

A virtual reality experience to raise sustainability awareness within the fashion industry

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Abstract

Nowadays, there is a pressing need to incorporate sustainable practices and promote environmental awareness. The fashion industry, characterized by resource-intensive consumption, significantly contributes to global sustainability threats. The authors proposed the adoption of Virtual Reality (VR) to design and develop the Fashion Footprint application, an experience aimed at enhancing sustainability awareness and fostering behavioral change. The findings suggest that VR technology is valuable in promoting sustainability awareness and driving positive behavioral shifts in the fashion industry.

Keywords: virtual reality (VR), sustainability, behavioural design

1. Introduction

Climate change is a pressing global issue that requires a collective effort (Ostrom, 2017). The transition towards more sustainable behaviors, namely with reduced or zero environmental impact, should result from a combined effort from a collective perspective (governments, organizations) and an individual one. In this context, a crucial role is played by companies, an increasing number of which are adopting sustainability strategies. In particular, for some time now, companies have realized that the approach to sustainability, seen as a kind of 'add-on' or something disconnected from the core business, is no longer sufficient. Sustainability has become an integral part of business, so initiatives in this area must be integrated into companies' competitive strategy (Ioannou and Serafeim, 2019). This is because:

- a) The most significant results are achieved by acting on the products' features and mode of use;
- b) An increasing number of customers (both companies and final users) and, more in general, stakeholders, are paying attention to how companies integrate sustainability into their core business.

Effective strategic management of sustainability involves important decisions regarding products, the target market, and supplier selection criteria and may even call into question the sustainability of the business itself. Companies often find themselves in a 'critical' position, where on one hand, they are required to redesign products with sustainability in mind, and on the other, they can play a significant role in raising awareness on these issues, helping end-users understand the impact of their choices. An essential example of an industrial sector strongly affected by this problem is the fashion industry. Overall, the fashion industry is undergoing a transformation towards greater sustainability, driven by a combination of consumer demand, regulatory pressure, and a growing recognition of the industry's environmental and social responsibilities.

The fashion industry is resource-intensive, consuming vast amounts of water, energy, and raw materials. It is also a major contributor to pollution, including water pollution from dyeing and chemical treatments, as well as carbon emissions from manufacturing and transportation. In addition, an important

element in this context is the "fast fashion" model, which promotes rapid production and consumption of clothing, resulting in overproduction, overconsumption, and high levels of waste (Niinimäki et al.). However, the increasing consumer awareness about the environmental and social impacts of the fashion industry has led to greater demand for sustainable and ethical products. So, an increasing number of fashion brands are incorporating sustainable behaviors in their company strategies by using sustainable materials in their designs, promoting "circular fashion," investing in innovative technologies to reduce their environmental footprint, and ensuring ethical labor conditions in their supply chains. Unfortunately, many consumers are not yet sensitive enough to this issue, and their purchasing behaviors are primarily linked to price and fashion rather than to the garments' quality and sustainability.

Given this foundation, there is a growing need for these companies to effectively communicate their sustainability strategies and initiatives, which runs in parallel with the increasing importance of raising awareness about sustainability, particularly within the context of industrial production. To do this, several communication strategies can be used. Virtual Reality (VR) has been proven to be a powerful tool for communicating sustainability strategies in a more immersive and engaging way. In fact, VR can be used for immersive storytelling, fostering a deeper emotional connection and understanding among stakeholders. It can also allow the visualization of complex sustainability data and offer virtual tours of facilities, providing a realistic 3D environment to explore and understand different aspects of sustainability. More in general, to effectively improve learning and awareness activities, interactive digital applications should be designed and developed to stimulate the users' "intrinsic motivation" (Lee et al., 2005) as defined by (Malone, 1981).

Starting from these premises, the research study is guided by the following questions:

1) Which impact can a virtual immersive experience produce on knowledge and awareness regarding the sustainable fashion issue? 2) To what extent a virtual immersive experience can promote a behavioral change regarding future sustainable fashion choices?

The study aims to communicate the urgency regarding the environmental impact of the fashion industry and to propose actions that can contribute to a more sustainable future.

On those bases, the authors identified the opportunity of adopting VR technology to design and develop the Fashion Footprint application, a VR experience to encourage final users to take more responsible actions toward sustainability awareness. Specifically, the VR experience will allow users to explore an industrial plant, interact with several machines used to produce fabrics and clothes and visualize the effect of those industrial activities on the environment. Consequently, some preliminary testing sessions with users have been performed. The analysis of the collected results shows that Fashion Footprint can help transfer knowledge to users and, in general, can have great potential in sustainability awareness.

2. Related works

Although many scholars have already highlighted the strategic implications of sustainability (Epstein and Roy, 2001; McWilliams et al., 2006; Porter and Kramer, 2006; Werther and Chandler, 2006; Carroll and Shabana, 2010; Bonn and Fisher, 2011), for a long time companies have experienced environmental sustainability as something "collateral" with respect to the core business: even where a formalized sustainability strategy was in place, the planned initiatives did not have a significant impact on the competitive strategy and decisions regarding products, target markets, etc. (Kiron, 2012; Kiron et al., 2013). In recent years, it has become clear that sustainability is having an increasingly important and pervasive impact, to the point of generating structural changes that put at risk the very existence of entire sectors of the economy (Hart and Milstein, 1999). Nowadays, sustainability strategies are increasingly integrated into business strategies, and sustainability has, in many cases, become the fundamental driver that guides strategic business choices (Ioannou and Serafeim, 2019). A fundamental push for this change in the approach to sustainability has come from a shift in the focus of reporting processes (and thus the measurement of corporate sustainability performance), with reference to the environmental dimension. Until recently, the measurement of the environmental impact focused on the so-called 'scope 1' and 'scope 2,' which means measuring impacts generated within the 'company boundaries' (for example, emissions in air generated by industrial processes) and 'indirect' emissions related to energy consumption (and therefore linked to the production of energy by suppliers, which, in turn, depend on the mix of sources used - fossil fuels, renewables, nuclear power -). Only recently, the European Council

introduced a new requirement for corporate sustainability: after 2025, companies will be required to report the impacts associated with the so-called 'scope 3,' which pertains to impacts generated along the supply chain, both upstream and downstream of the company itself (i.e., by all the direct and indirect suppliers on one hand, and by direct and indirect customers on the other, down to final consumers). As easily predictable, most emissions are generated within 'scope 3' (Downie and Stubbs, 2013; Cox and Herman, 2022; Radonjić and Tompa, 2018). This, in turn, depends to a great extent on the way in which the product is designed (Rocha et al., 2019): the choices made in the product development process define the number, kind and amount of raw materials/components that will be needed to manufacture that product. Similarly, these choices also affect the environmental impact during the use of the product.

2.1. The impact of the fashion industry on the environment

The fashion industry is a global sector encompassing the production, distribution, and consumption of clothing. With its vast scale and influence, it holds a significant place in our daily lives. However, the rapid growth and practices within the industry result in detrimental effects on the environment.

One prominent aspect of the environmental issue related to the fashion industry is the emergence of fast fashion. Fast fashion brands produce and market collections at affordable prices, frequently introducing new designs and trends at a rapid pace. This business model, which has become increasingly popular in recent years, relies on quick reaction to consumer demand changes (Long and Nasiry, 2022).

Unfortunately, this approach often leads to the production of low-quality garments that are designed to be worn only a few times before being discarded. The manufacturing process involved in fast fashion has a significant impact on the environment (Saicheua et al., 2012) by consuming a vast amount of water, energy, and other resources. Among the various processes, dyeing and finishing are particularly polluting and energy-intensive, contributing to the industry's environmental footprint.

The issue of textile waste is another pressing environmental concern. Approximately 85% of textiles end up in landfills or are incinerated, leading to the release of CO₂ emissions and toxic gases (Ellen MacArthur Foundation, 2021). According to the United Nations, textile waste witnessed an alarming increase of approximately 811% from 1960 to 2015 (Greenpeace, 2011; Hussain and Wahab, 2018), and approximately 85% of textiles end up in landfills or are incinerated, contributing to the release of greenhouse gases and toxic pollutants (United Nations Environment Programme, 2022). The environmental impact of the fashion industry extends beyond waste generation. It is estimated that the industry, encompassing both clothing and footwear, contributes over 8% of global greenhouse gas emissions and is responsible for 20% of global wastewater annually (Zurich Insurance Group, 2023; Berg et al., 2020). These staggering figures highlight the urgent need for sustainable practices within the industry to mitigate their detrimental effects on the environment. One alarming fact is the production and transportation of clothing, which contribute to significant greenhouse gas emissions of 10% yearly, 5% more than the total flight and maritime transport (Zurich Insurance Group, 2023). Water usage is another critical environmental impact of the fashion industry processes. Water consumption is a significant environmental concern in the fashion supply chain, and addressing this issue is a crucial aspect of fashion supply chain sustainability. The production of textiles requires vast amounts of water, particularly during processes like dyeing and finishing. According to estimates by the Ellen MacArthur Foundation, the fashion industry uses around 93 billion cubic meters of water annually, which is equivalent to filling 37 million Olympic swimming pools (Ellen MacArthur Foundation, 2021). In addition, the use of dyes, chemicals, and other treatments in textile manufacturing can lead to water pollution (Kant, 2012) as these substances often find their way into wastewater systems. The discharge of untreated or improperly treated wastewater can contaminate water bodies, harming aquatic ecosystems and posing risks to human health.

2.2. Immersive technologies for raising awareness and stimulating behavioral change in relation to sustainability issues

Addressing the environmental challenges posed by the fashion industry requires concerted efforts and innovative solutions. The state of the art suggested that interactive digital technologies are often adopted to raise awareness and educate customers about sustainability issues. A few examples, concerning the fashion sector, are represented by FastFashion (Lavish and Anplay, n.d.), an interactive minigame that

reveals the risks and negative impacts of fast fashion, or by Threads (Drew et al., 2022) an interactive platform where users can gain knowledge about fast fashion and obtain insights on more conscious consumption habits. Among the others, immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR) have been demonstrated to be powerful tools for raising awareness and stimulating behavioral change, concerning environmental and sustainability topics (Huh et al., 2020; Petersen et al., 2020; Chirico et al., 2021; Fauville et al., 2020). These technologies, due to their unique immersive nature, have the capacity to offer various experiences tailored to individual needs and learning preferences, thereby enhancing educational experiences (Liu et al., 2019). Furthermore, as highlighted by Scurati et al. (2021), solutions rooted in technologies like VR possess the distinct ability to influence human behavior and decision-making. They achieve this through the visualization of long-term consequences, the creation of both symbolic and tangible representations, and, notably, by involving users in the exploration and testing of future solutions.

As a visualization and communication technology, VR serves as a versatile platform that transcends disciplinary boundaries, making it a potent tool for instigating behavioral change and advancing sustainability. VR democratizes the process of envisioning, discussing, and shaping potential interventions, fostering human agency in both physical and virtual spaces (Nikolić and Whyte, 2021). Concerning the fashion industry, several studies explore the possible adoption of immersive technologies for educating about the garment production process (Azevedo, 2023; Asia News Monitor, 2017), or encouraging behavioral responses concerning sustainable fashion consumption (Zhou et al., 2022). An example is provided by Money Fashion, which consists of an AR experience, developed by the Frankfurt Fashion Movement (2022) for the global Fashion Revolution Week in 2022. Another example is provided by X-Ray Fashion (Carrozzini, 2018), a cinematic VR experience that combines Virtual Reality with a 49-square-meter physical installation.

3. Main Idea

Despite the provided examples, it seems to the authors' knowledge that limited studies have addressed the sustainability issue related to the fashion industry by proposing virtual immersive solutions. Instead, the existing immersive solutions concerning fashion seem more oriented toward promoting marketing purposes and supporting customers in the shopping fashion experience, yet not stimulating a virtuous behavioral change, nor influencing sustainable individual future choices.

3.1. The Fashion Footprint experience

Based on the conducted research, which highlighted the growing environmental concerns associated with the fashion industry, the authors identified the opportunity to create an immersive VR experience, named Fashion Footprint. This experience takes a unique approach by immersing young fashion consumers in the virtual environment, recreating a realistic experience, and engaging them emotionally in the topic. The VR experience provides a visually compelling representation of some sustainability fashion issues related to fabric manufacturing processes, allowing users to face the tangible impacts of the fashion industry on the environment. The purpose is to improve the users' understanding of the sustainability urgency and inspire the need for change, by creating an experience that fosters visual recognition of the fashion industry's impact on the environment and, as an outcome, a possible degree of awareness of actions that can be taken to tackle the negative impact. Since the Fashion Footprint experience also aims to inform the user on the impact of different fabrics in the clothing industry, the experience is based on two main staple clothing production lines, a cotton and a polyester one.

The experience begins by transporting users into the clothing production facility, where they are introduced to the various stages of clothing production. Through interactive VR elements, users gain first-hand insights into the fashion industry's environmental impact at each production step, including carbon footprint, resource consumption, and labor workforce. After an initial Introduction about the experience and main interaction modalities, the VR experience is divided into three main sections:

- 1) The Factory, showing the manufacturing steps in the factory;
- 2) The Corridor, highlighting the environmental impact;
- 3) The Shopping, providing a final evaluation of the user's performance.

These elements offer a comprehensive view of the fashion industry's environmental impact and enhance user engagement.

In the Factory section (1), users are immersed in the production process of both cotton and polyester fabrics. In this phase, users are invited to actively participate in the production process, obtaining insights about the environmental impact of each step of the production chain, including carbon footprint, resource consumption, and labor workforce. The production process reports the steps concerning filament extrusion, fabric creation and cutting, fabric dyeing, the transformation of fabric into t-shirts, and packing and shipping t-shirts. The Corridor section (2) focused on showcasing the environmental consequences of clothing production. Here, users can directly observe, by walking inside a glass transparent corridor, the fashion industry's impacts on the environment surrounding the fashion factory, in terms of pollution, resource depletion, and habitat destruction. In addition, in this phase, users receive insights about virtuous possible behaviors to adopt regarding sustainable fashion choices. The Shopping section (3) provides users with an opportunity to make informed decisions based on the knowledge gained throughout the experience. Users are presented with different clothing options and encouraged to choose sustainable and ethical products. The evaluation in this section assesses the user's performance and provides feedback on their choices, reinforcing the importance of responsible fashion consumption.

4. Design and development of the virtual experience

The Fashion Footprint experience employed a deliberate design approach to ensure a seamless immersive environment and user-friendly interactions.

The VR experience, developed by using the Unity 3D game engine (unity.com), has been designed to be deployed on a Meta Quest 2 headset and its associated controllers, by using the Unity XR Tech Stack. The virtual environment, representing the fashion production facilities (cotton and polyester plants), some natural elements (trees and lake), and the shopping area, have been recreated by using the 3D modeling software Blender (blender.com), to build a simple captivating virtual environment, capable of accurately depict the industrial processes and machinery, in order to convey the desired message effectively (see Fig.1).

To accommodate user movement and navigation within the VR environment, standard practices were respected. Users could freely navigate the space by using fundamental VR movements, such as teleportation, and the ability to turn in any direction. These user-friendly controls were intentionally adopted to minimize potential discomfort or dizziness that users might encounter while wearing the VR headset, thereby ensuring a smooth and enjoyable interaction.



Figure 1. Screenshot of the experience representing the virtual environments recreated for the Fashion Footprint experience (factory, natural environment, shopping area)

4.1. VR Interaction modalities

In the design of the experience, color-coded interactions and audio-visual clues have been adopted to help users navigate the VR environment and perform interactions. A key aspect of the interaction design was the use of the yellow color, adopted to highlight the elements within the VR environment that users could interact with, such as levers, wheels, and buttons (see Fig. 2).

During the experience, the interaction with different elements has been used to support users in gaining insights into the fashion industry's environmental impact at each production step. In particular, the interactions allow users to grab, touch, push, pull, and move around the virtual elements inside the environment. These interaction modalities empower them to perform tasks and explore the virtual

environment naturally and intuitively, by adopting a Learning by Doing approach (Thompson, 2010). In order to guide the user in performing the correct interactions, checkpoints were incorporated into the VR experience as well.



Figure 2. Screenshots of the experience showing few interaction modalities enabled by levers, wheels, and buttons, highlighted using the yellow color

Furthermore, throughout the experience, a narrator's voice has been implemented to guide the users in performing the correct interactions and to deliver valuable feedback and suggestions. Precisely, the narrator's voice has been designed to be triggered by specific interactions and events. These triggers were carefully synchronized with the users' progress, ensuring the information was delivered at the right moment to enhance their understanding, guiding them through the educational journey, and ensuring a cohesive and informative narrative.

4.2. Graphical user interface (GUI)

The graphical user interface (GUI) has been designed to be intuitive and user-friendly, featuring a minimal style with white text on a black background and integrated icons. Interface elements within the VR environment have been strategically placed for easy access to information. In the Introduction, the GUI informs users about the VR controls, supporting them to perform interactions correctly during the experience. In the Factory stage, informative panels along the production line (Fig. 3) conveys energy and carbon emissions data for each production step, fostering awareness of environmental impact. Additionally, panels indicating how to interact with each machine can be found above each handler (Figure 4) to facilitate the interaction. In the final Shopping stage, a panel provides the final evaluation score with immediate feedback on users' choices, reinforcing gained knowledge and inspiring users to adopt eco-conscious behaviors in their real-life fashion consumption (see Fig. 3). The final evaluation categorizes users' performance into three distinct types: "Good Job," "Good Knowledge," and "In Need of Improvement," based on users past clothing choices and their environmental impact. Users are assessed by the product category, with the final score determined by the balance of sustainable (e.g., second-hand, cotton, recycled textiles) and unsustainable choices (e.g., new polyester, mixed fabrics). This process encourages users to adopt sustainable practices, emphasizing considerations like material sourcing, production methods, and the circular economy in past fashion decisions.



Figure 3. Graphical User Interface adopted in the Introduction, in the Factory, and in the Shopping sections

5. User testing

The VR experience underwent rigorous testing and evaluation to assess its effectiveness in raising awareness about the fashion industry's environmental impact and stimulating behavioral change.

A total of 10 participants (6 males and 4 females) from 18 to 34 years old participated in the study. The participants either had a high school diploma (3) or a bachelor's degree (7) as the highest level of education. During each testing session, participants were required to fill out a pre-experience questionnaire and three post-experience questionnaires.

The pre-experience questionnaire collected demographic data and information about participants' knowledge of the fashion industry's environmental impact and their shopping habits. It also included questions about their expectations for using VR technology to raise awareness about climate change.

After the experience, participants were asked to compile a questionnaire concerning the perceived gained knowledge about the sustainability fashion issues and their intention of attitude change. This questionnaire was composed of multiple-choice questions based on various proposed answers, or on a 4-point Likert Scale (1= not at all; 4=very much). In addition, to evaluate the VR experience, the System Usability Scale (SUS) (Brooke, 1996) questionnaire has been adopted.

On average, the test lasted 15 minutes per participant, including the compilation of pre-experience and post-experience questionnaires.

5.1. Results analysis

5.1.1. Sustainability awareness and behavioral change

The effectiveness of the VR experience in raising awareness and behavioral change has been measured by comparing the data collected with the pre-experience questionnaire and the first post-experience questionnaire. In general, the data analysed suggests a moderate improvement in participants' knowledge and awareness regarding the sustainable fashion issue. Before the experience, many participants declared to have limited knowledge of the environmental consequences associated with clothing production (3 not at all, 3 slightly). However, after completing the VR experience, participants declared an improvement in their understanding of key sustainability factors within the fashion industry (4 slightly, 4 moderately, 2 very much).

In addition, before the experience, most of the participants declared to buy clothes mostly online or in retail stores, leaving the second-hand option as the one they used the least. Nevertheless, in the last stage of the VR experience, during the simulated Shopping activity, most of the participants made sustainable choices, underlying a possible change in their attitude. Indeed, as mentioned above, at the end of the activity, participants obtained a score evaluating their clothes selection, resulting in 5 participants getting the maximum score of 100 and in 3 getting a score of 50 (see Fig. 4).

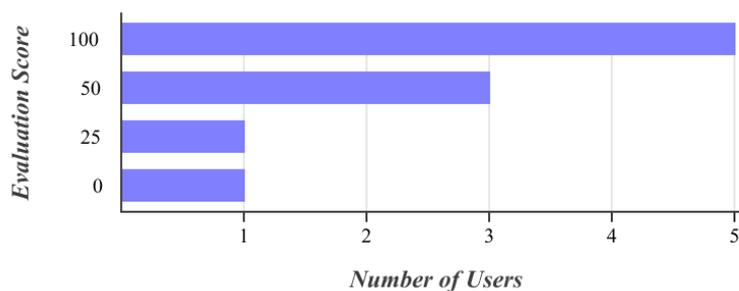


Figure 4. Final evaluation scores obtained by participants in the Shopping section experience

Similarly, the post-experience questionnaire revealed that 9 of the participants declared the intention to make changes in the way they consume clothing and fashion garments, 7 of them considered starting to opt for sustainable fashion brands, while 6 considered shopping second-hand or vintage clothing to tackle fast fashion's impact on the current climate change situation. Other chosen actions included minimizing fast fashion purchases (6) and reducing clothing waste (4), as reported in Fig. 5.

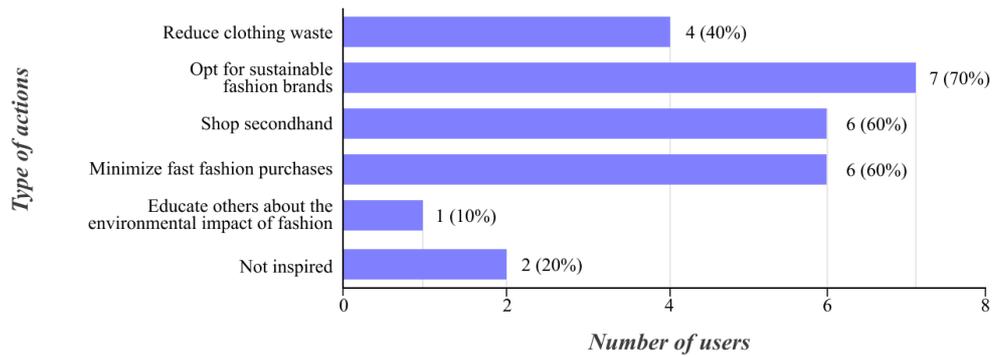


Figure 5. Future intentions on behavioral change attitudes reported by the users after the experience

5.1.2. System Usability Scale (SUS)

As part of the post-experience assessment, a System Usability Scale (SUS) test was performed to review the overall usability of the experience. This questionnaire comprises 10 questions concerning usability aspects, and each question offers 5-point Likert scale options (1= strongly disagree; 5= strongly agree). The SUS results yield a score between 1-100, where an average of 68 is considered sufficient to assess the overall experience (Sauro, 2011). On average, the SUS score obtained was 77,25 with a moderate deviation of approximately 13,69. When translating this into a qualitative grade, the SUS gave good usability for the whole experience, as shown in Fig. 6.

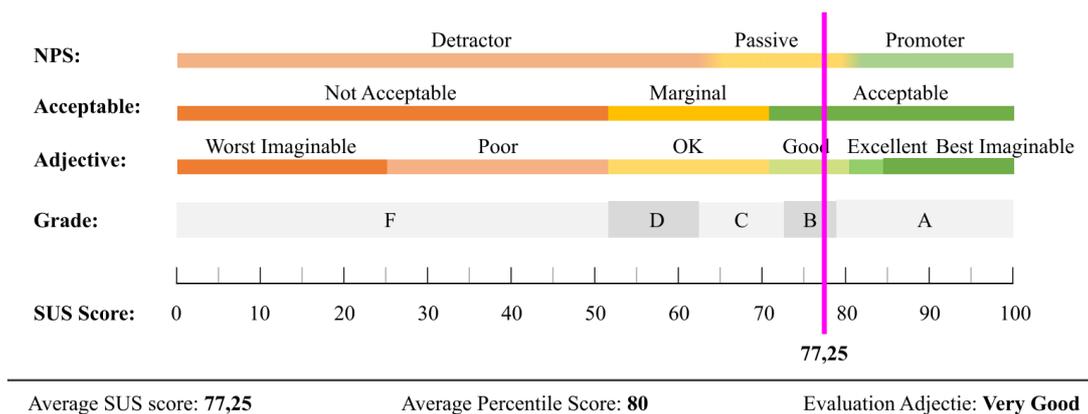


Figure 6. Results of the System Usability Scale (SUS) questionnaire, showing a positive evaluation score

6. Conclusions and future steps

In conclusion, the presented study underscores the critical role of collective and individual actions in addressing the pressing global issue of climate change. The transition to more sustainable behaviors necessitates a combined effort from governments, organizations, and individuals. Companies, in particular, play a pivotal role in integrating sustainability into their core business strategies, recognizing the need to go beyond superficial 'add-on' initiatives.

The fashion industry, as highlighted, is undergoing a significant transformation towards sustainability due to consumer demand, regulatory pressure, and increased awareness of environmental and social responsibilities. While challenges persist, including the prevalence of fast fashion and consumer preferences based on price and trends, many fashion brands actively incorporate sustainable practices into their strategies.

The study introduces the innovative use of Virtual Reality (VR) technology, exemplified by the Fashion Footprint application, as a powerful tool for enhancing sustainability awareness. Preliminary testing demonstrates the effectiveness of this VR experience in improving participants' knowledge and awareness of sustainable fashion issues. The post-experience questionnaire reveals a positive shift in

participants' attitudes and intentions, with a notable inclination towards sustainable fashion choices. Moreover, the System Usability Scale (SUS) results indicate a good overall usability score, supporting the feasibility of incorporating VR technology for sustainability awareness initiatives. In summary, the findings suggest that VR technology, as exemplified by the Fashion Footprint application, has the potential to be a valuable tool in promoting sustainability awareness and driving positive behavioral changes in the fashion industry. As the world grapples with the challenges of climate change, innovative approaches such as this can contribute to a more sustainable and responsible future.

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