Costume as Interface: Wearable Technology and the Future of Interactive Storytelling in Theatre

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ABSTRACT

Theatre has long relied on costume as a symbolic medium of representation, yet the rapid integration of digital technologies demands a re-examination of its dramaturgical role. While existing research in scenography and wearable computing has explored interactivity, costume design remains under-theorized, often treated as a static artifact rather than a dynamic participant in storytelling. This study addresses this gap by conceptualizing costume as an interactive interface that operates across aesthetic, material, and narrative dimensions. Drawing on an interdisciplinary framework informed by performativity theory, actor-network theory, and design affordances, the research employs a triangulated methodology: literature analysis, comparative case studies, and cross-case synthesis. Findings from recent productions, including Ying Gao's Flowing Water, Standing Time (2022), Polymorf's Symbiosis (2023), and Pauline van Dongen's Solar Shirt 2.0 (2022), demonstrate how smart textiles, sensors, and biofeedback garments function as narrative triggers, enhance performer-audience interactivity, and extend material responsiveness into dramaturgical agency. The results establish costumes not merely as visual accessories but as active narrative agents. Academically, this reconceptualization advances debates on embodiment, interactivity, and techno-materiality. Practically, it provides designers and practitioners with strategies for integrating wearable technology in ways that align innovation with narrative coherence, performer comfort, and ethical responsibility.

Keywords: Wearable Technology, Smart Textiles, Theatrical Costume Design, Interactive Storytelling, Narrative Agency

INTRODUCTION

Theatre has always been a space of synthesis, where visual design, embodied performance, and technological innovation converge to produce multisensory narratives[1]. Within this composite, costume design has historically been regarded as a discipline of material craft and symbolic representation. Costumes traditionally communicate historical period, cultural identity, or character psychology, shaping the aesthetic and semiotic landscape of performance[2]. Yet as performance practices increasingly incorporate digital scenography, virtual reality, and interactive media, the role of costume demands re-evaluation[3]. No longer confined to decorative or representational functions, costumes can be reconceptualized as narrative interfaces, dynamic mediators between performer, audience, and story, particularly when augmented by wearable technologies such as smart textiles (fabrics with integrated responsive properties such as color or texture change), embedded sensors (miniaturized devices that capture bodily or environmental data), and responsive materials (materials that physically react to stimuli like light, heat, or motion)[4]. This transformation situates costume design at the forefront of theatre's ongoing technological evolution, where fabric and code intertwine to generate new modes of storytelling[5].

Despite growing scholarly interest in digital scenography, immersive theatre, and human-computer interaction, research on the intersection of costume design and wearable technology remains relatively fragmented[6]. Studies

in performance studies and design research often treat costume as a static visual artifact, focusing on semiotics or material craftsmanship, while engineering-oriented research on wearables privileges functionality over narrative potential[7]. As a result, the dramaturgical agency of technologically enhanced costumes, their ability to shape, extend, or even initiate narrative events, has been underexplored. This constitutes a significant gap in both theory and practice. Although experimental projects have begun to incorporate light-emitting fabrics, motion-responsive garments, or haptic feedback systems (technologies that deliver tactile sensations such as vibration or pressure to the wearer), systematic frameworks that analyze their narrative contributions remain scarce[8]. Consequently, the integration of intelligent materials and sensors into theatre is often viewed as a novelty rather than a substantive redefinition of costume design.

This paper aims to address this gap by conceptualizing costumes not only as aesthetic objects but as interactive interfaces that contribute directly to theatrical narration. By combining insights from costume design theory, wearable technology studies, and performance analysis, the study develops a framework for understanding how smart materials and embedded sensors transform the role of costume in storytelling. Specifically, it investigates how costumes can register performers' movements, physiological signals, or environmental cues, and translate them into real-time narrative effects, ranging from dynamic changes in color or texture to the triggering of audiovisual responses that reshape audience perception. Such an approach situates costume at the nexus of embodiment and computation, proposing a reconceptualization that foregrounds its potential as an active dramaturgical agent.

The methodological strategy underpinning this research is interdisciplinary. First, a critical literature review synthesizes scholarship from theatre studies, design research, and human–computer interaction, mapping the conceptual terrain of interactive narratives and smart materials. Second, comparative case studies analyze selected productions and experimental projects that have employed wearable technologies in costume design, drawing from performance documentation, technical reports, and design notes. Third, the study employs a comparative framework to contrast conventional costume functions with technologically enhanced ones, emphasizing differences in narrative agency, material responsiveness, and audience engagement. This triangulated approach ensures both theoretical depth and empirical grounding, enabling a nuanced analysis of how intelligent costumes operate within the ecology of contemporary performance.

The significance of this research is both academic and practical. Academically, it contributes to a growing body of literature that seeks to bridge the gap between design disciplines and digital technologies. By theorizing costume as interface, the study extends debates in performance studies about embodiment, interactivity, and materiality, while also offering design research a case for the integration of aesthetic and technological considerations. Practically, the findings provide theatre practitioners and costume designers with a conceptual and methodological toolkit for integrating smart materials and sensors into their work in ways that are narratively meaningful rather than superficially spectacular. At a moment when theatre increasingly competes with digital entertainment forms, such innovations may enhance the medium's distinct capacity for embodied, live, and interactive storytelling.

In this sense, the research not only addresses an underexplored area within costume studies but also contributes to the broader discourse on the future of theatre technology. By demonstrating how wearable technology can reposition costumes as active participants in dramaturgy, it argues for a reimagined relationship between fabric and code, one that aligns costume design with the evolving demands of interactive performance and opens new possibilities for narrative innovation in twenty-first-century theatre.

LITERATURE REVIEW

Theatrical Costume as Narrative Medium

Costume has long been regarded as a vital semiotic resource in theatre, shaping audience interpretation of character, setting, and cultural context. Traditional scholarship emphasizes costume's capacity to signal historical authenticity, symbolic meaning, and aesthetic coherence within a performance[9]. For instance, research in performance studies highlights how garments establish cultural memory and character identity by embedding visual codes into fabric and silhouette[10]. Yet this perspective largely frames costume as a static text to be read rather than as a dynamic participant in storytelling. In recent decades, performance theory has broadened to acknowledge embodiment and materiality, suggesting that costumes interact with performers' gestures and audience perceptions in ways that exceed mere symbolism[11]. However, even within this expanded lens, the dramaturgical role of costume is still often interpreted retrospectively, as a representational layer added to performance, rather than as an active, interactive system capable of shaping the unfolding narrative in real time. This conceptual limitation underscores the need to reconceptualize costume as an agent of narrative production rather than a passive signifier.

Wearable Technology and Smart Materials

In parallel, the field of wearable technology has witnessed rapid innovation, driven by advances in smart textiles, responsive fabrics, and sensor-embedded garments. Smart materials are now capable of altering color, texture, or luminosity in response to environmental stimuli, while miniaturized sensors can detect motion, temperature, or biometric signals. These developments have been widely studied in design and human-computer interaction (HCI), where wearables are typically analyzed for their functional, medical, or utilitarian applications[12]. In artistic domains, early explorations of smart fabrics have appeared in fashion design, interactive art, and dance performance, often showcasing garments that visually react to body movement or environmental changes[13]. Nevertheless, the application of wearable technologies in theatre remains sporadic, and the scholarship tends to privilege either the technical engineering of the garments or their visual novelty, without systematic attention to narrative agency. The potential for costumes to act as performative interfaces that both register and produce story elements remains an underdeveloped area of inquiry, requiring a synthesis of design theory, performance studies, and technological research.

Interactive Narratives in Theatre

Research on interactivity in theatre has largely concentrated on scenography, virtual reality, and immersive environments. Scholars of digital performance emphasize how interactive systems reconfigure the relationship between stage, performer, and audience, enabling spectators to influence narrative outcomes or experience stories across multiple media platforms[14]. Immersive theatre companies have experimented with audience movement, choice-making, and digital augmentation, yet costumes rarely occupy a central role in these frameworks[15]. Instead, interactivity is usually anchored in scenographic design, lighting, or digital projections. A small but growing body of experimental theatre practice demonstrates how sensor-enabled costumes can extend interactive possibilities by making the actor's body itself a site of narrative production, for example, through garments that trigger soundscapes or lighting changes in response to physiological data. However, scholarly analysis of such practices is limited, and the theoretical frameworks used to study interactive performance often overlook costume as a technological agent. Bridging this gap requires integrating perspectives from costume studies and wearable computing to develop models that account for how garments themselves can drive narrative transformation.

THEORETICAL FRAMEWORK AND METHODOLOGY

Conceptual Framework: Costume as Interface

For clarity, in this study wearable technologies mainly refer to smart textiles (responsive fabrics) and embedded sensors (devices capturing bodily or environmental signals), which together enable costumes to act as interactive systems.

This study adopts an interdisciplinary framework that reconceptualizes costume as an interactive interface rather than a static visual artifact. Drawing from theories of embodiment, performativity, and techno-materiality, the framework proposes that costumes operate at three intersecting levels: aesthetic representation, material responsiveness, and narrative agency. At the aesthetic level, costume remains a symbolic structure communicating character, culture, and atmosphere. At the material level, smart textiles and sensors imbue the garment with responsive qualities that register bodily or environmental changes. At the narrative level, these responses actively shape the unfolding story by triggering visual, auditory, or atmospheric cues.

Figure 1 illustrates the tripartite model of "Costume as Interface." The diagram demonstrates how aesthetic, material, and narrative layers converge, positioning the costume as a mediator between performer, audience, and environment. This visualization underscores the departure from costume as decorative artifact to costume as an adaptive storytelling agent, highlighting the new dramaturgical role enabled by wearable technologies. Importantly, the arrows in the model indicate that these three layers are mutually reinforcing rather than independent, meaning that visual symbolism, material responsiveness, and narrative agency co-construct performance dynamics. By situating the costume at the center of these interactions, the figure clarifies how wearable technologies transform fabric into an active dramaturgical system capable of initiating and shaping story events.
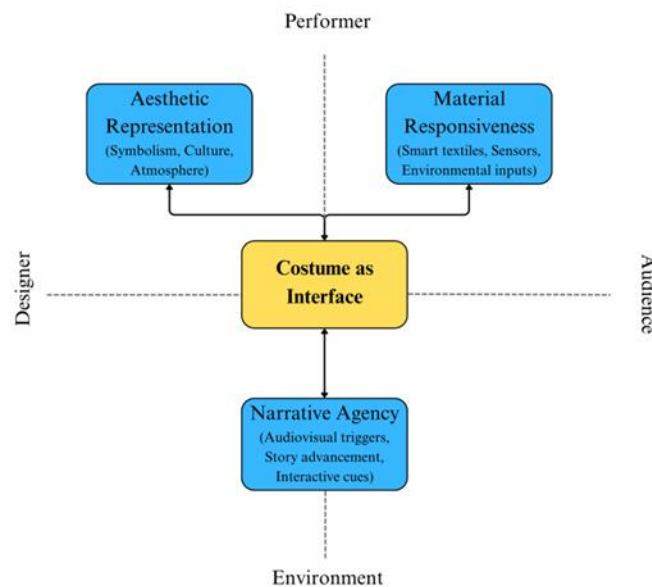
Figure 1. Conceptual framework: Costume as Interface

Theoretical Anchors

The framework builds upon three theoretical anchors. First, performativity theory highlights how bodies and garments co-constitute meaning through embodied action. Second, actor-network theory (ANT) provides tools to understand costume as a non-human actor that shapes relational dynamics within the performance ecology. Third, design theory emphasizes the affordances of materials, framing smart textiles and sensors as active components of the dramaturgical system. Together, these theories allow us to analyze costume not as mere representation but as a narrative device with agency.

Figure 2 presents the theoretical anchors of this study. The diagram places performativity, ANT, and design theory in a triangular schema, with "costume as interface" at the center. Each anchor contributes a unique dimension, embodiment, relationality, and affordance, that collectively sustains the analytical model. This means that performativity theory explains how bodies and garments co-produce meaning through action, ANT situates the costume as a non-human actor within a network of performers and technologies, and design theory highlights the functional possibilities that materials and sensors afford. By visualizing these anchors as equally weighted vertices, the figure emphasizes that the reconceptualization of costume as interface is only viable when all three perspectives are integrated rather than considered in isolation.
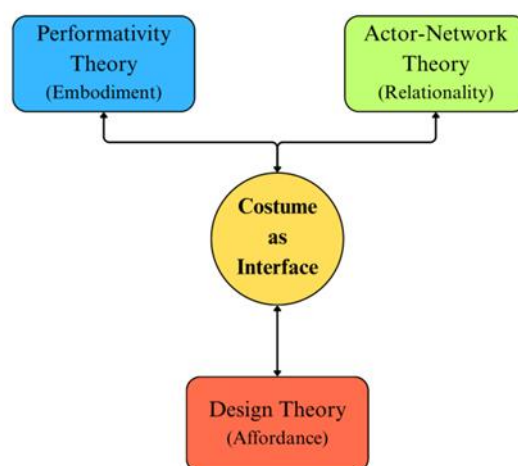

Figure 2. Theoretical anchors underpinning the Costume as Interface framework

RESEARCH METHODOLOGY

To operationalize this framework, the study employs a qualitative and comparative research design that integrates three interconnected stages. The first stage involves a literature analysis, synthesizing academic sources

from theatre studies, wearable technology, and design research to identify existing conceptualizations of costume and interactivity. The second stage conducts case study analysis, examining selected productions and experimental projects that incorporate smart textiles, sensors, or biofeedback garments in theatrical performance, drawing on both Western immersive theatre and East Asian experimental stage design to ensure cultural breadth. The third stage applies a comparative framework to contrast traditional costume functions with technologically enhanced ones, highlighting differences in narrative agency, audience engagement, and material responsiveness.

This triangulated design ensures both theoretical depth and empirical grounding, enabling a comprehensive analysis of interactive costume practices. By structuring the methodology in successive yet interconnected stages, the study balances systematic rigor with the flexibility necessary to capture the evolving intersections between costume design, wearable technology, and narrative interactivity..

Case Selection and Data Collection

Case studies were selected based on three criteria: (1) explicit integration of wearable technology into costume design, (2) availability of performance documentation and design notes, and (3) relevance to narrative interactivity. To ensure both contemporaneity and analytical validity, the study focused on recently documented projects from 2022 onward that exemplify how smart textiles and sensors are transforming theatrical costumes. These include Ying Gao's interactive collection Flowing Water, Standing Time (2022, Montreal), which employs AI-driven, photo-reactive textiles that shift in appearance under changing light conditions; Polymorf Collective's immersive artwork Symbiosis (2023, Stedelijk Museum Amsterdam), where participants wear bio-sensor costumes (garments equipped with physiological sensors such as heart-rate and respiration monitors) that alter the narrative environment in response to physiological signals; Pauline van Dongen's Solar Shirt 2.0 (2022, Netherlands), which integrates flexible solar textiles into wearable garments that simultaneously generate energy and transform aesthetic qualities; and a series of European biometric dance performances (2022-2023) that used heart rate and respiration sensors to translate performers' bodily rhythms into real-time soundscapes and lighting effects.

Data sources include published design reports, exhibition catalogues, video documentation, and critical reviews from international festivals and museums. This multimodal dataset allows for a comprehensive examination of both aesthetic intentions and technological functions, while ensuring that the selected cases reflect the most current directions in wearable technology and theatre practice.

Analytical Procedures

Analysis proceeded in two phases. First, each case was examined to identify how wearable technologies were integrated into costume design, focusing on the interplay between material responsiveness and narrative function. Second, cross-case comparison was conducted to highlight recurring strategies, innovations, and challenges. Attention was given to how sensors and smart textiles redefined the dramaturgical agency of costume, shifting it from representational support to interactive narrative driver. Coding categories included material responsiveness, narrative integration, performer-audience interaction, and technological sustainability.

Ethical and Practical Considerations

The research also acknowledges ethical and practical dimensions. From an ethical standpoint, biometric data collected via wearable sensors raise issues of privacy and consent, requiring designers and researchers to establish clear boundaries. Practically, challenges such as performer comfort, garment durability, and technical reliability affect the feasibility of integrating wearable technology into live performance. These factors are integral to evaluating the long-term sustainability of interactive costumes.

Summary

In sum, this chapter establishes a conceptual and methodological foundation for the study. By framing costumes as interfaces, grounded in interdisciplinary theory, and by employing a qualitative, comparative methodology supported by visual models, the research advances a systematic approach to understanding wearable technology in theatrical costume design. The integration of smart textiles and sensors is not simply a matter of technical novelty; it redefines costume as an active narrative agent, positioning fabric and code as co-authors of performance.

FINDINGS AND DISCUSSION

Costumes as Narrative Triggers

The first finding highlights how wearable technologies enable costumes to act as narrative triggers rather than static representations. Case analyses show that LED-embedded fabrics and motion sensors transform garments into dynamic storytelling devices. For instance, in Ying Gao's recent interactive collection Flowing Water, Standing Time (Montreal, 2022), garments incorporating AI-driven, photo-reactive textiles responded to changing light conditions and subtle audience movement, directly signaling shifts in mood and agency. Similarly, in Polymorf Collective's immersive artwork Symbiosis (Amsterdam, 2023), participants wore bio-sensor costumes that generated synchronized audiovisual effects in response to physiological signals, extending narrative symbolism through embodied interactivity. These examples demonstrate how costumes can serve as dramaturgical nodes, activating audiovisual responses that both represent and propel narrative development.

Figure 3 presents examples of narrative-triggering costumes. The images and annotations illustrate how smart textiles, motion sensors, and projection mapping expand the dramaturgical capacity of garments. The figure underscores the departure from costumes as passive embellishments to their repositioning as catalysts of interactive storytelling, where each technological element functions as a narrative switch. As shown in Ying Gao's Flowing Water, Standing Time (2022), LED-embedded textiles respond to ambient light and audience movement, visually signaling mood transitions and thereby activating narrative change.
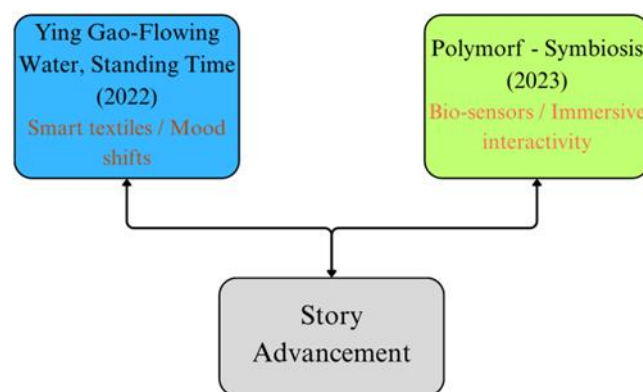

Figure 3. Costumes as narrative triggers through smart textiles and motion sensors

Performer-Audience Interactivity

A second finding concerns the enhancement of performer–audience interaction. Sensor-enabled costumes allow performers' bodies to directly shape the audience's experience, collapsing the distance between action and reception. In Polymorf Collective's immersive project Symbiosis (Amsterdam, 2023), participants wore custom-made bio-sensor suits that captured physiological signals such as heart rate and respiration, which were then translated into synchronized audiovisual environments, intensifying emotional resonance and narrative immersion. This direct transmission of embodied data into performative output created a visceral sense of intimacy, aligning with interactive theatre's aim to immerse audiences within narrative ecologies. Compared with traditional theatre, where interactivity relies on dramaturgical structure or audience choice, wearable technologies offer a new dimension in which the costume itself mediates communicative loops.

Figure 4 provides a schematic of performer-audience interaction mediated by smart costumes. The diagram illustrates the flow of data from performer to sensor, sensor to costume system, and finally to audiovisual outputs perceived by the audience. This model clarifies how wearable technology collapses traditional theatrical hierarchies, establishing a feedback loop in which costume becomes the conduit of embodied communication. In Polymorf Collective's Symbiosis (2023), this process is exemplified as bio-sensor suits captured participants' heart rate and respiration, which directly generated synchronized audiovisual environments, making physiological data an immediate narrative driver.
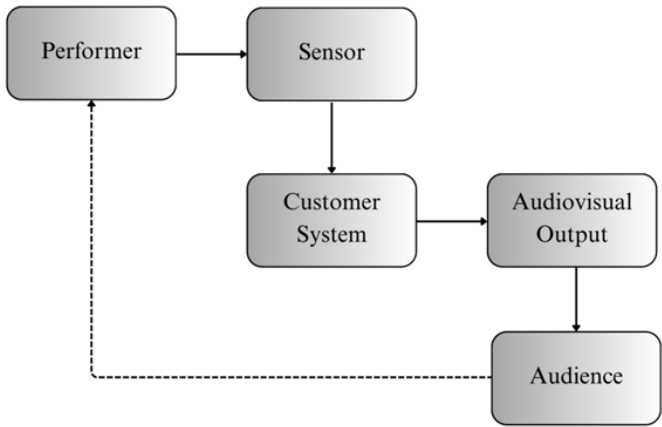
Figure 4. Performer-audience interactivity mediated by sensor-driven costumes

Comparative Insights with Existing Research

Contrasting the findings with existing research reveals significant innovation. Previous studies on digital scenography emphasized the role of immersive projections and stage design but often ignored costume's dramaturgical potential. Our analysis demonstrates that smart costumes occupy a unique position, situated between performer embodiment and technological augmentation. Unlike VR headsets or projection mapping, wearable garments maintain the tactile and material presence central to theatre, while simultaneously opening interactive channels. This hybrid capacity distinguishes costumes from other technological interventions, situating them as a bridge between traditional theatrical embodiment and emerging interactive media practices. The results therefore extend theoretical debates in performance studies, moving from the semiotics of costume to its performativity as an interactive interface.

Material Responsiveness and Narrative Agency

The study also finds that material responsiveness amplifies narrative agency. Smart textiles capable of thermochromic (color-changing in response to temperature variations) or electrochromic (color-changing when an electric current is applied) change allow costumes to visually narrate transformation without reliance on external scenography. For example, Pauline van Dongen's Solar Shirt 2.0 (Netherlands, 2022) integrated flexible solar textiles that not only generated energy but also altered their functional and aesthetic qualities depending on light exposure, symbolizing transformation as a live, embodied spectacle. Such integration situates costume as both medium and message, aligning with the framework of "costume as interface." Moreover, biofeedback-driven garments blur the line between performer autonomy and technological agency, raising critical questions about authorship in theatre.

Table 1 summarizes the comparative dimensions of material responsiveness and narrative agency across case studies. The table categorizes each production by technological feature, narrative function, and dramaturgical impact. This structured overview makes visible the recurring patterns: costumes act simultaneously as narrative indicators, dramaturgical drivers, and immersive mediators, underscoring their multifaceted role in contemporary interactive theatre.

Table 1. Comparative dimensions of material responsiveness and narrative agency

Case Study	Technological Feature	Narrative Function	Dramaturgical Impact
Ying Gao – Flowing Water, Standing Time (2022, Montreal)	AI-driven, photo-reactive smart textiles	Visualizes shifting moods and agency through changing light conditions	Positions costume as a live mediator of emotional atmosphere
Polymorf Collective – Symbiosis (2023, Amsterdam)	Bio-sensor suits capturing heart rate and respiration	Generates synchronized audiovisual effects responding to physiological signals	Blurs boundaries between performer and audience, creating immersive interactivity
Pauline van Dongen – Solar Shirt 2.0 (2022, Netherlands)	Flexible solar-powered textiles	Alters functional and aesthetic qualities depending on light exposure	Embeds transformation within costume itself, symbolizing sustainability and material agency

European Biometric Dance Performances (2022–2023)	Heart-rate and breath sensors	Converts performer physiology into soundscapes and lighting	Enhances intimacy and embodiment, foregrounding performer–audience relational dynamics

Theoretical and Practical Implications

From a theoretical perspective, these findings confirm the viability of reconceptualizing costume as interface. Performativity theory explains how embodied action activates responsive garments; ANT situates costume as a non-human actor shaping theatrical networks; and design theory clarifies the affordances of smart textiles. Collectively, the analysis demonstrates that technologically enhanced costumes extend dramaturgical agency by generating interactions unavailable through traditional design. Practically, these insights provide guidance for designers: wearable technologies must be integrated with dramaturgical intent rather than as mere spectacle. Sustainable design considerations, such as performer comfort, material durability, and energy efficiency, are also crucial for ensuring long-term adoption.

Critical Challenges and Future Potentials

The analysis also surfaces limitations and challenges. Technical malfunctions risk disrupting narrative flow, while reliance on biometric data introduces ethical concerns around privacy and performer autonomy. Additionally, the cost of developing sensor-driven costumes may restrict accessibility for smaller companies. Yet these challenges do not diminish the potential of wearable technologies; instead, they highlight the importance of interdisciplinary collaboration between designers, engineers, and performers. Future research might explore AI-driven adaptive costumes that autonomously adjust narrative cues, or sustainable smart fabrics that reduce ecological impact. These directions align with broader discourses on theatre's future in the digital era, suggesting that costume design can serve as a testbed for integrating creativity, technology, and ethics.

Summary

In summary, the findings demonstrate that wearable technology fundamentally transforms the dramaturgical role of costume in theatre. By functioning as narrative triggers, mediators of performer-audience interaction, and embodiments of material responsiveness, smart costumes extend the ontology of performance. The comparative analysis confirms that costumes are no longer confined to representational roles but can act as interactive agents that reshape storytelling. These insights affirm the study's central claim: fabric and code together redefine costume design, marking a paradigm shift in how theatre envisions the fusion of technology and narrative.

CONCLUSION

This study has examined how wearable technology transforms theatrical costume design from a symbolic accessory into an interactive narrative agent. By conceptualizing costume as an interface, the research bridged theories of performativity, actor-network relations, and design affordances, demonstrating that garments embedded with smart textiles and sensors can actively participate in dramaturgy. Findings from the literature review and case analyses confirmed that technologically enhanced costumes operate across multiple levels: as narrative triggers that activate audiovisual cues, as mediators of performer–audience interaction, and as embodiments of material responsiveness that extend storytelling beyond visual representation.

The significance of these results is twofold. Academically, the study expands the scope of costume research, moving beyond semiotic readings to embrace interactivity and technological agency. It contributes to performance studies by reframing costumes as non-human actors within theatrical networks, and to design research by highlighting how intelligent materials reshape dramaturgical practices. Practically, the findings provide designers and theatre practitioners with concrete strategies for integrating wearable technology into production, emphasizing the importance of aligning technical innovation with narrative coherence, performer comfort, and ethical considerations.

Future research should address scalability, sustainability, and accessibility. The development of AI-driven adaptive costumes and ecologically sustainable smart textiles holds promise for broadening application while reducing costs and environmental impact. Moreover, ethical frameworks must be refined to govern biometric data use in live performance. Ultimately, this research affirms that the convergence of fabric and code signals a paradigm shift in theatre, where costumes no longer simply clothe characters but actively author stories.

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