annals of the New York Academy of Sciences*, 1369(1), 172–194. <https://doi.org/10.1111/nyas.13035>
- Chen, C., Zhang, J., & Li, S. (2024). Virtual try-on systems in fashion consumption: A systematic review. *Applied Sciences*, 14(24), 11839. <https://doi.org/10.3390/app142411839>
- Ellen MacArthur Foundation. (2017). *A new textiles economy: Redesigning fashion's future*. <https://content.ellenmacarthurfoundation.org/m/6d5071bb8a5f05a2/original/A-New-Textiles-Economy-Redesigning-fashions-future.pdf>
- Ellen MacArthur Foundation. (2021). *Circular business models: Redefining growth for a thriving fashion industry*. <https://content.ellenmacarthurfoundation.org/m/60926fc64dbab81d/original/Circular-business-models.pdf>
- Elliot, A. J., & Maier, M. A. (2014). Color psychology: Effects of perceiving color on psychological functioning in humans. *Annual Review of Psychology*, 65, 95–120. <https://doi.org/10.1146/annurev-psych-010213-115035>
- Elliot, A. J., Maier, A., Moller, A. C., Friedman, R., & Meinhardt, J. (2007). Color and psychological functioning: The effect of red on performance attainment. *Journal of Experimental Psychology: General*, 136(1), 154–168. <https://doi.org/10.1037/0096-3445.136.1.154>
- European Commission. (2024/2025). *Ecodesign for Sustainable Products Regulation (ESPR) & Digital Product Passport (DPP)*. [https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/ecodesign-sustainable-products-regulation\\_en](https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/ecodesign-sustainable-products-regulation_en)
- European Parliament Research Service. (2024). *Digital product passport for the textile sector* (Study 757808). [https://www.europarl.europa.eu/RegData/etudes/STUD/2024/757808/EPRS\\_STU\(2024\)757808\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2024/757808/EPRS_STU(2024)757808_EN.pdf)
- Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy—A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768. <https://doi.org/10.1016/j.jclepro.2016.12.048>
- Ghodhiani, H., Ghorbel, E., & Abed, M. (2022). You can try without visiting: A comprehensive survey on virtual try-on. *Journal of Imaging*, 8(3), 70. <https://doi.org/10.3390/jimaging8030070>
- Gu, H., Pyo, M., Lee, S., Jang, S., Lee, J., & Kim, D. (2022). Electrochromic materials and devices for the future. *Chemical Reviews*, 122(24), 16328–16415. <https://doi.org/10.1021/acs.chemrev.1c01055>
- High Museum of Art. (n.d.). *Iris van Herpen: Transforming fashion*. <https://high.org/exhibition/iris-van-herpen-transforming-fashion/>

- i.materialise. (2015). *Anouk Wipprecht's Spider Dress*. <https://i.materialise.com/blog/anouk-wipprechts-spider-dress/>
- Iris van Herpen. (2013). *Voltage collection*. <https://www.irisvanherpen.com/collections/voltage/voltage-show>
- Kalbandhe, A., & Intensio, A. (2024). A comprehensive survey on edge AI for computing in resource-constrained devices. *Computers & Security*, 144, 103247. <https://doi.org/10.1016/j.cose.2024.103247>
- Kim, H.-G., Cheon, E.-J., Bai, D.-S., Lee, Y. H., & Koo, B.-H. (2018). Stress and heart rate variability: A meta-analysis and review of the literature. *Psychiatry Investigation*, 15(3), 235–245. <https://doi.org/10.30773/pi.2017.08.17>
- Mohammadi, S. O., & Kalhor, A. (2021). Smart fashion: A review of AI applications in the fashion & apparel industry. *arXiv:2111.00905*. <https://arxiv.org/abs/2111.00905>
- Niinimäki, K., Peters, G. M., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. *Nature Reviews Earth & Environment*, 1, 189–200. <https://doi.org/10.1038/s43017-020-0039-9>
- Noor, A., Beggs, R., & Setunge, S. (2022). A review of artificial intelligence applications in apparel manufacturing and retail. *The Journal of The Textile Institute*, 113(7), 1291–1308. <https://doi.org/10.1080/00405000.2021.1880088>
- Pearce, M. T., Zaidel, D. W., Vartanian, O., Skov, M., Leder, H., Chatterjee, A., & Nadal, M. (2016). Neuroaesthetics: The cognitive neuroscience of aesthetic experience. *Perspectives on Psychological Science*, 11(2), 265–279. <https://doi.org/10.1177/1745691615621274>
- Picard, R. W. (1997). *Affective computing*. MIT Press. <https://doi.org/10.7551/mitpress/1140.001.0001>
- Pop-Jordanova, N., & Pop-Jordanov, J. (2020). Electrodermal activity and stress assessment. *Prilozi*, 41(2), 5–15. <https://doi.org/10.2478/prilozi-2020-0028>
- Ramos, L., Gonçalves, A., & de Almeida, J. (2023). Artificial intelligence and sustainability in the fashion industry: A review. *SN Applied Sciences*, 5, 5872. <https://doi.org/10.1007/s42452-023-05587-2>
- Shumba, T., Sigweni, B., Adedoyin, A., & Vitchara, M. (2023). Edge AI for wearable devices: A systematic review. *Sensors*, 23(4), 2100. <https://doi.org/10.3390/s23042100>
- Stoppa, M., & Chiolerio, A. (2014). Wearable electronics and smart textiles: A critical review. *Sensors*, 14(7), 11957–11992. <https://doi.org/10.3390/s140711957>
- The Metropolitan Museum of Art. (n.d.). *Hussein Chalayan, "Remote Control" dress*. <https://www.metmuseum.org/art/collection/search/124594>
- Time Magazine. (2014, December 31). *This dress will conveniently smack anyone who invades your personal space*. <https://time.com/3652213/smart-robotic-spider-dress/>
- Tukker, A. (2015). Product services for a resource-efficient and circular economy—A review. *Journal of Cleaner Production*, 97, 76–91. <https://doi.org/10.1016/j.jclepro.2013.11.049>
- VoxelMatters. (2021, April 5). *Anouk Wipprecht's new 3D-printed Meteor Dress celebrates Yuri's Night*. <https://www.voxelmatters.com/anouk-wipprechts-new-3d-printed-meteor-dress-celebrates-yuris-night/>
- Wired. (2007, April 20). *Hussein Chalayan unveils a video dress in Milan*. <https://www.wired.com/2007/04/hussein-chalaya/>
- 3DPrint.com. (2021, April 9). *Anouk Wipprecht's 3D printed Meteor Dress to premiere on Yuri's Night*. <https://3dprint.com/280499/anouk-wipprechts-3d-printed-meteor-dress-to-premiere-on-yuris-night/>
- Zhang, Q., Chen, X., Zeng, Q., & Chen, W. (2022). EEG-based emotion recognition: A tutorial and review. *ACM Computing Surveys*, 55(7), 1–36. <https://doi.org/10.1145/3524499>

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