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The Fusion of Fashion and Technology

Uncovering the Benefits and Drawbacks of Digital Fashion

Metropolia University of Applied Sciences

Master of Culture and Arts

Master's Degree Programme in Fashion and Clothing

Thesis

12 November 2023

Abstract

Author(s):	Emma Granqvist
Title:	The Fusion of Fashion and Technology - Uncovering the Benefits and Drawbacks of Digital Fashion
Number of Pages:	64 pages + 1 appendix
Date:	12 November 2023
Degree:	Master of Culture and Arts
Degree Programme:	Master's Degree Programme in Fashion and Clothing
Instructor(s):	Natalia Särmäkari, Postdoctoral Researcher

The intersection of fashion and technology has given rise to digital fashion, an evolving phenomenon reshaping the landscape of fashion. This research aims to provide a comprehensive understanding of the potential of digital end products, by investigating the implied benefits and challenges in phygital and virtual fashion contexts.

The thesis was conducted with a case study research approach combining secondary evidence from multiple sources and primary data generated from several observational fields. The research material was analysed following thematic analysis principles. The commissioner of this thesis was LUME, an academic research project examining the creative field in the evolving virtual space.

This research provides extensive knowledge on the current state of digital fashion. While digital fashion practices are at an experimental phase, multifaceted value chain impacts have been addressed. Immersive technologies and virtual environments allow fashion brands to access global markets and enhance consumer experiences through engaging content. In contrast to a rising demand for interactive brand experiences and digitized clothing, critical attitudes and technological challenges are holding back mainstream adoption. Utilization of 3D tools and immersive technologies in the value chain of physical clothing can result in more efficient processes and enhanced product design, however, the required financial resources and multidimensional expertise are preventing widespread implementation. Dematerialization has the potential of contributing to more sustainable production and consumption of clothing, underlining the importance of research and exploration within this field.

Keywords: Digital fashion, phygital, immersive experiences, avatar, 3D design

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Tiivistelmä

Tekijä(t):	Emma Granqvist
Otsikko:	Muodin ja teknologian yhdistyminen - Digitaalisen muodin hyödyt ja haasteet
Sivumäärä:	64 sivua + 1 liite
Aika:	12.11.2023
Tutkinto:	Vestonomi (ylempi AMK)
Tutkinto-ohjelma:	Vaatetusalan tutkinto-ohjelma (ylempi AMK)
Ohjaaja(t):	Tutkijatohtori, TaT Natalia Särmäkari

Muodin ja teknologian risteyksessä on syntynyt muotimaailmaa muuttava ilmiö, digitaalinen muoti. Tämän tutkimuksen tavoitteena on tarjota kattava käsitys digitaalisten vaatteiden mahdollisuuksista, tutkimalla niihin liittyviä hyötyjä ja haasteita fygitaalisissa ja virtuaalisissa konteksteissa.

Opinnäytetyö toteutettiin tapaustutkimuksena sisältäen toissijaista aineistoa useista lähteistä sekä havainnoinnista saatua ensisijaista tutkimusdataa. Tutkimusaineisto analysoitiin teema-analyysin periaatteita noudattaen. Tämän opinnäytetyön toimeksiantaja oli LUME, joka on akateeminen tutkimushanke, jossa tutkittiin luovaa kenttää kehittyvässä virtuaalimaailmassa.

Tämä tutkimus tarjoaa kattavaa tietoa digitaalisen muodin nykytilasta. Vaikka digitaalisen muodin käytännöt ovat vasta kokeiluvaiheessa, niillä on havaittu monipuolisia vaikutuksia arvoketjuun. Digitaalisen muodin teknologiat ja virtuaaliympäristöt antavat vaatebrändeille mahdollisuuden päästä kansainvälisille markkinoille ja parantaa kuluttajakokemuksia interaktiivisen sisällön avulla. Vaikka vuorovaikutteisten brändikokemusten ja digitalisoitujen vaatteiden kysyntä kasvaa, kriittiset asenteet ja teknologiset haasteet ovat estäneet niiden yleistymisen. 3D-työkalujen ja immersiivisten teknologioiden hyödyntäminen fyysisten vaatteiden arvoketjussa voi johtaa tehokkaampiin tuotantoprosesseihin ja parempaan tuotesuunnitteluun, mutta taloudellisten resurssien ja moniulotteisen asiantuntemuksen tarve ovat estäneet laajamittaisen käyttöönoton. Vaatteiden dematerialisointi voi edistää vaateteollisuuden kestävämpää tuotantoa ja kulutusta, mikä korostaa tutkimuksen merkitystä tällä alalla.

Avainsanat: Digitaalinen muoti, fygitaalinen, immersiivisyys, avatar, 3D suunnittelu

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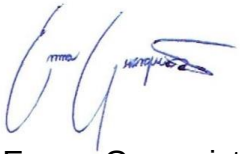
Contents

Acknowledgements

I would like to express my sincere gratitude to everyone who contributed to this research. Firstly, I want to thank Laura-Maija Hero for inviting me to take part in the LUME project. Our active communication and sharing of ideas as well as your genuine support have played an important part in this research. I also want to express my gratitude to LUME for enabling this thesis and for including me in your book. I also want to sincerely thank my thesis supervisor Natalia Särmäkari for the professional guidance throughout the research process. Having a supervisor with such in-field expertise and research experience has been extremely valuable.

Furthermore, I want to thank Essi Karell, head of the Master's degree programme in fashion and clothing, for helpful advice and encouraging support when I needed it the most. I also want to express my gratitude to Metropolia University of Applied Sciences for providing an inspiring academic environment with the necessary resources for this research. I am also grateful to my fellow students for offering compassion throughout the studies. I also want to thank the event organizers as well as the speakers for emphasizing contemporary topics and enabling networking. I am grateful to all professionals contributing to this study through insightful conversations and sharing of knowledge. A big thank you to Stereoscape for demonstrating interest in my thesis and for involving me in your work. I also want to express my gratitude to my employer for providing flexible working hours to facilitate my studies. Lastly, I want to thank my family and friends for offering emotional support throughout the research.



Emma Granqvist,
12 November 2023

1 Introduction

Fashion, as a visual form of communication and self-reflection, has throughout the years evolved in response to societal shifts, consumer demand and technological advancements. In the digital age with sustainability as a primary focus, the fashion industry finds itself at the intersection of innovation and dematerialization, giving rise to the phenomenon known as digital fashion. Metaverse and Web 3.0 are at the centre of current debates, deriving exploration of innovative business models and new channels of revenue streams.

While dressing avatars, acquiring in-game skins and applying AR filters are common practices in virtual worlds and social media (Desai, 2022; Javornik et al., 2022), digital fashion is considered a novel concept in the fashion industry. Established fashion brands have recently started to explore the possibilities of digitized products in production and retail alongside their traditional products and business operations. This emerging phenomenon represents a paradigm shift in how clothing is created, monetized, and experienced, driven by cross-industry collaborations and advancing technology. Digital fashion embodies the fusion of Fashion 4.0 technologies and traditional craftmanship, giving rise to new business models and practices that challenge and redefine established norms in the fashion value chain.

Previous academic studies in the field of digital fashion are naturally few, given the novelty of the phenomenon. Bertola & Teunissen (2018) have studied the impacts of The Fourth Industrial Revolution on the fashion industry emphasizing the potential of driving the industry towards more sustainable and customer-driven practices. Casciani et al. (2022) investigated the impacts of digital transformation on the textile and apparel industry, indicating that adoption of 3DVD technologies can enable multicentred business-model innovations and result in optimized supply chain processes. Särmäkari (2022) conducted the doctoral thesis on the authorship and professionalism of Fashion 4.0 designers, underscoring the transformed role arising from an open-source philosophy,

posthumanism, intellectualisation of practices, new employment possibilities and cross-industry entries. The research provides a general overview and definition of digital fashion and includes an extensive synthesis of existing literature.

This thesis aims to generate a comprehensive understanding of the current state of digital fashion by focusing on the value-creation and revenue potential of digital end products in phygital and virtual contexts. The research discovers how traditional fashion brands can benefit from digital end products while addressing the current challenges. Furthermore, the thesis investigates the environmental considerations of digital fashion, as well as its potential in contributing to a more sustainable future of fashion. The research is conducted using a case study strategy, including thematic analysis of secondary evidence from both academic and non-academic sources as well as primary data generated from observation. The purpose of this thesis it to help fashion brands and professionals navigate through the digital fashion space with the essential knowledge. The paper provides a multitude of digital fashion cases to facilitate the comprehension of this dynamic field.

1.1 Creatives in Metaverse, LUME

This thesis was conducted for LUME, creatives in Metaverse (FI: luovat metaversumissa), a non-commercial academic research project carried out by Metropolia University of Applied Sciences (Metropolia, n.d.). The project was funded by European Social Fund and took place 1.10.2022–31.5.2023 (ibid.). The objective of the project was to identify the essential competences for creative professionals when operating in the virtual environments of Web 3.0 Additionally, it addressed new operating models and earning opportunities for the creative field in the metaverse (ibid.).

The project resulted in the following book, which was published in June 2023 on Theseus.fi:

> Halonen, K. & Hero, L.-M. (2023). *Luovat web3-ajassa – Unelmia, haasteita ja ansaintamahdollisuuksia.* Metropolia University of Applied Sciences publications, TAITO-series 116, Helsinki. ISBN 978-952-328-395-4 (pdf), ISSN 2669-8021 (pdf). https://urn.fi/URN:ISBN:978-952-328-395-4

The book comprises several articles written by researchers Katri Halonen and Laura-Maija Hero, and creative professionals from different industries. Together with Laura-Maija Hero, I co-wrote the following article, which can be found in the attachment 1, pp. 77–83:

> Granqvist, E. & Hero, L.-M. (2023). Digital Fashion Business in the Metaverse – A Multiple Case Study. *In "Luovat web3-ajassa – Unelmia, haasteita ja ansaintamahdollisuuksia".* Metropolia University of Applied Sciences publications, TAITO-series 116, Helsinki. ISBN 978-952-328-395-4 (pdf), ISSN 2669-8021 (pdf), 70–88. https://urn.fi/URN:ISBN:978-952-328-395-4

The article provides an overview on the current state of digital fashion by focusing on the following research questions: How does the fashion industry operate in XR (extended reality) environments? How are fashion NFTs created and traded? The article includes a light multiple-case study of seven phenomena in digital fashion presenting digital fashion creators and collections, immersive fashion spaces, NFT platforms and cross-industry collaborations. The primary aim was to create an extensive understanding of the utilization of immersive technologies, 3D tools and NFTs in the fashion industry. While the article functions as a light introduction to digital fashion business, this paper investigates the phenomenon further with a more centralized focus on the value-creation and revenue potential. As LUME officially ended in May 2023, this final report could not be utilized in the project. The purpose of this research

is to provide knowledge for fashion industry professionals and to contribute to future research in this field.

Digital fashion is a novel and evolving phenomenon that is progressively attracting attention in the media. Several use-cases and research indicate a significant value-creation and revenue potential as well as positive impacts on the sustainability. The global digital fashion market was valued at USD 119.5 million in 2021 and is expected to reach a valuation of USD 6.76 billion by 2027 (Global Research Insights, 2023).

1.2 Research objectives

This thesis examines the emerging phenomenon of digital fashion with a focus on digital end products, which in the context of fashion refer to digital-only outfits or digital representations of physical garments. The products are either digitally “worn” on the physical body as a *phygital* experience, or on the avatar in virtual spaces. This study covers both phygital and virtual fashion, as I acknowledged several similarities and unclear distinctions between the two phenomena. Figure 1 (p. 11) illustrates the conceptual framework for this thesis.

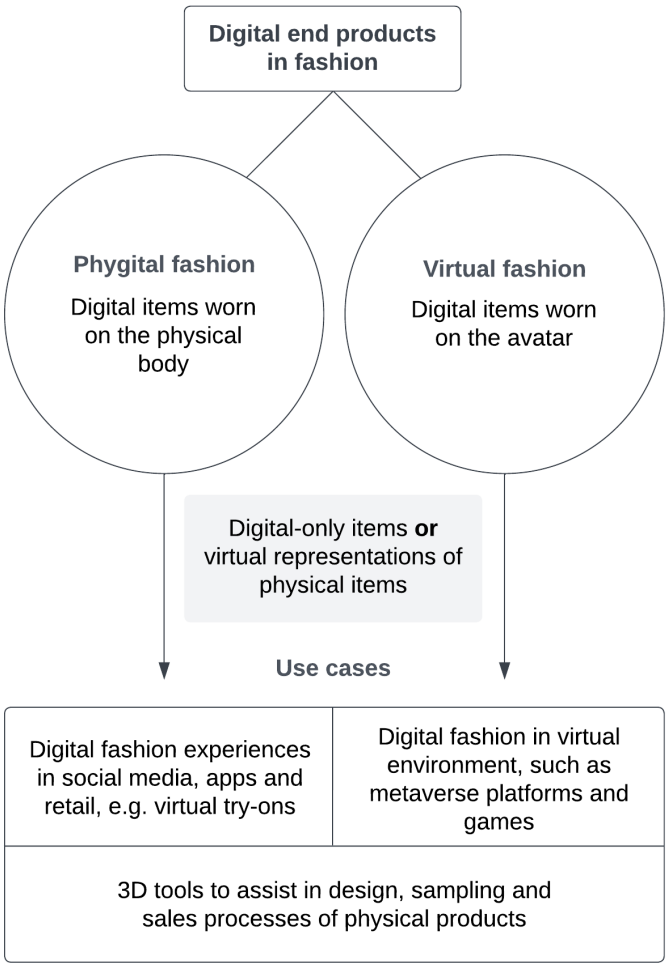


Figure 1. Conceptual framework. Design: Emma Granqvist.

Phygital is a trending word, referring to the incorporation of digital elements in real life experiences (Ginsburg, 2022). In the context of fashion, it refers to digital layers, such as 3D items “worn” on the physical body in images or as real-time rendered experiences with augmented reality (AR). Phygital fashion is commonly used in social media, apps and retail, while avatar fashion takes place in computer-generated virtual spaces, such as metaverse platforms and online games. Digital end products created with 3D tools are also being utilized in the production and sales processes of physical products, making it a diverse tool with many possible business impacts.

The purpose of this thesis is to create an extensive understanding of the dynamic field of digital fashion. The research encompasses investigation of

digital end products in the following contexts: 1.) avatar fashion in virtual environments, 2.) phygital fashion in social media, apps and retail, and 3.) 3D tools in the production and sales processes of physical products. The thesis focuses on the following research questions:

Main RQ: What is the current state of digital fashion in terms of value-creation and revenue potential?
Sub-RQ1: How can traditional fashion brands benefit from digital end products?
Sub-RQ2: Which are currently the biggest challenges in the digital fashion space?

When examining new business models in fashion, it is essential to consider the environmental impacts they imply. The fashion industry produces over 92 million tonnes of textile waste and consumes 79 trillion litres of water per year (Niinimäki et al. 2020, p. 189), making it a polluting industry that must be approached thoughtfully. Niinimäki et al. (ibid.) emphasize the urgent need for fundamental changes in the fashion business model throughout the supply chain, as well as a shift in consumer behaviour to decrease clothing purchases and expand garment lifetime. This research includes investigation of the environmental aspects of digital end products and addresses the potential positive impacts on the fashion industry.

When starting to explore digital fashion and associated phenomena, I came across unclear definitions, confusing information and missing knowledge. Digital fashion is a novel but emerging concept that is being explored in a range of ways by big international brands. In the Finnish market it is an undiscovered area with very few cases of applications. Digital fashion is an important field of research, considering the missing knowledge and its value-creation potential. Additionally, this thesis raises awareness of Industry 4.0 technologies and the evolving virtual environments which are likely to affect consumer behaviour and the way businesses operate.

2 Theoretical background

Digital fashion is a novel phenomenon that is evolving at fast pace. It is an extensive concept with a variety of meanings and applications. Kerry Murphy, co-founder of The Fabricant, illustrates digital fashion as the merge between the physical and digital worlds (Scandinavian MIND, 2022). Särmäkari (2022, p. 10) elaborates on the term as follows:

> First, it refers to digital tools used to assist in design processes, communication, showroom activities, sales and experiences. Second, it refers to digital end-products, either digital-only outfits in virtual spaces, virtual representations of physical garments or garments that incorporate digital technology. Third, it refers to a novel fashion culture that builds its own discourse, values and differentiation strategies, driven by the contemporary challenges of the fashion industry, technological possibilities and attitudes of digital culture.

The phenomenon has given rise to digital fashion designers that use various novel technological applications in their work (Särmäkari, 2022, p. 11). 3D fashion items are commonly created with CAD (computer-aided design) software and 3D design tools such as Vstitcher, Clo 3D, Blender and Marvelous Designer. With advancing technology other alternatives have been discovered, such as automation with generative artificial intelligence where unique designs are created based on input data or directly translated from 2D images (read about the YOONA case in attachment 1, p. 88). Algorithmic fashion design is a concept discussed by Särmäkari (2022, p. 11) referring to fashion design processes that employ data analytics, artificial intelligence and automation. Volumetric capture is another commonly used tool for creating realistic looking 3D objects and virtual environments, a technology utilized by Balenciaga and Marni (see chapter 2.3.2, pp. 25–26).

Digital fashion can be considered as an evolution of digital transformation and the Fourth Industrial Revolution, and is often discussed in association with the metaverse and Web 3.0 (see definitions pp. 15–18). These phenomena and their relation to digital fashion are elaborated in the following chapters.

2.1 Industry 4.0 transforming the fashion system

The Fourth Industrial Revolution, also called *Industry 4.0*, is described as a model where industrial systems are transformed by major changes in production and consumption (Bertola & Teunissen, 2018, p. 353). In the context of fashion, Industry 4.0 is bringing transformative changes in the back and front end of the value chain as it focuses on decentralization, interoperability in manufacturing, utilization of real-time data, virtualization of products, enhancement of customer experience and modularity in design (ibid.). According to Särmäkari (2022, p. 32) the most relevant Industry 4.0 technologies in fashion design are 3D tools, generative artificial intelligence and virtual platforms. Utilization of 4.0 technologies result in faster and more intelligent and innovative processes, products, services, and business models (Bertola & Teunissen, 2018, p. 353).

Särmäkari (2022, p. 104) points out that digital fashion in the 4.0 era is characterized by an open-source philosophy and a culture that values decentralised collectivism. This is applied through transparency, co-creation with consumers and sharing of items in online communities (ibid.), which is somewhat contradictory to the traditional methods where auteurism and individualism are fundamental values (ibid.). This open-source and decentralized philosophy as well as community driven approach are strongly present in The Fabricant’s vision, which is to build an entire digital fashion industry where everyone can create, share, and monetize digital assets (Scandinavian MIND, 2022). Read more about The Fabricant in attachment 1, pp. 85, 88.

Achieving a more sustainable fashion industry is one of the main motivating forces in the Fashion 4.0 realm. An established resilient infrastructure driven by innovation can result in more sustainable consumption and production practices (Vaseem Akram et al., 2022, p. 1–2). Sustainability is according to Vaseem Akram et el. (ibid.) achievable through integration of technologies such as the Internet of Tings (IoT), Artificial Intelligence (AI), blockchain and Extended Reality (XR). Augmented reality (AR), which is an XR technology, is a rising tool in the digital fashion space. The combination of AR and digital fashion are shaping the future of shopping, enabling new interactive brand experiences.

2.2 The immersive web providing new business opportunities

The development of virtual environments and their predicted significance in the next iteration of the web is expected to build demand on digital clothing. The metaverse has during the past few years been a discussed topic that involves strong contradictory arguments regarding its structure, societal impact and value-creation potential. Some see it as a rebranded gaming platform (Araújo Lopes et al., 2022, p. 5), while others envision it as a holistic virtual universe with revolutionary impacts on the society and individuals. Some refer the metaverse to any kind of interactive virtual environment.

Author Matthew Ball (2022, p. 29) defines the metaverse as follows:

> A massively scaled and interoperable network of real-time rendered 3D virtual worlds that can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communications, and payments.

Heli Nelimarkka, CEO of Stereoscape, pointed out in discussion that there are currently three main categories of the metaverse: 1. the social multi-brand

metaverse, e.g. Decentraland, 2. the company-specific metaverse, such as the virtual showroom by H&M, and 3. the industrial metaverse for working with complex systems (personal communication, October 6, 2023). This thesis focuses on the social multi-brand and company-specific platforms, where digital fashion activation currently takes place. See figures 2–3.

Figure 2. Metaverse Fashion Week in Decentraland (screenshot, 2023).

Figure 3. H&M virtual showroom. Courtesy of Journee, 2022.

Web 3.0, which contributes to the development of the metaverse, refers to the next major evolution of the internet. Web 3.0 aims to decentralize data with blockchain technology and solve the issues detected in today's Web 2.0 (Rijmenam, 2022, 4–5). Currently the infrastructure of the web is owned and controlled by centralised entities such as big tech companies (ibid.). Personal data are stored across the web in multiple databases managed by companies and organisations, making it nearly impossible for the individual user to manage or delete its own data due to the high value it provides businesses (ibid.). Web 3.0 attempts to solve this by giving the power of data and ownership of digital asset in the hands of the users (ibid.). While Web 3.0 provides a foundational structure for the metaverse, it is not a condition for its existence.

In a report conducted by McKinsey & Company (Araújo Lopes et al., 2022, p. 12), John Hanke, CEO of Niantic, described the metaverse as a digital extension of the real world where the physical and digital experiences become deeply merged. As a concept, the metaverse consist of four core building blocks: 1.) content and experiences, 2.) platforms, 3.) infrastructure and 4.) hardware and enablers (ibid.). With real-time synchronous communication between humans and machines, and access to a variety of technologies such as AI, IoT, 5G (soon 6G) and XR technology, the metaverse could provide extensive opportunities for the users (Rijmenam, 2022, p. 15). Cathy Hackl, chief metaverse officer and co-founder of Journey, pointed out in an interview (Araújo Lopes et al., 2022, p. 49) that the metaverse is not about escaping reality. It is rather about augmenting life with virtual content and experiences to make people happier and their lives more meaningful (ibid.). The metaverse aims to elevate productivity and enable deeper connections between family and friends (ibid.). Contradictory, there are critical arguments regarding the impacts on the mental and physical wellbeing.

Research indicates that there is clear curiosity regarding the metaverse. In the survey published by McKinsey & Company (Araújo Lopes et al., 2022, p. 29), almost 60 percent of the respondents demonstrated an interest in the transition

of everyday activities to the metaverse. The most significant driver of excitement was connectivity, which comprised a number of activities including virtual shopping, which 64 percent reported being excited about (bid., p. 30). Shopping was reportedly the most preferred activity in the immersive world compared to traditional physical alternatives (ibid., p. 31). Women interested in the metaverse are particularly excited about customizing the avatar and attending events, while the male respondents prioritize connecting with people and investing in virtual real estate (ibid., p. 15).

According to Araújo Lopes et al. (ibid., p. 48), there are currently about 100 virtual worlds existing, some considered as prototypes of the envisioned metaverse. While the majority are focused on gaming and socialization, there are exploratory business applications ranging from advertising, teaching, recruiting, tourism to public services and many more (ibid., p. 39). Emmi Jouslehto, CEO and co–founder of Arilyn, pointed out at an event organized by Epicenter, that the fashion industry is adapting fast to the metaverse as there are clear ways to benefit in this specific field (personal communication, March 22, 2023). Innovative Web 3.0 fashion companies have been established and big global brands have quickly implemented new technologies and business models. However, when looking at smaller companies and fashion brands in Finland, the progress towards more immersive experiences and virtual environments is very slow.

Despite the hesitation and slow adaption in Finland, global fashion brands see the metaverse as the next frontier for consumer engagement and commerce. Robert Triefus, executive vice president and chief marketing officer at Gucci, argues that virtual worlds indicate a paradigm shift resulting in a significant new revenue stream for brands (Williams, 2022, pp. 61–62). Triefus (ibid.) and Rijmenam (2022, p. 34) are convinced that the metaverse will affect all industries and play a fundamental role in the revenue growth for companies in the years ahead. Rijmenam (ibid.) emphasizes the importance of organizations ability to strategically adapt to the forthcoming changes in order to exist in the years ahead (ibid., p. 35).

2.2.1 Avatars for self-expression and social networking

Fashion at the core, is a social and psychological phenomenon that conveys signals about a person's identity, community and position in the society (Crane, 2000, p. 1; Weedon, 2004, p. 7). Thus, fashion acts as a tool to express personal identity and foster a sense of belonging to a group. The same philosophy applies to the virtual realm where the digital identity and community are conveyed through avatars. The avatar is, therefore, a crucial aspect of the metaverse and digital fashion. Meta (2022) defines an avatar as a digital expression of a person's personality or personalities that conveys individual characteristics. Rijmenam encapsulates an avatar as a visual representation of an identity, which can be controlled by a real person or a computer-driven non-existing digital agent, also known as a *non-player character*, NPC (Rijmenam, 2022, p. 47). Avatars can be anything from 2D images to hyper-realistic 3D representations of humans, called *digital humans* (ibid.).

Players invest significant time in modifying their digital presence before engaging in online interactions with others (Kafai et al., 2010, p. 1, as cited in Yee, 2006). In virtual worlds, users find creativity, status, exclusivity and self-expression being fundamental aspects of their digital presence (Araújo Lopes et al., 2022, p. 41–42). Today with advanced technology, avatars can be crafted with precision including increasingly humanlike features (Papagiannis, 2017, pp. 93–96). According to artist, scientist and VR pioneer Dr Jacquelyn Ford Morie (ibid., pp. 93–96), avatars in the future will be able to act on behalf of a person. These intelligent avatars or digital humans are 3D computer-generated beings that can be animated to behave like people in the virtual world (Epic Games, n.d.), with capability of responding to the users' expressions and body language (Silva & Bonetti, 2021, p. 1; Collier et al., 2019, p. 1).

The users will have multiple digital identities in the metaverse (Rijmenam, 2022, pp. 48, 52). As in the physical world, people adjust their appearance, clothes and behaviour depending on the social context (ibid.). The avatar is, however, not bound to a person's physical identity, which enables endless of

opportunities for self-expression and identity-exploration (ibid.) Rijmenam (ibid.) describes the metaverse as a relatively safe environment with less judgement compared to the real world (ibid.), a statement I feel doubtful about. Can we truly be what we want in the virtual space? In discussions with field experts, it became evident that young people are carefully choosing their avatars' appearance to be socially accepted by others. Perhaps avatars can contribute to harmful body norms and beauty ideals, an aspect to seriously reflect about when creating a brand presence in the virtual world. While avatars are becoming more humanlike, some metaverse experts have argued in discussions, that users will most likely want their avatars to differentiate from their actual selves with fictitious features alongside real-life characteristics (personal communication, October 10, 2023). Appearing as your true self in the metaverse could be intimidating and take away some of the fun and creative aspects of the avatar.

2.3 Digital fashion applications

Cases of digital fashion applications are continuously increasing among fashion brands. In the research conducted by Casciani et al. (2022, p. 776–778), the results demonstrate that 3DVD technologies (=3D modelling, virtual reality, augmented reality, 2D/3D scanning and digital twinning) are utilized by two major groups of companies (ibid.). The first one is established fashion companies that through external collaborations or internal competence digitize part of their business (ibid.). Hugo Boss, for instance, has integrated digital showrooms and 3D samples in their B2B sales process (Hugo Boss, 2023). The second group utilizing 3DVD technologies is digitally born start-ups such as digital fashion-consulting agencies that digitize collections or create digital retail experiences (Casciani et al., 2022, p. 776–778). The second group also comprises digital fashion companies that produce their own digital products or host other brands as collective platforms (ibid.). An example of this is DressX, a digital fashion start-up company, that creates their own digital collections, collaborates with fashion brands, and functions as a collective platform for digital fashion designers.

The convergence of physical and digital is resulting in a new form of commerce: *iCommerce* or immersive commerce (Rijmenam 2022, p. 62). A business model defines the way an organization creates, delivers and captures value, and a business model innovation is based on one of the following objectives (Osterwalder et al, 2010, p. 14):

> 1.) to satisfy existing but unanswered market needs, 2.) to bring new technologies, products, or services to market, 3.) to improve, disrupt, or transform an existing market with a better business model, or 4.) to create an entirely new market (ibid.).

I can see all four objectives being relevant and present in the already existing business models of digital fashion. There is a clear demand for digital fashion assets in virtual worlds as discussed in chapters 2.2 and 2.2.1. Companies such as The Fabricant and DressX are focused on building an entirely new industry, while traditional fashion brands are often aiming to elevate consumer experiences, improve business processes or finds new revenue streams through digital fashion. ICommerce includes three business models: 1.) *direct-to-avatar* (D2A), 2.) *digital-to-physical* (D2P) and 3.) *physical-to-digital* (P2D). D2A refers to digital-only products used in virtual spaces (Rijmenam 2022, p. 62), which is a common concept in online games and metaverse platforms. D2P provides users a virtual experience of a product before delivering the physical one, while P2D offers the consumer a digital replication of a purchased physical product (ibid.). Digital-to-physical and physical-to-digital are at the beginning of exploration with Prada as one of the fashion companies in the forefront. The NFT collection “Timecapsule” launches once a month a limited-edition physical item connected to a gifted NFT (non-fungible token), which is available for only 24 hours (Prada, n.d.).

NFTs, which are unique digital assets based on the blockchain (Beyer, 2023), are common in the digital market. NFT use-cases in fashion range from verifying product authentication and ownership to serving as collectibles or investments (Amed et al., 2022, pp. 58–59). A number of established fashion

brands have started to sell NFTs alongside their physical products. According to a case study conducted by Dune (2023), fashion brands generated over $200 million in NFT sales on Ethereum Blockchain in 2022. Nike took markedly the first place with a total NFT revenue of $186.13 million, following Dolce Gabbana (ibid.). Dolce Gabbana have created a nine-piece digital couture collection “Collezione Genesi” (figure 4), that generated a total value of $5.7 million (Njuguna, 2021; UNXD, 2021).

Figure 4. Collezione Genesi by Dolce Gabbana. Courtesy of UNXD, 2021.

The NFT market presents an economic model with royalty systems that the fashion industry has never seen before, allowing creators to be fairly compensated for their work (Ginsburg, 2022). Rijmenam (2022, p. 60) believes that it will become common for large fashion brands to sell digital products alongside their physical ones to generate additional revenue and gain visibility in the metaverse. When approaching the digital market, companies must remember that high quality content requires a variety of expertise, either in-house or through third-party collaborations (Amed et al., 2022, p. 60).

2.3.1 Phygital fashion experiences

Phygital fashion experiences are progressively increasing with innovative ways of integrating technology in retail, ecommerce and apps. Virtual try-ons with augmented reality (AR) have become a common tool for making shopping experiences more engaging. AR is an immersive technology that adds an interactive real-time rendered digital overlay on top of the physical environment (Papagiannis, 2017, p. 1). AR combined with machine learning and artificial intelligence (AI) can simulate a garment's fit on the physical body (London, 2021), making it a viable solution for clothing try-ons. This technology has most commonly been implemented in ecommerce and social media on platforms such as Snapchat.

AR driven solutions have also been utilized in physical retail for clothing try-ons and as a tool for providing additional information about products. In 2023, AR company ZERO10 collaborated with fashion brands to demo their AR try-on technology (Cureton, 2023; Hirschmiller, 2023). AR mirrors were implemented in Tommy Hilfiger, Coach and JD Sports stores or storefront to catch consumers attention and enable effortless try-ons of selected products from their collections (ibid.). See figure 5.

Figure 5. ZERO10's AR mirror. Courtesy of Hirschmiller, 2023.

AR mirror technology is powered by strong computer power, real-time rendered clothing in 4K resolution with cloth simulation technology which enables realistic garment simulations (Hirschmiller, 2023). 3D body tracking creates a replication of the user in the three-dimensional space (ibid.), enabling clothing try-ons on the body in motion. Tommy Hilfiger has also implemented AR in their consumer application, allowing users to receive location-specific AR content, such as colour alternatives about online-exclusive products through image recognition (AdventureClub, n.d.).

Phygital fashion experiences are also provided by digital fashion companies such as DressX and The Fabricant. On the DressX platform (figure 6), the consumer uploads a pre-outfit photo in form-fitting clothes, which the digital item will be added on top on (DressX, n.d.-a). Find out more about this service based on influencer Safiya Nygaard's experience in attachment 1, p. 87.

Figure 6. Digital dress sold on DressX. Courtesy of DressX, n.d.-b.

Daria Shapovalova, co-founder of DressX, distinguishes two primary customer segments in this field: Millennials and GenZ (Amed et al., 2022, p. 58). Phygital looks are commonly shared on social media platforms or acquired for other digital content creation purposes. DressX has also created an app for AR try-ons, which this research examines further in chapters 4.2 and 4.3, pp. 46–54.

The app functions as a platform where users can capture photos and videos of AR looks and share them with the DressX community.

AR technology has also been utilized in fashion events to provide additional effects to visitors or exclusive content to app holders. In 2023, XR and metaverse company OVER (2023) created an AR fashion show in Milan featuring giant avatars walking through Piazza del Duomo wearing designs from brands such as Pinko and Balmain. Fashion brand Injury has on the other hand realized a sci-fi influenced catwalk experience by showcasing the 2023/24 collection on both avatars and real-life models (ABC News In-depth, 2023). Phygital experiences have also taken place during London Fashion Week 2023 with immersive exhibitions enabling visitors to interact with brands' collections through AR lenses (Cappasity, 2023). AR is a trending technology with increasing experimental implementations in the fashion industry.

2.3.2 Digital fashion in virtual environments

The integration of digital fashion in virtual worlds is continuously evolving, offering users new opportunities for self-expression, creativity and social interactions through their avatars. The gaming industry, with its long history in connecting people and building online communities, has become a targeted platform for fashion brands (Amed et al., 2022, p. 57). Games are becoming a digital extension of the physical world where people can meet and socialize (ibid.). With more than three billion global players and a market value of $184 billion in 2022 (McDonald, 2023), it is an industry with a lot of potential.

Established fashion brands such as Balenciaga, Gucci, Burberry, Ralph Lauren have embraced virtual platforms through third-party collaborations (read about these cases in attachment 1, pp. 82–84). Balenciaga launched their fall 2021 collection as a video game (Hitti, 2020), which was completely unique to the fashion industry. Balenciaga was also the first fashion brand to release a collection of NFTs in the game Fortnight (Maguire, 2021). Burberry has sold NFTs in the multiplayer game *Blankos Block Party* in collaboration with Mythical

Games (Burberry, 2022), while Marni (n.d.) has created a 360-degree immersive space, presenting the spring/summer 2022 collection on 3D scanned models (figure 7).

Figure 7. 360-degree immersive space with 3D scanned models. Courtesy of Marni, n.d.

Traditional fashion events and campaigns are progressively entering the digital realm. In March 2022 the metaverse platform Decentraland arranged Metaverse Fashion Week for the first time, featuring digital fashion shows, exhibitions, parties and pop-up stores by established fashion brands and individual creators (Hirschmiller, 2022). I participated in the second edition of the event in March 2023 to generate deeper knowledge for this research. The observations are presented in chapters 4.3 and 4.4, pp. 46–54. Roblox and Zepeto are other popular destination for fashion brands. Ralph Lauren, Louboutin, Gucci and Bulgari to name a few, have launched their own virtual spaces in Zepeto for permanent presence, occasional events or product launches (Araújo Lopes et al., 2022, p. 43; LazyMeow, 2022). Virtual fashion stores are also found on Roblox by established brands and individual creators.

The possibilities of fashion business in virtual worlds are extensive. According to Wolfson (2022) digital fashion items in virtual worlds should offer some sort of consumer engagement or utility features. Attaching additional powers to a digital item, such as ability to fly or run faster makes the item more valuable (Rijmenam 2022, p. 60). Utility can also mean providing a discount on the equivalent physical product or giving VIP access to a brand experience. (Wolfson 2022; Rijmenam 2022, p. 60). According to Alan Cooper, director of product and consumer communications at Epic Games, the purpose of fashion activations in games is to gain market awareness among the digital audience (Maguire, 2021). To enter this new virtual market with high quality content, brands need a strategic mindset and willingness to create partnerships within the industry (Amed et al., 2022, p. 60).

3 Methodology

This thesis is conducted using a case study strategy combining theoretical investigation of secondary documents and exploratory observation in several fields. The case study was chosen as its purpose is to produce deep and detailed information about a current phenomenon in its real-life context (Ojasalo et al, 2015, p. 52). The case study is according to Yin (2009, pp. 2, 13) a relevant research method when a.) the research focuses on “how” or “why” questions, b.) the investigator has little or no control over the studied events, and c.) the research examines a contemporary phenomenon or series of events. The case study research approach seemed highly relevant for this thesis as it matches all the above-mentioned aspects.

Case study research is explicitly relevant for descriptive, explanatory and exploratory research (Farquhar, 2012, p. 7). This thesis is partly descriptive and partly exploratory as it aims to describe the current state of digital fashion by exploring the benefits and challenges through secondary and primary evidence. The research type is collective, which means examining a specific phenomenon through several different cases (ibid., pp. 7–8). In this research the findings are generated through extensive investigation of use-cases, applications, and

platforms of digital fashion in the following contexts 1.) avatar fashion in virtual environments, 2.) phygital fashion in social media, apps and retail, and 3.) 3D tools in the production and sales processes of physical products.

This case study has an inductive research approach that determined the research design and strategy. The purpose of an inductive approach is to generate theory by looking for patterns in a set of data (Farquhar, 2012, p. 25), which this research achieves through thematic analysis. The case study approach allows the researcher to receive an extensive understanding of the nature and complexity of the studied phenomenon (Farquhar, 2012, p. 8). Case study research is described as subjective as the investigator is often immersed in the studied case to generate in-depth comprehension (ibid., p. 10).

3.1 Data collection

A characteristic of the case study research is to study the case horizontally using multiple sources of data (Olsen, 2012, p. 183, as cited in Yin, 1989), which strengthens the findings and ensures the validity of the statements (Farquhar, 2012, p. 7). This thesis combines several data collection methods that are complementary to each other and can therefore enable extensive investigation of the phenomenon. Triangulation, meaning studying a case from different perspectives, is an essential concept in the case study research that provides strong foundations for the findings (ibid., p. 7). Figure 8 (p. 29) describes the approach on triangulation in this research.

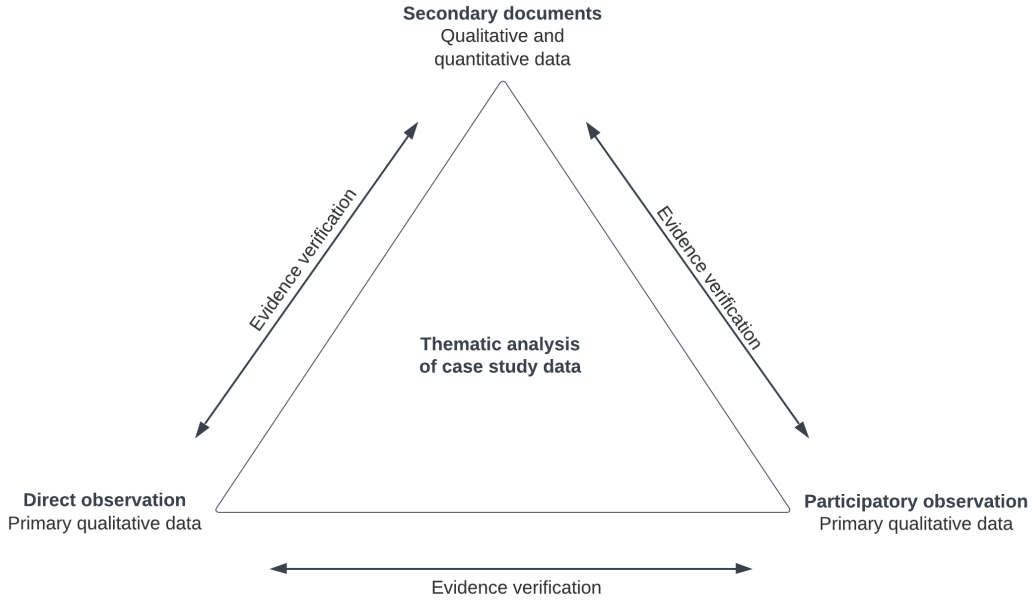


Figure 8. Data triangulation. Design: Emma Granqvist.

While this research uses mainly qualitative evidence, a small amount of quantitative data from secondary sources is included to justify particular statements. Complimentary evidence from primary and secondary sources are enabling diverse findings and ensuring validity of the conclusions. Subjective views generated from observation are compared to secondary data sources and others' arguments, and vice versa, while non-academic sources provide information that is missing from literature and research. Table 1 (p. 30) presents an overview of data sources and methods.

Table 1. Data matrix.

Research questions	Data collection method	Data source	Data analysis method
Primary RQ: What is the current state of digital fashion in terms of value-creation and revenue potential? **Sub-RQ1:** How can fashion businesses benefit from digital end products? **Sub-RQ2:** Which are currently the biggest challenges in the digital fashion market?	Secondary data collection	Academic articles, surveys reports and literature Descriptive case articles and blog posts Videos, podcasts, social media posts and website content	Thematic analysis
	Participant observation	Virtual space 3D creation tool AR app	
	Informal observation	Physical events Online events Other social interactions	

Research data is collected from several secondary sources and observational fields and analysed using thematic analysis principles. The thesis includes a multitude of non-academic research sources to describe use-cases of digital fashion practices which facilitate the comprehension of the dynamic field. A comprehensive presentation of use-cases is necessary when helping fashion brands and professionals navigate through the digital fashion realm. The following chapters present each research method in detail.

3.1.1 Participant observation

In the case study research, the investigator commonly studies the phenomenon in its real context to generate insights within specific situations (Farquhar, 2012, p. 6). In this research it was achieved through participant observation in several contexts of digital fashion. According to Yin (2018, p. 122), observational evidence can provide additional information to the research and new dimensions for understanding of the case. The Metaverse Fashion Week arranged by Decentraland, a metaverse platform, was a priority field of observation in this research. The objective was to generate an accurate comprehension of the current state of avatar fashion in a virtual and interactive environment. Before attending the event, I conducted an observation plan which is presented in table 2 (p. 31).

Table 2. Observation plan for the Metaverse Fashion Week.

Category	Focus	Purpose	
Avatar	• Avatar selection and modification possibilites.	To generate basic under-standing of the platform	
Environment	• Impressions of the visual aspects of the surroundings. • The size of the space.		
User experience	• Does the platform work as expected? • Is the space easy to navigate?		
Services	• What kinds of services and events does the platform provide?		
Digital fashion and brands	• Brand exposure on the platform. • What kinds of services, products or exhibitions do the brands provide? • How is digital fashion monetized on the platform?	To generate knowledge relevant to the reseach objectives	Priority focus
Users	• Number of users on the platform (approximately). • What are users doing on the platform, which spaces or events seem to be the most popular? • Are there indications of interest in digital fashion?		
Interaction	• Interaction between users. • Engagement with brands.		

Metaverse Fashion Week is a novel concept in the fashion industry that has caught considerable amount of attention in media. The main purpose of observing the event was to address the benefits and challenges of digital fashion business on social metaverse platforms. The event was documented with written notes and screenshots. Documenting the observational field with photos can generate additional value and help to convey characteristics of the case (Yin, 2018, p. 122). The second significant field of observation was the DressX app, which is one of the most notable AR apps in digital fashion (see the observation plan in table 3, p. 32).

Table 3. Observation plan for the DressX AR app.

Category	Focus	Purpose
App features	• How does the app work? • What kinds of features does it provide? • Is it user-friendly?	To generate basic under-standing of the app
AR experience	• How is the product offer? • How is the AR renders and product quality? • What works well and what does not? • Is the experience engaging?	To generate knowledge relevant to the reseach objectives
Community	• How can I interact with the DRESSX community? • What kind of content are the users sharing?	

Priority focus

The purpose was to generate insights into the user experience and value of AR fashion. The analyses of both observational fields are based on a combination of my own subjective views and secondary reviews found in online searches. During this thesis, I also gained insights into the creation of digital end products. Addressing the benefits and challenges of 3D garment creation is essential when evaluating whether to choose this business path or not. I joined an online course by Browzwear to learn 3D garment creation using Vstitcher. The course started with the basics of 3D creation and moved on to more advanced features. The course comprised extensive content: selection and modification of avatars, 3D creation of imported DFX files, basics of digital pattern making, stitching of garments and seam constructions, selection and modification of textiles and components, tech pack creation and collection management, rendering of 3D models and finally the basics of animation.

3.1.2 Informal observation and discussions

This research included informal observation at several physical and online events. The highlighted topics at the events have been digital fashion and related phenomena such as the metaverse, Web 3.0 and emerging technologies such as AI, XR technology and blockchain. The purpose of participating in these events was to gather knowledge, address opinions, identify common topics and to build networks with technology experts. The events have included panel discussions and presentations. Although a big part

of these events has been irrelevant to the study, most of them have provided some sort of useful evidence and ideas for this research. Casual discussions with fashion and technology professionals at events and other occasions, have provided meaningful insights for this research. These discussions are not considered as interviews as they have happened randomly without pre-planned topics or questions. Some arguments will be brought up anonymously or referred to the person in question, when permission was granted.

3.1.3 Documentation

This research uses a wide range of documents which were collected through systematic searches and active participation in physical and online events. Documentation and personal diary have been essential for keeping the research insights and evidence coordinated. Figure 9 (p. 34) presents the different types of documents that were utilized in this research.

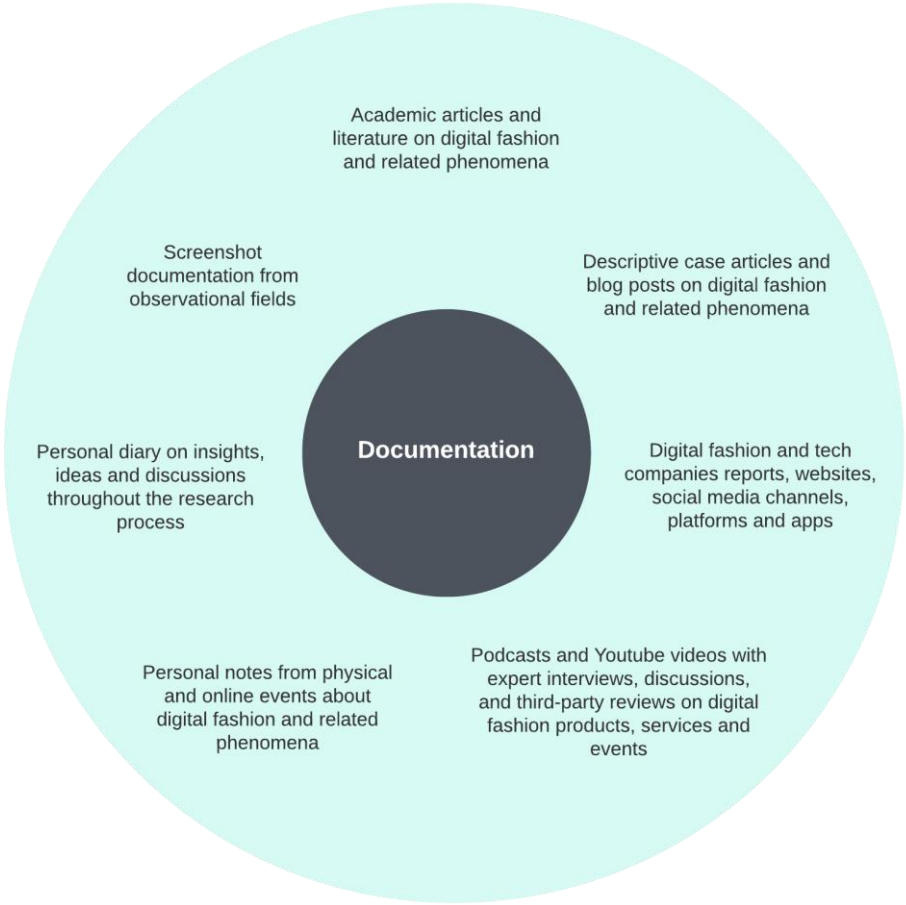


Figure 9. Research documents. Design: Emma Granqvist.

The thesis comprises secondary data from academic research and literature as well as non-academic articles and blog posts on digital fashion and related phenomena. Further investigation has been conducted on digital fashion and technology companies' reports, websites, social media channels, platforms and apps. Podcasts and YouTube videos have provided interviews and discussions with industry expert and third-party reviews of digital fashion products, services and events. The observations and output at physical and online events have actively been documented. Personal diary on insights, ideas and discussions has been an essential documentation method throughout the research process. Additionally, visual documentation has been conducted through screenshots from observational fields.

The abundance of information on the Internet makes reviewing documents challenging and time-consuming (Yin, 2018, p. 117). Therefore, it is important to focus on pertinent material. Yin suggests (ibid.) to sort all material by their apparent relevance to the inquiry and then, focus on the material that appears to be the most relevant and put aside the rest for later review (ibid.). I followed this suggestion and listed all references in one document. I categorized the references by topics and ranked them according to reliability and relevance.

Documentation is a helpful tool when verifying spelling, titles, names, and information from other data sources (Yin, 2018, p. 115). When documentary evidence is contradictory to other sources, further investigation is required. (ibid.). Due to the novelty of digital fashion and related phenomena some information was contradictory to each other. Considerable amount of time was spent on thoughtful investigation and comparison of different definitions and views on digital fashion and associated phenomena, while keeping in mind that digital fashion is at an early stage and is still taking shape. The phenomenon is, furthermore, often associated with the metaverse and Web 3.0, which do not yet exist. Therefore, I this research focuses on the current state of digital fashion in its present existing contexts.

3.2 Thematic analysis

Thematic analysis is a method of data analysis in qualitative research used for identifying meanings in a set of data (Braun & Clarke, 2012, pp. 1, 3). The researcher analyses the way the studied topic is talked and written about, then identifies common patterns and offers insights (ibid., p. 1). The purpose is to identify patterns which are meaningful and relevant to the research question (ibid.). This research focuses on finding patterns regarding the benefits and challenges of digital end products in fashion. Thematic analysis is a flexible method that can be conducted in several different ways with an inductive or deductive approach (ibid., p. 3). This research has an inductive analysis approach with an experiential orientation to the data. The themes in inductive analysis are derived from the content in the collected data, while a deductive

analysis is more critical with themes derived from concepts brought to the data by the researcher (ibid.). Thematic analysis always contains features of both approaches (ibid.). Inductive analysis is commonly experiential as it focuses on participant- and data-based meanings (ibid.). This research generates themes from observational evidence and secondary data sources following the six-phase approach described by Braun and Clarke (2012, pp. 5–11). The six-phase approach is illustrated in figure 10.

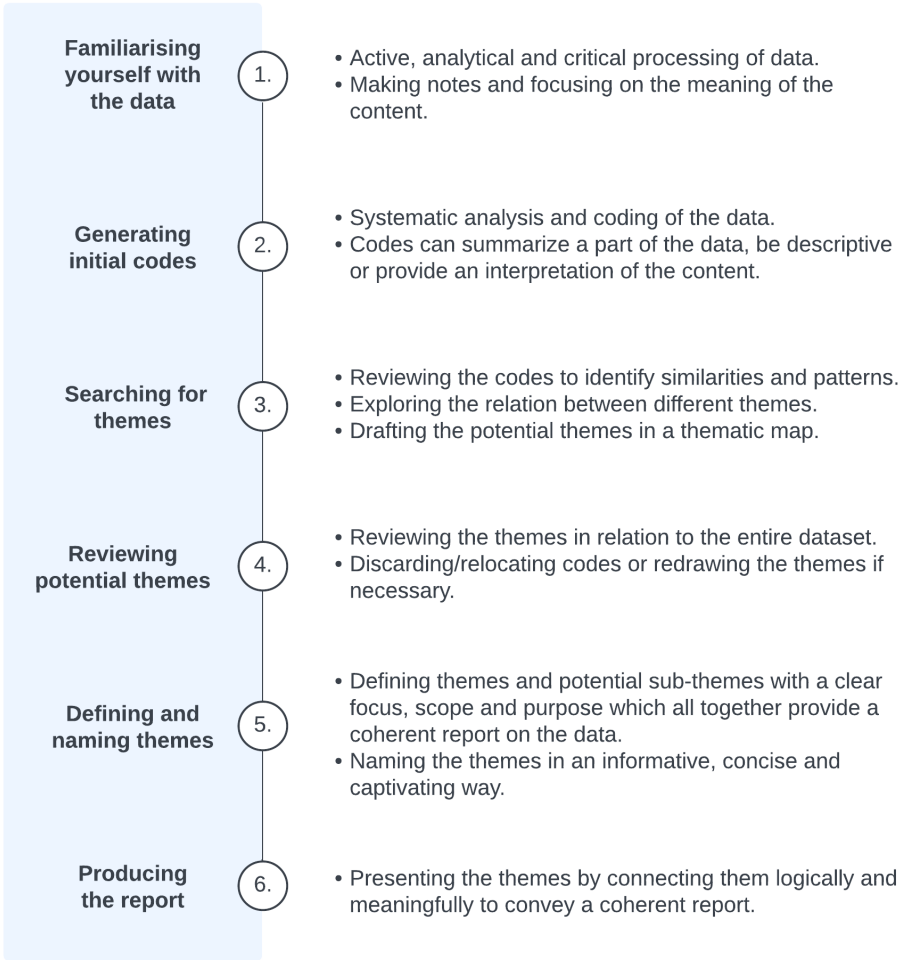


Figure 10. Six-phase approach in thematic analysis. Design: Emma Granqvist (adapted from Braun and Clarke, 2012, pp. 5–11).

The aim of the first phase is to become immersed in the content of the dataset and address knowledge that might be relevant to the study (Braun & Clarke, 2012, p. 6). In the coding phase is it important to have an inclusive, thorough and systematic approach, and to ensure that the codes occur in more than one

data item (ibid., p. 7). When the codes are addressed and linked to their initial data content, the next step is time to look for themes (ibid.). The number of generated themes is in relation to the amount of coded data (ibid., p. 8). It is essential to create themes with depth and detail to achieve a valuable analysis (ibid.). The candidate themes are illustrated in a thematic map for further review (ibid.), while in the reviewing phase, it is important to consider the quality, depth, relevance and boundaries of the themes (ibid., p. 9). The purpose is to create themes which convey the most essential elements of the data in relation to the research objectives (ibid.). A good thematic analysis should according to Braun and Clarke (2012, p. 9) have clear and simple themes, preferably with a singular focus directly addressed to the research objective, and without overlapping one other or being repetitive. The themes should however be related to each other and as an entity generate a coherent story about the data (ibid.).

3.3 Research process

This research started in December 2022 when taking part in the LUME-project. The article “Digital Fashion Business in the Metaverse” is considered as the first phase of this research, providing on introduction to the phenomenon of digital fashion. Figure 11 (p. 38) presents the research process including the first phase, the article, and the second phase, this report.

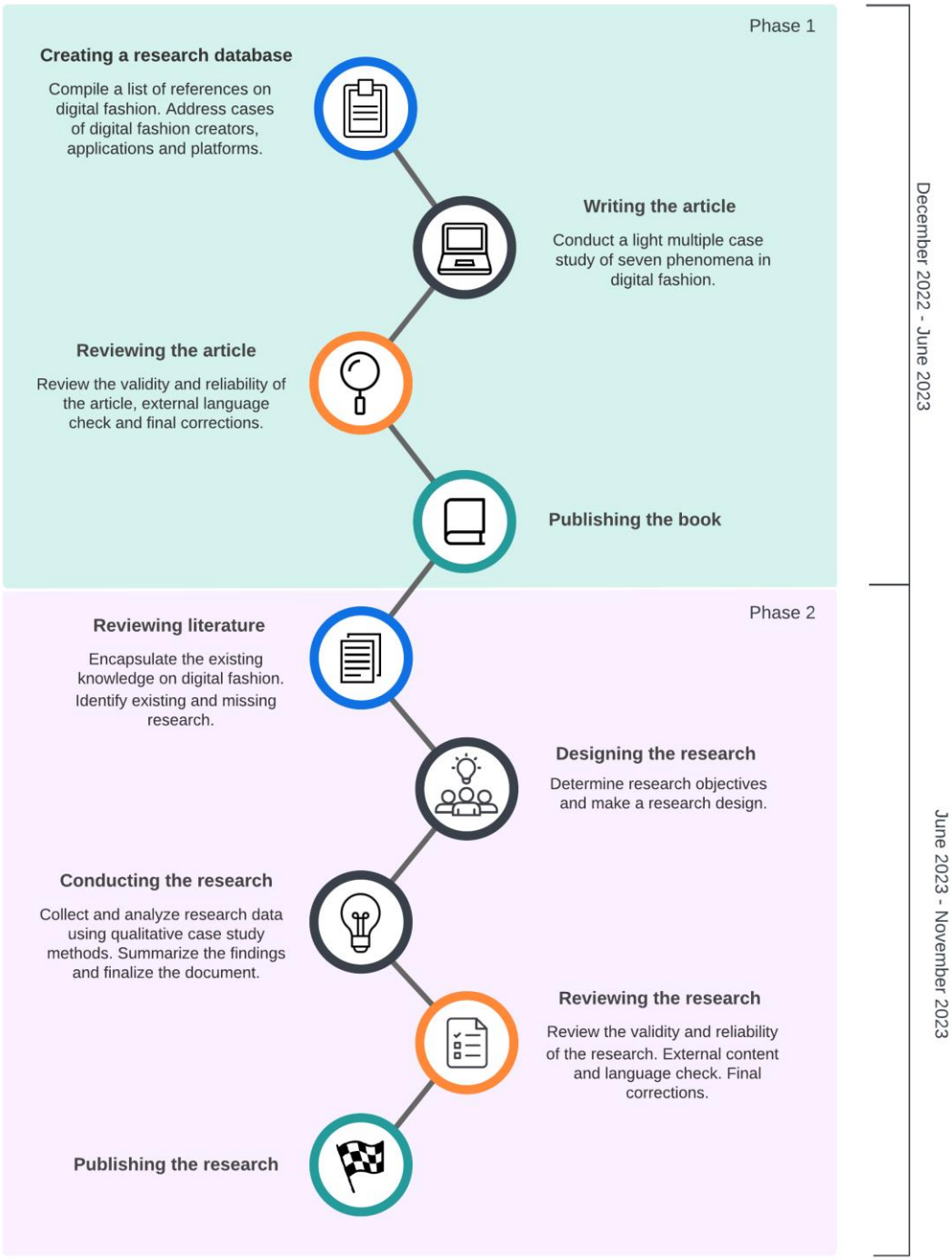


Figure 11. Research process. Design: Emma Granqvist.

I started the research by creating a database of relevant sources. The article, which comprises a light multiple case study of seven phenomena in digital fashion, was written in close collaboration with researcher Laura-Maija Hero. The article got externally language checked and published in June 2023 as a

part of the book “Luovat web3-ajassa - Unelmia, haasteita ja ansaintamahdollisuuksia”.

Once the article was finalized, I continued investigating digital fashion through previous research and literature. The database composed in the first phase of this research came to use and was constantly updated with data sources and information. The objectives and framework of the thesis started to take shape after identifying the existing and missing research. The research objectives and methodology were drafted together with Laura-Maija Hero (LUME) and my thesis supervisor Natalia Särmäkari. During summer–fall 2023 research data were collected and analysed. Once the report was finalized and validity reviewed, the thesis was thoroughly evaluated by myself, my supervisor and external language controllers. Once the final adjustments were done, the thesis got published on Theseus.fi in November 2023.

4 Results

Digital fashion and associated phenomena such as the metaverse are discussed topics with strong contradictory arguments regarding their value-creation and revenue potential. This research considers both the positive and critical perspectives of digital fashion in several presented contexts to create a holistic understanding of its current state. The following sub-chapters present the discovered themes (5) following thematic analysis principles. The thematic map (figure 12, p. 40) presents the themes and most relevant codes for this research.

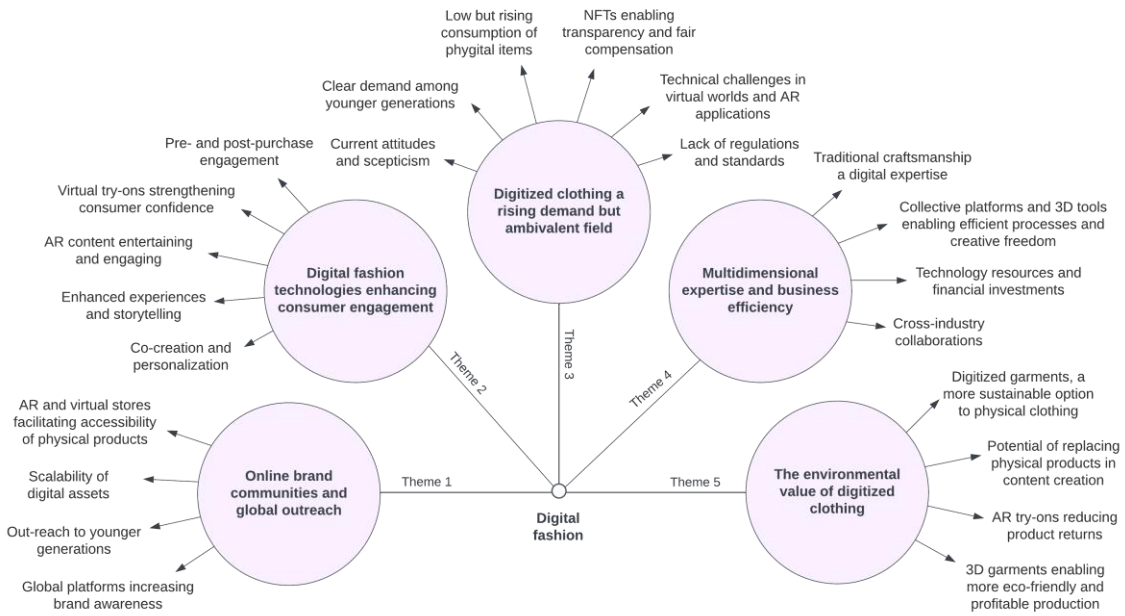


Figure 12. Thematic map. Design: Emma Granqvist.

The codes within the themes provide extensive answers to the research questions regarding the benefits and challenges of digital fashion business in phygital and virtual contexts. Every code is generated from multiple sources, combining secondary and primary case study evidence. The following chapters present the findings within each theme.

4.1 Online brand communities and global outreach

Digital fashion activation in online platforms allows fashion brands to establish a strong and diverse digital presence with access to global audiences dominated by younger generations. Araújo Lopes et al. mentioned in their report (2022, p. 41), that digital environments enable direct-to-consumer shopping services regardless of physical distance, which is beneficial for both the business and the consumer. Amed et al. (2022, p. 58) emphasized the opportunity to reach out to the younger consumers, which are the most potential consumers of digital clothing.

Research indicates that the digital presence is becoming an essential part of our identity as the time spent online for socialization purposes increases. According to a report conducted by The Business of Fashion (Malik & Lee, 2021), approximately 70 percent of GenZ and GenX consumers in the US, rated their digital identity as important. Kerry Murphy explained in Scandinavian MIND (2022), that they do not differentiate their digital and physical lives, which makes purchasing digital items as natural as regular shopping. Also, Millennials are addressed as potential customers of digital fashion especially for content creation purposes. Daria Shapovalova, co-founder of DressX, explained in an interview (Amed et al., 2022, p. 58) that millennials understand the concept of digital fashion as they are known for purchasing luxury goods to elevate their social media presence. Jenny Campbell, chief marketing officer of Kate Spade, argued that brands should focus on reaching out to GenZ, even if they are not the primary customers or targeting group (Vogue Business, 2021). GenZ are trendsetters that make fashion pieces go viral (ibid.), which could lead to increased brand awareness and eventually sales growth.

Araújo Lopes et al. (2022, p. 41) argued that virtual environments can enable new revenue streams of virtual asset but also drive sales of physical product as the brand visibility expands to new channels. There are factors indicating that in-game activation can raise interest in brands. Two days after Balenciaga launched its collection in Fortnite, the Google searches on the brand increased with more than 40 percent (Araújo Lopes et al., 2022, p. 42, according to Google Trends). Regarding this, we must remember that popular gaming platforms such as Fortnite, which are known for the monetization of skins, are for most fashion brands impossible platforms to enter. Being granted a spot in an attractive place or having the chance to collaborate with a successful company is challenging and comes with a high cost, both in the physical and virtual space. Big brands with stronger financial resources are therefore in the forerun of implementing digital fashion practices.

Through in-game activation brands can reach out to online communities which are commonly big in size and globally widespread. As mentioned in chapter

2.3.2, the gaming industry has more than three billion global players (McDonald, 2023), making it a powerful platform to increase brand awareness. Virtual worlds and online platforms can function as tools for establishing online brand communities (OBC). OBCs enable fashion consumers to interact with each other without time or location constraints. As a result, OBCs are considered as a powerful tool for shaping customers' purchasing behaviour (Brogi et al., 2013, p. 1). The extent of engagement and shared content among OBC members have a direct impact on behaviours related to brand loyalty (ibid., p. 7).

The scalability of digital fashion is a significant benefit compared to traditional physical fashion where increasing product volume, launching new items or expanding sale points require significant financial investment. Kerry Murphy mentioned that the lack of geographical boundaries and materialistic limitations in the digital space facilitate the scaling of digital products (Scandinavian MIND, 2022). Virtual platforms enable digital fashion designers to showcase and sell their creations to a global audience which can accelerate fast into significant revenue streams. Virtual environments have also enabled earning opportunities for young tech-savvy people. CSapphire, a 21-year-old digital fashion designer on Roblox become a successful and desired creator at an early age. Her virtual clothing store had more than 5.4 million visitors between 2015–2021 with over 2.5 million items sold reaching a six-figure revenue in the past few years (ABC News In-depth, 2023; Salamone, 2021). This shows how virtual worlds have given rise to a new digital fashion ecosystem, that enables new opportunities not only for fashion brands but also for young creators.

Digital fashion implemented with AR can also elevate the scalability of physical products by making product try-ons accessible without the need for physical stores or products. AR mirrors can enable try-ons of products not available in-store (McKinsey and Company, 2022, p. 47), making the products easier to access. According to Araújo Lopes et al. (2022, p. 41), virtual stores can reduce the need for physical stores which would result in lower costs. AR experiences have also been proved to catch consumers attention effectively. According to Snaps AR research (Deloitte Digital, 2021), AR applications in retail catches

attention almost two times more than equivalent non-AR experiences. AR can therefore be an efficient tool for providing information and try-ons both alongside physical products and as a replacement.

4.2 Digital fashion technologies enhancing consumer engagement

Digital fashion and enabling technologies have the potential of enhancing consumer engagement in several ways by offering services and features that are novel to the fashion industry. As digital fashion continuously evolves, technology and consultancy companies are offering fashion brands innovative ways to engage with consumers. Research and descriptive case articles indicate that immersive experiences and interactive content can strengthen the brand image and consumer loyalty, resulting in accelerated sales and increased customer satisfaction.

Business practices in the digital age are characterized by customer-centricity and personalization (Muutosagentit, 2022). On-demand production, where products are tailored accordingly to customers' orders is a rising trend that responds to the sustainability issues related to overstock (Amed et al. 2019, p.83). While on-demand manufacturing requires smaller capital investment, it is challenging to implement due to complex supply chains and higher production costs when producing smaller batches (ibid.). In the digital fashion realm, the customer's demand is in focus, providing next-level product personalization possibilities (Araújo Lopes et al., 2022, p. 40). Digital fashion emphasizes co-creation between brands and consumers, which encourages creativity and gives a stronger sense of individuality and ownership. Personalization can therefore provide additional value and an emotional connection to the product as emphasized by Maghan McDowell, senior innovation editor at Vogue Business, at the "Fashion Tech Summit: Sustainability and Fashion" event organized by DressX (personal communication, July 22, 2023).

Digital fashion implemented with AR has the potential of improving retail in several ways. An AR survey conducted by Google in 2019 (Vieira, 2020), discovered that 6 out of 10 people wished to have the opportunity to visualise where and how a product could fit into their lives, while 2 out of 3 were interested in using AR for shopping. From the fashion industry perspective, I am convinced that AR try-ons could have significant impacts on shopping, as long as it is strategically implemented with high quality garment simulations. Trying a garment effortlessly at home with different outfits and combinations could lead to more deliberated purchases and higher customer satisfaction. Carolina Arguelles, Global Product Marketing Lead in Augmented Reality at Snap, argued that AR enhances the shopping experience and builds a longer-term loyalty to the brand (London, 2021). According to Snaps' consumer research (Deloitte Digital, 2021), AR in shopping results in a 94 percent higher conversion rate than non-AR supported products. Although this high figure may not be entirely reliable, AR is an effective tool for enhancing customer engagement which can have significant impact on sales.

AR has demonstrated ability to boost consumer engagement online as individuals are inclined to share their AR experiences on their social media profiles. Research indicates that almost all consumers that use AR want to continue engaging with the technology after the purchase to share their experiences and views with the online community (Alter Agents, 2022). A notable 74 percent of Snaps' users find AR to be entertaining (Deloitte Digital, 2021, p. 46), underscoring its potential to enhance the overall consumer experience. AR features have also shown potential in enhancing the physical in-store consumer experience (Araújo Lopes et al., 2022, p. 41). George Yashin, CEO of ZERO10, mentioned that AR mirrors in retail have resulted in enhanced user engagement, extended time spent in the store and longer lasting impressions (Hirschmiller, 2023). ZERO10´s AR mirror implementation for the Tabby bag at Coach storefront in Soho indicated a high level of consumer engagement. During the project's one month-long run more than 75 000 try-ons where tracked. (Hirschmiller, 2023). While conversion rates were not available, the high number of try-ons proves the potential of attracting attention with this

technology. As I was exploring the AR try-ons in the DressX app, I found the experience captivating despite its lacking quality. In the Helsinki XR Center's showroom, I tried AR and VR devices which proved the ultimate potential of XR technology in fashion. Watching a hyper-realistic catwalk show through AR glasses was impressive, but the use-cases of this advanced technology are still to be seen. The ongoing development of XR devices and smart glasses, however, demonstrate a potential mainstream adoption in the consumer market.

AR in fashion is currently at an experimental phase providing novel and exciting experiences to the consumer. As individuals become more acquainted with AR try-ons, it is essential to improve the quality and thoroughly plan the content to sustain people's interest. According to Alter Agents (2022, p. 47), 49 percent of consumers expressed a desire for informative content through AR, while 42 percent seek instructional guidance. This underlines the importance of valuable content, beside its entertaining aspects. In addition to enhanced shopping experience, AR provides a better visual understanding of the product. 56 percent of consumers in Snaps' consumer survey agreed that AR increases assurance about product quality (Deloitte Digital, 2021). A better sense of the product will not only make shopping easier, but also reduce the number of product returns which is a big challenge in the ecommerce of fashion. This topic is discussed more in chapter 4.5, pp. 57–58.

Digital fashion, at the core, encourages creative expression and exploration of unconventional ideas. McDowell emphasized at an event (personal communication, July 22, 2023), how elevating outfits with digital elements enhances storytelling, which is an essential aspect in fashion and branding. I envision fashion brands gifting in-app AR filters in attachment to physical products to provide additional post-purchase value and diversity to the product. Providing this sort of exclusive content to product owners could make the product more desirable among younger people and derive consumer engagement on social media.

In virtual spaces, such as games and metaverse platforms, it is evident that digital fashion or skins are playing an important role in character expression. As mentioned in chapter 2.2.1, users are spending significant amount of time on modifying the visual representation of the character before interacting with others. When I entered Decentraland to observe the Metaverse Fashion Week, I found myself choosing the outfit and the visual features carefully, similarly to when I used to play other games (figure 13).

Figure 13. My avatar in Decentraland (screenshot, 2023).

Inside Decentraland I noted how other users had invested effort in customizing their avatars, aiming for unique appearances rather than sticking with the default look. This indicates the importance of the digital representation and the demand for avatar clothing, as discussed in chapter 2.2.1. Digital fashion has multi-faceted impacts on consumer engagement as it responds to consumer demands and digital trends in both the virtual and phygital realm.

4.3 Digitized clothing a rising demand but ambivalent field

The applications of digital fashion are constantly increasing and expanding to new dimensions, placing it in an exciting but uncertain phase. Amber Slooten, co-founder and creative director of The Fabricant, points out that the digital

fashion market is experimental, and that success cannot be guaranteed (Amed et al., 2022, p. 60, as cited in Nanda, 2021).

What is the purpose of clothing that lacks physical wearability, is a frequently raised concern when discussing digital fashion. In casual conversations with fashion industry experts and other individuals I have observed several patterns. First and foremost, many individuals lack a clear understanding of what digital fashion and related phenomena entail. Secondly, I have noted a prevailing sense of scepticism, particularly among older generations and those who are less familiar with the concept. Conversely, some people have expressed a keen interest in the topic, especially those with an open-minded attitude and a general curiosity in technology. Kerry Murphy told in a podcast (Scandinavian MIND, 2022) how he and Amber Slooten encountered substantial scepticism after establishing The Fabricant, the first digital fashion house. People questioned the rationale behind the concept, perceiving it as nonsensical (ibid.). These reactions and missing comprehension surrounding the subject are understandable, given the novelty of the phenomenon. Murphy pointed out that the fashion industry often upholds a traditional mindset that values conventional craftsmanship (ibid.). Furthermore, he stated that traditional fashion enthusiasts have reservations and fears regarding the digital identity (ibid.). Arguably, it appears to be more of a lack of interest, knowledge and understanding. Traditional fashionistas place significant importance on their digital lives considering their active presence on social media. While traditional fashionistas could be natural consumers of phygital fashion, the challenges remain in changing their attitudes and behaviour.

The direct-to-consumer sales of phygital fashion are according to a secondary report and observations relatively low. Olga Chernysheva, chief sustainability officer at DressX, presented their consumer survey reports from 2020 and 2022 at the online event “Fashion Tech Summit: Sustainability and Digital Fashion“ (personal communication, July 22, 2023). According to the report, 25 percent of their consumers, which accounted for the biggest share, spent $10–$30 during the whole year (ibid.). The report encompassed certain findings that indicated a

positive progress in the digital fashion consumption. In 2020, 15 percent had purchased at least five items, while in 2022, the corresponding percentage had risen to 28 percent (ibid.).

Although it is evident that digital clothes cannot entirely replace physical ones, DressX and other cases have demonstrated that certain physical garments could be substituted. In the DressX survey of 2022, 54 percent of the respondents agreed that some physical garments aimed for content creation can be replaced by digital replications, while 61 percent agreed that digital fashion can simplify and make content creation more affordable (ibid.). Another encouraging finding was the increased number of consumers who want to continue purchasing digital fashion. In 2022, the number was 77 percent, a notable improvement from the 54 percent reported in 2020 (ibid.). These results indicate that existing consumers of digital fashion are becoming more satisfied with the service and are progressively recognizing its value. However, the number of customers was not specified, which would have enabled a more precise assessment of the current consumption and revenue potential of the direct-to-consumer market of phygital fashion.

When I was exploring the AR app by DressX, I noticed both positive and concerning elements regarding the technology. The application provides a wide range of digital fashion items, some with a free AR try-on function where users can capture photos or videos of the outfits. The products can also be purchased as "metalooks", referring to the service where they are added onto uploaded photos. Most of the AR looks appeared unrealistic due to bad recognition of the body parts and silhouette, which emphasizes that AR technology is not yet advanced enough for high-quality renders. One of the successful features was the AR try-on of accessories. Items such as sunglasses and jewellery were rendered with precision recognizing facial features in motion. These items had a notably more realistic appearance as solid materials are easier to replicate compared to fabric textures. Bettina von Schlippe, publisher of Vogue Singapore, talked at the DressX event about the current blockers of digital fashion going mainstream (personal communication, July 22, 2023). She

highlighted that the quality and experience are the keys to success, which the technology is not yet fully ready for (ibid.). It is evident that AR try-on technology needs further development to achieve its full potential.

The DressX app also functions as an online fashion community where users can share and see other people's phygital looks. When looking through the feed, I could only notice AR try-on content, which indicates that people are mostly using the free feature instead of acquiring purchasable looks. This raises the concern, are regular consumers willing to pay for digital fashion? The purchasable looks provided by DressX are notably much more realistic looking than the AR renders (see attachment 1, p. 87). Considering the digital craftmanship behind this service, with looks being created on demand for individual consumers, it is clearly a time-consuming business model. This raises the second significant concern, can the direct-to-consumer market can be a profitable business?

To generate in-depth insights on avatar fashion, I participated in the second edition of Metaverse Fashion Week (MWFW) arranged by Decentraland. The event had gained considerable amount of media attention highlighting the participation of luxury fashion brands. Dan Olson (2023) made a review on Metaverse Fashion Week 2023 calling the video "The Future is a Dead Mall" by referring to both Decentraland and the envisioned metaverse, which he is strongly critical about. Olson showed some of Decentraland's marketing materials, which were extremely exaggerated from the actual event (ibid.). Olsen talked about the narrative of MWFW, referring to the exclusive image that Decentraland has created by involving high-end brands and companies on the platform (ibid.). As a fashion enthusiast I was disappointed by the low-polygon avatars and the limited customization possibilities which, on the other hand, is understandable. Rendering of high-polygon avatars and environments require strong computing power, which would aggravate the accessibility and user experience for the majority of consumers (Rijmenam 2022, p. 49).

The actual platform was very large and after watching other people's experiences and reviews, I realized that I had only seen a small part of it. The avatar could be teleported to different areas by choosing the coordinates on a navigation map, but finding specific areas or showrooms was quite difficult. A number of fashion brands such as Tommy Hilfiger, DKNY and Dolce Gabbana participated in the event with their own showrooms and exhibitions (figure 14).

Figure 14. DKNY showroom in Decentraland (screenshot, 2023).

The platform felt more like a game than a fashion event. I wished the platform would have had more interesting and engaging content with the possibility to communicate with the brands in some way. It remained unclear to me who this event was aimed for. At traditional fashion weeks, the spotlight is often on the fashion shows. I went to see a virtual fashion show in Decentraland that had an intriguing event description emphasizing high-end fashion, cutting edge technology and innovation. "The avatars will be choreographed to perfection", was enthusiastically stated. I was the only one attending the fashion show, and I noticed that the marketing material was completely exaggerated. The low-polygon avatar models walked the runway in extreme slow motion, to a disturbing beat showcasing clothes, that I could barely see.

Another big concern I faced in Decentraland was the lack of people. I observed the event at different times for four days, and the areas were most of the time completely empty. Another major issue that limited my experience was the technical challenges, which according to several articles was improved in this edition compared to the previous year. Loading Decentraland and moving between different areas took a lot of time. A fully functioning experience would perhaps have required a more powerful computer, which the majority of users would not have. This insight made me question the capabilities of the big envisioned metaverse. Rijmenam (2022, p. 42) stated that distributed ledger technologies will not be advanced enough to deliver hyper-realistic and live-streamed immersive experiences with hundreds of thousands of interactive users present in the same space at the same time. This explains why today's virtual worlds have a restricted number of present users and quality related limitations (ibid.). At the “Fashion Tech Summit: Sustainability and Fashion”, Bettina von Schlippe, publisher of Vogue Singapore, mentioned the lack of interoperability as a major issue (personal communication, July 22, 2023), which is challenging to achieve due to the lack of technical standards across virtual platforms (Rijmenam 2022, p. 61). Despite the challenges in virtual worlds, I addressed a few interesting spaces in Decentraland, that incorporated physical elements such as panel discussions with real people and exhibitions displaying photographs of physical collections. I attended an exhibition and presentation about AI generated photography which was demonstrated by the creator himself on a screen. The exhibition was a success and attracted a crowd of other avatars.

Maghan McDowell emphasized the importance of making new services and technologies user-friendly (personal communication, July 22, 2023). Digital fashion must be easy to try, dress and share (ibid.). Digital assets are often minted as NFTs and traded with cryptocurrencies, a market many people perceive as intimidating due to fraud risks. NFTs are used as they can verify the authenticity and ownership of digital assets, which is especially beneficial to luxury brands battling counterfeiting (Araújo Lopes et al., 2022, p. 42). Despite lacking regulations, NFTs contribute to a more transparent ecosystem with fair

compensations and possible earnings from secondary sales depending on the royalty system (Beyer, 2022). According to discussions at the DressX event (personal communication, July 22, 2023), the digital fashion market needs the same level of regulations as the traditional fashion industry has. This would result in a more desired and secure platform for both creators and consumers. Cases of counterfeit has in recent times have, however, raised discussions and pushed the development forward in a more secure direction. Read about the case of Mason Rothschild and Hermes lawsuit in attachments 1, p. 90. With increasing utilization of generative artificial intelligence in product design, copyright and data privacy are at current debates. Härkönen (2023) argued that AI poses threats to fashion designers and brands as it blurs the authenticity of designs and raises transparency issues regarding the origin. European Union aims to establish regulations for AI to ensure safer conditions for the users (European Parliament, 2023). This chapter demonstrated the complexity of digital fashion practices, making it field that needs to be approached strategically with a comprehension of the imposed risks.

4.4 Multidimensional expertise and business efficiency

Digital fashion business requires a wide range of skills due to its multidisciplinary nature. When 3D modelling is incorporated in the production of physical products, additional preciseness with more detailed information is needed, to drive a well-functioning workflow where all parts are synchronized. When investigating 3D garment creation using Vstitcher, I quickly realized that high quality outcome requires several fields of expertise. 3D garments are created following traditional processes (pattern making, sewing etc.), but in a digital format on an avatar with adjustable measurements and body features, figure 15 (p. 53).

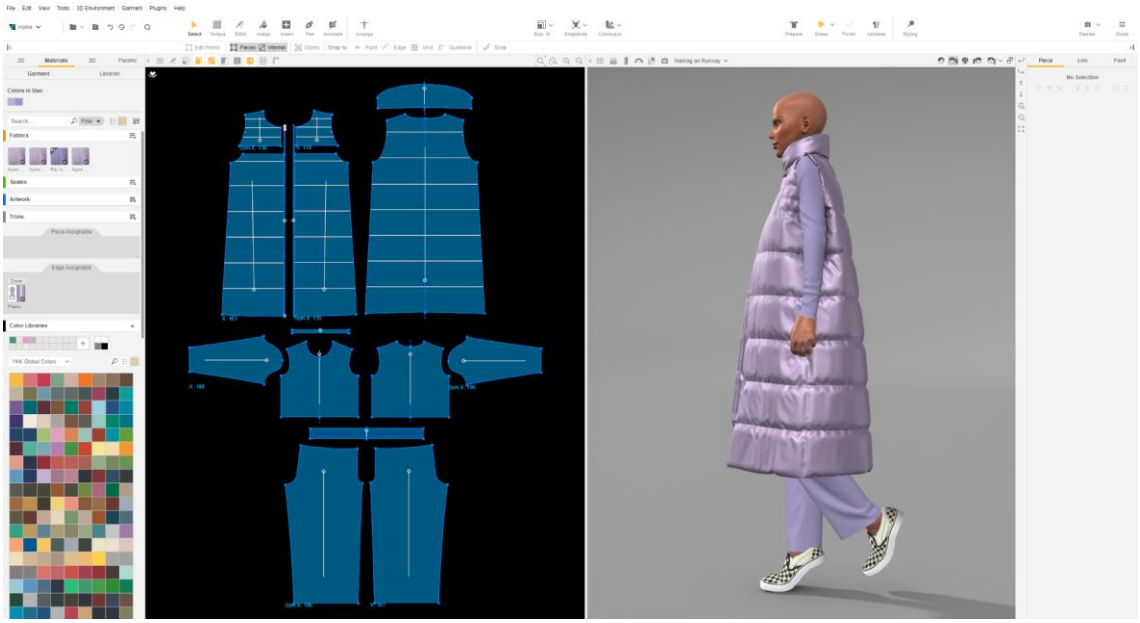


Figure 15. 3D garment creation with Vstitcher (screenshot, 2023).

Digital fashion designers must, therefore, have a strong foundational knowledge of traditional fashion design principles, including pattern making, sewing and seam constructions, as well as an understanding of textile properties. Proficiency in patternmaking is crucial when creating 3D garments. Pattern issues result in bad-fitting clothes, an aspect I found time-consuming and complex to resolve. In addition to traditional fashion design expertise, the creator must have technical proficiency in using digital tools. Daria Shapovalova mentioned in a video (Dell, 2021) that the creation of one item takes 2–4 days, which proves the amount of work and level of craftmanship.

On a corporate level, businesses must have a wide range of understanding and expertise of digital platforms and technologies depending on the application. Being capable of managing online communities, creating user-friendly interfaces and having an understanding of business operations in virtual environments may be crucial aspects for driving operations successfully. Maghan McDowell pointed out at “The Tech Edit” weekly LinkedIn seminar (personal communication, October 31, 2023), that poorly implemented technology can have harmful effects on the brand. As digital fashion continuously evolves, staying up to date with emerging technologies and

consumer preferences is essential. As discovered in the theoretical background, digital fashion practices are often driven by a combination of in-house expertise and cross-industry collaborations, something that smaller brands may find challenging. Based on several discussions with fashion industry professionals, the biggest obstacle for integrating digital fashion in the business is the lack of required expertise and financial resources for tools or consultancy services (personal communication, 2023). Kevin Murphy mentioned that digital fashion is especially challenging for small struggling brands without capacity or resources for 3D tools (Scandinavian MIND, 2022).

Despite the required skillsets and resources, digital fashion practices can result in significant benefits and value-chain impacts when implemented strategically. Hugo Boss, a tech-driven fashion brand that has used 3D tools since 2012, argues that integration of 3D can help in pushing superior product development forward and enable a level creativity that cannot be achieved through physical practices (Hugo Boss, 2023). In my investigation of 3D tools, I noticed the potential of accuracy in product design. Designs can be developed to finest detail, making it an applicable tool for elaborating designs and creating realistic looking digital samples. While detailed 3D modelling is time-consuming, experimenting with colours and other design features is more efficient digitally than through physical practices. Hugo Boss (ibid.) mentioned that collective 3D practices and digital libraries facilitate the workflow within teams, resulting in several beneficial outcomes across the value chain. The creation-to-shelf timeline was reportedly 85 percent faster, and the physical samples per collection were 30 percent fewer (ibid.). With integration of 3D tools, the processes have become more efficient and product quality better while decreasing the environmental footprint (ibid).

4.5 The environmental value of digital fashion

Dematerialisation of clothing is according to Moreira and Niinimäki (2022, p. 20) one of the business models contributing to the circular economy in the fashion industry. Circular economy refers to a system where products and materials are

kept in circulation through various processes without harming the climate or creating waste (Ellen MacArthur Foundation, n.d.). Circular economy addresses global issues such as climate change, biodiversity loss, waste, and pollution (ibid.). The production and consumption of digital fashion is fundamentally independent of water, chemicals and the logistical challenges within the traditional fashion value chain. Rijmenam pointed out (2022, p. 58) that digital fashion only requires servers and computers, which can be powered by renewable energy. Digital fashion has however raised some critique due to the energy that validation of NFT transactions on the blockchain consumes (Amed et al., 2022, p. 60).

The sustainability benefits of digitized clothing are emphasized by digital fashion houses such as DressX and The Fabricant. According to calculations, the production of a digital garment in comparison to a physical garment emits 97 percent less carbon dioxide (DressX, n.d.-c; Scandinavian MIND, 2022). Additionally, a digital garment saves 3300 litres of water, which is the average usage in the production of a physical product as presented at the DressX online event (O. Chernysheva, personal communication, July 22, 2023). DressX is bringing this information to their customers, by mentioning in the product description the amount of energy and water they save when buying a digital product instead of a physical one (figure 16, p. 56).

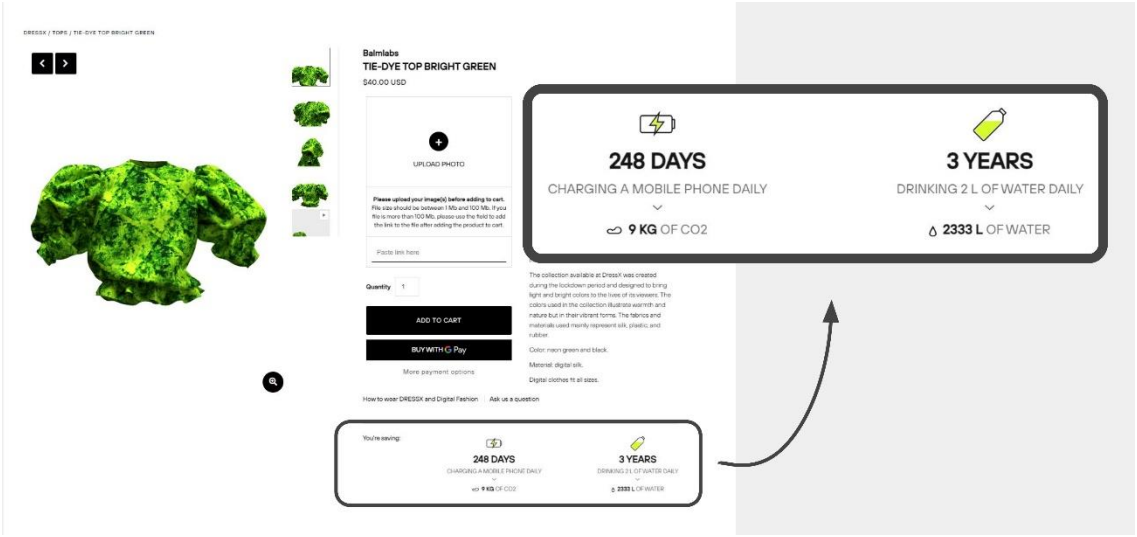


Figure 16. Energy and water saved when purchasing digital fashion (screenshot, DressX, n.d.-d).

Increasing awareness of the sustainability aspects of digital fashion is arguably essential for driving behaviour change towards a digital and more environmentally friendly market. Kerry Murphy, however, argued that sustainability will never be the purchasing driver for consumers (Scandinavian MIND, 2022). While it may not be the primary reason for purchasing digital assets, it adds value to the product and perhaps makes digital fashion reach out to eco-conscious consumers. People are progressively becoming more environmentally conscious as sustainability awareness increases (Bouronikos, 2022). An extensive study on global consumers across 17 countries showed that 78 percent find environmental sustainability important, while 63 percent have made modest to significant shifts towards more sustainable consumption in the past five years (Jain et al., 2021, p. 3–4). Sustainability is therefore an aspect that consumers are considering when making purchasing decisions and a key differentiator for businesses in value proposition (ibid.). The study shows that the younger consumers are more actively shifting towards more sustainable practices (ibid.). Albella et al. (2022) have similarly addressed eco-conscious values among millennials and GenZ. In previous chapters it got determined that these generations are also the primary consumers of digital fashion. This

correlation indicates that sustainability communication could have an influence on the growth of digital fashion consumption.

When discussing digital fashion, it is essential to evaluate its sustainability impacts on traditional fashion practices and shopping behaviour. The research conducted by Bertola & Teunissen (2018, p. 366) indicate that 4.0 technologies have the potential to make the fashion industry more sustainable. In the DressX survey (2023), 13 percent of the respondents reported a decrease in shopping of physical garments since they started to consume digital fashion. This indicates that digitized clothing has the potential of reducing shopping of physical items, which eventually could decrease over-consumption and textile waste. Daria Shapovalova discussed how social media has triggered consumers to purchase clothes for content creation purposes, resulting in massive amount of one-time uses and product returns (Dell, 2021), a problem DressX is aiming to solve.

The environmental benefits of digital fashion have also been addressed in retail. In 2021, Farfetch launched a pre-order collection campaign in partnership with DessX with the idea of avoiding the environmental impacts related to the production and logistics of physical samples (Retail Technology Innovation Hub, 2021). Pre-order looks from the newest collections were digitised and used in editorial photoshoots and by influencers in social media (ibid.). Farfetch stated that they saved 346,698 litres of water as well as 2,515 kg CO2, which is equivalent to 29 years of using a smartphone for 10 hours a day. According to calculations, a similar campaign with physical samples would have caused a 97.86 percent larger carbon footprint (ibid.). Hugo Boss is another company striving toward more sustainable and efficient practices by digitizing samples and integrating digital showrooms in their B2B global sales processes (Hugo Boss, 2023).

Rijmenam (2022, p. 63–64) stated that iCommerce has the potential of revolutionizing online shopping and reducing the large number of product returns, as it allows the consumer to try on the product virtually before

purchasing it. Jillian Anderson, head of global sales at Ares, presented at the DressX event (personal communication, July 22, 2023), that fashion brand Princess Polly achieved a 24 percent decrease in return rates after implementing a size recommendation tool and a digital try-on feature with size-adjustable avatars. Araújo Lopes et al. (2022, p. 47) argue that virtual try-ons are giving a clearer sense of the products which enable more deliberated purchases. A study on augmented reality in retail (Alter Agents, 2022), showed that 80 percent of consumers who use AR during shopping feel more confident in their purchase decisions.

From the design and production perspective, digital fashion can be used to better understand the market before launching a new collection (Rijmenam, 2022, p. 96). This means that digital fashion could enable more accurate production management and contribute to reduction of overproduction and textile waste. Whether digital fashion can be used and trusted in the market research, depends arguably on the target group and context. The players purchasing digital in-game assets are most likely a different segment than the brand's regular consumers. Additionally, as discussed in chapter 2.2.1, the digital persona commonly differentiates from the real-life identity, representing a fictional character. Phygital fashion could be more accurate and reliable from the market research point of view, considering that the wearer is a physical person and not an avatar.

5 Discussion

As I explored the intersection of fashion and technology, it became apparent that digital fashion is not only an isolated trend for online communities but a powerful tool for driving businesses towards more collective, efficient and sustainable practices. The implications of digital fashion encompass the entire value chain, including design, production, communication and retail.

The thesis was conducted using a case study research approach to generate extensive knowledge about digital fashion. The case study research has raised

some concerns by research investigators which I deliberated before starting this research. Yin (2009, p. 14) believes that a lack of rigor is the greatest cause of criticism, leading to unsystematic procedures, and allowance of indistinct evidence or biased views to influence the findings and conclusions (ibid.). The plan of this thesis was thoroughly prepared at an early stage before the actual start of the research, which enabled deep reflection on the research framework, a critical analysis of its importance and utilization potential and well-considered choices of research methods. All sources of evidence have been thoroughly reviewed separately, and analysed together to ensure that the findings are based on the convergence of information from multiple sources.

A critical point of view in this research, is the extensive utilization of non-academic sources, such as articles, blog posts and reports conducted by media, fashion brands and digital fashion consultancy companies, which may not be entirely reliable due to sales-driven motives. These sources were, however, important due to missing academic sources about certain topics, and especially crucial for describing use cases and user experiences of digital fashion applications. This research does also use data triangulation as well as primary evidence to provide multiple measures of the same case, which strengthens the validity of the findings (Yin, 2018, p. 128). The reliability of the research was ensured by systematic analysis of research data and a thorough presentation of the results. The quality of the study was refined through several dialogues with my supervisor Natalia Särmäkari who has expertise in the studied topic and research practices. The thesis content and methodology were also discussed with Laura-Maija Hero from the LUME project. Additional support and research advice has been received from Essi Karell, head of the Master's degree programme.

Another concern regarding the case study strategy, that deserves careful consideration, is that it often consumes a lot of time and produces huge and indistinct documents (Yin, 2018, p. 15). Comprehensive documentation and well-organised storing of research material was essential to stay focused and coordinated throughout the research. As conducting this research took a lot of

time, keeping myself motivated and determined was crucial for achieving high-quality outcome. As a traditional fashion designer without previous knowledge in digital fashion, this research required intense studying and dedication.

The purpose of this research was to contribute to the ongoing dialogue about digital fashion and to share knowledge regarding its potential and challenges. This thesis has raised considerable amount of interest, which I consider as a success. The published article I co-wrote together with Laura-Maija Hero has enabled outreach to a broader audience and led to increased attention in my work. Stereoscape, a company specialised in interactive 3D solutions, virtual showrooms and immersive experiences, came across the article and demonstrated interest in my work. We engaged in a captivating collaborative project that involved exploration of immersive experiences in the fashion industry. Our findings were shared with fashion industry professionals at the event "Metaversumi – muodin uusi ulottuvuus", arranged by Suomen Tekstiili- ja Muoti (STJM). The event highlighted contemporary topics surrounding the metaverse which indicates a rising interest in this field.

The novelty of digital fashion makes analysing its outcome challenging, an aspect brought to light at the event arranged by STJM (personal communication, October 10, 2023). The lack of historical data makes measuring and defining success challenging which puts businesses in a place, where they need to carefully deliberate what to measure and what they want to achieve (ibid.). Despite the novelty and uncertainty regarding this field, clear potential and benefits have been discovered. This study covered a broad range of perspectives and use-cases of digital fashion, providing fashion industry professionals diverse knowledge which is essential to comprehend when entering the digital realm. While a more centralized focus would have enabled deeper investigation and reflection, this broad research scope was a well-considered choice. The anticipated importance and utilization potential of the findings were key aspects when defining the research.

In forthcoming research with more existing data, every discovered theme in this research can be further investigated. The sustainability aspects of digital fashion technologies are especially important to examine more profoundly, considering the multitude of challenges the fashion industry entails. Another essential field of future research is artificial intelligence and generative AI, an rapidly evolving area that is revolutionizing design processes, supply chain optimization and consumer experiences. Considering the fast development of different technologies and the progressive implementation of digital fashion practices, knowledge must be updated and re-evaluated within brief timeframes.

6 Conclusions

This thesis examined the dynamic world of digital fashion in online platforms and virtual spaces, revealing a multitude of opportunities for fashion brands to improve business practices and respond to the shifting consumer demand in the digital age. This research investigated the value-creation and revenue potential imposed by digital fashion practices in several presented contexts. The research addressed the benefits as well as the challenges through thematic analysis of case study evidence generated from secondary and primary data sources. The research scope encompasses digital end products in the following phygital and virtual contexts: 1.) avatar fashion in virtual environments, 2.) phygital fashion in social media, apps and retail, and 3.) 3D tools in the production and sales processes of physical products. Table 4 (p. 62) presents the most essential findings in this research.

Table 4. Research findings.

Main RQ: What is the current state of digital fashion in terms of value-creation and revenue potential?

Sub-RQ1: How can fashion businesses benefit from digital end products?	**Sub-RQ2:** Which are currently the biggest challenges in the digital fashion space?
Global audience and new revenue streams • Access to global markets • Increased brand awareness among younger generations • Digital fashion a tool for establishing or strenghtening OBCs • Scalability and cost-efficiency of digital assets • Virtual spaces, digital fashion platforms and NFTs enabling new revenue streams	**Current attitudes** • Fashion industry old-fashioned and slow in adapting to new technologies and innovative practices • Sceptic views, missing knowledge and lack of understanding regarding digital fashion • The NFT market percieved as intimadating due to fraud risks
Elevated experiences and enhanced engagement • Interactive content resulting in long lasting impressions and stronger brand loyalty • Pre- and post-purchase consumer engagement on social platforms • Digital fashion a tool for offering exclusive content and additional value • Co-creation and customization enhancing consumer engagement and creativity	**Technological limitations** • Technical issues in virtual environments resulting in bad user experience • Unrealistic and low quality rendering of AR try-ons • Lack of standards preventing interoperability of digital assets
Eco-friendly practices and impacts • Digital fashion contributing to circular economy and eco-conscious practices • Digital end products offering environmentally friendly options to physical clothing in content creation, campaigns and sampling. • Virtual try-ons reducing physical product returns • Reduced need for physical samples when utilizing 3D tools	**Financial resources and expertise** • Investment in software, tools, in-house expertise, third-party collaborations or consultancy services challenging for SMEs • Creation of high-quality and detailed 3D garments time-consuming and complex • 3D garment creation requiring multifaceted competencies combining traditional fashion design principles and technical expertise
Production quality and efficiency • Collective platforms facilitating the workflow • 3D tools enabling higher product quality and efficient processes with more creative and accurate design possibilities	

Digital fashion transcends geographical boundaries which makes it a powerful tool to access global markets and online communities. Through digital fashion practices, brands can establish new online brand communities (OBCs) or strengthen already existing ones with new engaging content. OBCs have a direct impact on consumer behaviour and brand loyalty (Brogi et al., 2013, p. 7), which indicates the potential of driving sales through engaging digital fashion content. Digital assets are easy and cost-efficient to scale as there are no materialistic, geographical or practicality related limitations. Digital end products

can, therefore, enable new revenue streams of virtual asset but also drive sales of physical product with increased brand visibility.

In the digital age, the consumers are continuously expecting more personalized products and engaging brand experiences, a demand that digital fashion practices respond to in several ways. In virtual worlds consumers can customize their avatars with personalized outfits, or even co-create and monetize digital assets with NFTs. In the phygital realm, augmented reality (AR) brings engaging, informative and entertaining content to physical retail, ecommerce and apps, allowing consumers to interact with brands in unprecedented ways. As discovered in consumer surveys (see London, 2021; Deloitte Digital, 2021; Vieira, 2019), AR can provide a better visual understanding of the product, reduce the number of product returns and eventually, result in stronger consumer loyalty and accelerated sales.

From the sustainability perspective, digital fashion has the potential to generate several positive environmental outcomes. Calculations show that a digital garment compared to a physical one, has a 97 percent smaller CO2 footprint in production (O. Chernysheva, personal communication, July 22, 2023; Scandinavian MIND, 2022), making it a sustainable alternative to regular clothing when possible. Digital fashion has the potential of replacing physical products in content creation, campaigns and sampling, shown by companies such as Hugo Boss and Farfetch (see Hugo Boss, 2023; Retail Technology Innovation Hub, 2021). Utilization of Fashion 4.0 technologies and collective platforms in the value chain of physical products, can result in higher product quality, increased creativity, reduced textile waste, and more efficient processes.

While the multifaceted possibilities and benefits of digital fashion are evident, this research discovered a number of challenges, demonstrating its novel and experimental phase. Sceptic attitudes and a lack of understanding regarding digital fashion is apparent. Digital fashion purchased for the avatar or used for content creation in social media is often considered as nonsensical. The

younger tech-savvy generations compared to older people, have, however, a better understanding of the value and purpose of digital clothing. We can, therefore, expect a turnaround in the direct-to-consumer market once the younger generations enter the working life with increased purchasing power.

The digital fashion phenomenon includes some concerns among businesses and consumers. The NFT market and technologies such as AI, are sometimes perceived as intimidating due to fraud risks and lacking regulations. Cases of counterfeit and cyber-attacks have, however, resulted in various strategies, such as upcoming AI regulations, to battle these issues and improve the data security. This research has also revealed some issues related to technical challenges in the virtual and phygital contexts of digital fashion, such as bad user experience and errors in virtual worlds and unrealistic AR renders in virtual try-ons. Interoperability is another challenging aspect of avatar fashion, referring to cross-platform compatibility of digital assets, prevented by the lack of standards across platforms (Rijmenam 2022, p. 61; B. von Schlippe, personal communication, July 22, 2023). Digital fashion is part of a new ecosystem involving many stakeholder groups, which emphasizes the crucial need for extensive international collaborations.

Integration on digital fashion requires financial investment in software and tools as well as multidimensional expertise, which has prevented many brands from choosing this path. This highlights the need for proper in-field education to gain the needed skillsets for successfully entering the digital fashion realm. High-quality and detailed garment creation in 3D is complex, time-consuming, and requires a wide range of competencies such as traditional fashion design expertise and technical proficiency, often acquired through third-party collaborations or consultancy services. As digital fashion is yet at an early stage, anticipating long-term significance and impacts is challenging. The integration of 3D tools and immersive technology in production and retail of physical products has demonstrated clear benefits, while trading direct-to-consumer digital fashion assets remains an uncertain field.

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Appendices

Digital Fashion Business in the Metaverse – A multiple case study

Appendix 1

Luovat web3-ajassa – Unelmia, haasteita ja ansaintamahdollisuuksia

Julkaisija: Metropolia Ammattikorkeakoulu
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Taitto: Emilia Reponen
Välisivujen kuvitus: © Studiostoks (Creative Market)
Metropolia Ammattikorkeakoulun julkaisuja
TAITO-sarja 116, Helsinki 2023

ISBN 978-952-328-395-4 (pdf)
ISSN 2669-8021 (pdf)

Tämä julkaisu on tuotettu osana Luovat Metaversumissa (LUME) -esiselvityshanketta. Hankkeen keskeisenä tavoitteena on ollut paikantaa web3 ja metaversumi kehityksen myötä luoville aloille kohdentuvia osaamistarpeita. Esiselvitys on tehty 1.10.2022—31.5.2023 välisenä aikana. Hankkeen toteuttajina ovat Metropolia Ammattikorkeakoulu ja Humanistinen ammattikorkeakeakoulu ja sitä on rahoittanut Euroopan unionin sosiaalirahasto.

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Appendix 1

Sisältö

Appendix 1

2.4 Digital Fashion Business in the Metaverse – A Multiple Case Study

Emma Granqvist and Laura-Maija Hero

Entering a New Era of Fashion

Digitalisation and the fourth industrial revolution are leading to transformative changes in the fashion industry. Industry 4.0 is described as a model where all major industrial systems are transformed by new production and consumption processes, often with the goal of targeting a sustainable future. To succeed in the digital age, companies must understand the changes in consumer behaviour and be profoundly focussed on providing holistic and valuable experiences (Bertola & Teunissen, 2018, p. 353; Muutosagentit, 2022). Digital fashion is considered the next significant step in the digitalisation process of the fashion industry, which plays an important role in the evolution of Fashion 4.0 (Särmäkari, 2021, p. 1).

Digital spaces and online consumption are changing with the emergence of the Metaverse and Web 3.0. Digital environments are transforming from transaction-focussed platforms into multi-dimensional and immersive spaces with community-building at the core (Amed et al., 2022, p. 57). Executive vice president and chief marketing officer at Gucci, Robert Triefus, noted that the attitudes toward digitalisation within the fashion industry have changed throughout the years (Williams, 2022, p. 62). In 2000, it was commonly believed that e-commerce could never be a luxury experience, whereas today it is seen as a viable tool to enhance the customer experience.

Recent years have seen the emergence of digital innovations in the fashion industry, such as digital clothing NFTs, collaborations with the gaming industry and fashion events arranged in virtual worlds. Windsor, co-founder and joint managing director at Dimension Studio, stated that we are at the starting point of a new era, where the meaning of fashion is changing (Amed et al., 2022, p. 58, as cited in Soar, 2021).

Metaverse and Web 3.0 Unlocking New Opportunities for Digital Fashion

Digital fashion has entered the spatial internet in a major way. Virtual metaverse platforms are home to avatars with stylish, valuable and individual digital clothing, garments and accessories. According to Särmäkari (2022), the term digital fashion refers to three things. First, it refers to digital tools used to aid design processes, communication, showroom activities, sales and experiences. Second, it refers to digital end-products, such as digital-only outfits in virtual spaces, virtual representations of physical garments or garments that incorporate digital technology. Third, it refers to a novel fashion culture that builds its own discourse, values and differentiation strategies, driven by the contemporary challenges of the fashion industry, technological possibilities and attitudes toward digital culture (Särmäkari, 2022).

> Author Matthew Ball (2022, p. 29) defined the metaverse as follows:
>
> [a] massively scaled and interoperable network of real-time

> rendered 3D virtual worlds that can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communications, and payments.

Thus, customising the appearance of avatars in the Metaverse with purchased digital outfits, so-called 'skins', has long been a common concept in the online gaming industry (Desai, 2022).

Web 3.0, which the Metaverse is a part of, refers to the third major evolution of the internet that focusses on data decentralisation through blockchain technology. In the current Web 2.0, the infrastructure is owned and controlled by centralised entities, and data are stored in multiple databases managed by companies and organisations. Web 3.0 will improve data security and put the power of data and digital asset ownership in the hands of the users. Further, Web 3.0 will use cryptocurrencies for online transactions instead of relying on middlemen, such as payment processors and banks (Ethereum, 2023; Lehtonen et al., 2022).

Creating digital fashion is different from designing physical garments. The realisation of a physical collection has production limitations and high costs, whereas designing digitally only requires 3D design software. The financial barriers in the physical world prevent many talents from being discovered (Ginsburg, 2022). Virtual worlds seem to offer relief to this challenge. Indeed, consumers, companies and investors are showing great interest in the Metaverse and its future potential. Recent research shows that about 60% of consumers are excited about shifting everyday activities from the physical world to the Metaverse. The time people spend in virtual worlds is continuously increasing, especially among the tech-savvy and younger population. A virtual world refers to any simulated and computer-generated space, ranging from 2D games to immersive 3D environments. An appealing factor of virtual worlds is the community spirit and engagement with others. Some fashion brands have started to see the Metaverse as a platform where they can engage with customers in a deeper and more creative way. Futurist Cathy Hackl points out that the Metaverse is not about escaping reality but rather about augmenting life with virtuality to make it more meaningful (Amed et al., 2022, p. 57; Ball, 2022, p. 30; McKinsey & Company, 2022a).

Särmäkari (2022, p. 104) elaborated on digital fashion design:

> Fashion 4.0 designers tend to apply an open-source philosophy to their work, in the form of co-creation with consumers, sharing their creations, flexibility of the products and general transparency. This challenges the authorial ideals that underlie the traditional figure of fashion designers. Although the nature of work itself has always been

> mostly collective, the values were traditionally based on auteurism and individualism. In contrast, digital fashion designers might have total control and unlimited space for creativity, enabled by their tools, yet the values of digital fashion culture highlight decentralised collectivism.

Robert Triefus argued that virtual worlds are an indication of a paradigm shift, leading to a significant new revenue stream for brands, and that the metaverse will play a fundamental role in revenue growth in the years ahead (Williams, 2022, pp. 61–62). A report by McKinsey & Company (2022a) indicated that investment in the Metaverse has increased tremendously in the past few years, and it could generate a value of $5 trillion by 2030.

An NFT is a unique digital asset based on the blockchain. In the fashion industry, NFTs are used in a variety of ways, ranging from product authentication to serving as collectibles and investments. Anything that can be digitised can be made into an NFT. Blockchain technology verifies the authenticity and ownership of an NFT and therefore allows creators to be correctly compensated for their work, which supports a more sustainable economy in the creative industry. The monetary value of an NFT can increase significantly due to its fundamental uniqueness (Amed et al., 2022, pp. 58–59; Beyer, 2023).

NFTs are usually purchased with cryptocurrency, which is a digital form of currency that is secured via cryptography, a process that prevents counterfeit and fraud. There are thousands of existing cryptocurrencies, with Bitcoin (BTC) and Ethereum (ETH) among the most well known. Cryptocurrencies can be bought and sold by anyone on decentralised exchange platforms and stored in a crypto wallet (Beyer, 2023). The NFT market presents an economic model that the fashion industry has never seen before. Designers can receive a royalty from secondary sales depending on the contract. The same benefit applies to digital material designers, as they earn a royalty every time their design is utilised commercially in a garment (Ginsburg, 2022).

As artificial intelligence and other technologies are advancing and the demand for realistic avatar representations continues to grow, avatars are becoming more intelligent and human-like. According to artist, scientist and VR pioneer Dr Jacquelyn Ford Morie, avatars in the future will learn from human behaviour and be able to act on behalf of a person. Morie predicted that everyone will have a 3D scan of themselves in the near future (Papagiannis, 2017, p. 96).

Aims and Method

This article examines digital fashion in virtual and augmented contexts by focussing on the following research questions: How does the fashion industry operate in XR (extended reality) environments? How are fashion NFTs created and traded? The primary aim is to create an extensive understanding of the digital fashion business in the Metaverse as well as

Figure 1. Selfridge flagship store in Decentraland (Hirschmiller, 2022a). Courtesy: Selfridges.

the NFT ecosystem and associated technologies, which must be understood when operating in the NFT market. The article concludes by presenting the risks and business opportunities based on the presented cases and the literature.

The article includes a light multiple-case study of several fashion phenomena in XR environments. The material comprises descriptive case articles (N=29, marked with * in References) on digital fashion creators and collections, immersive fashion spaces, NFT platforms and cross-industry collaborations. In addition, secondary research from reliable institutions, secondary interviews with industry professionals as well as other relevant and reliable studies are utilised. The seven following cases are examined: 1) Avatar fashion shops for social networking: Meta and Ralph Lauren; 2) Fashion x Gaming: Balenciaga and Burberry; 3) The Fabricant, which offers the first digital-only garments; 4) Luxury brands in the NFT market place: Gucci, Dolce & Gabbana; 5) The marketing of luxury digital fashion: Influencers for DressX; 6) The Fabricant: Facilitating the NFT ecosystem; and 7) YOONA: Automating design with AI.

Fashion Brands and Design Collectives Offering Self-Expression through Avatars

Metaverse fashion shows and exhibitions are core platforms for digital fashion. As the interest in the Metaverse has increased, some fashion brands have started to explore virtual worlds by creating their own virtual spaces. As a forerunner, Gucci has created a virtual 3D exhibition called Gucci Garden, where visitors can explore the brand and the historic Palazzo della Mercanzia (Gucci Garden, n.d.). In 2021, the company launched a

two-week immersive virtual exhibition on Roblox, which attracted 19 million visitors (Gucci, n.d.; Williams, 2022, p. 63).

In March 2022, the metaverse platform Decentraland arranged the first-ever Metaverse Fashion Week, a four-day virtual event featuring digital fashion shows, exhibitions, parties and pop-up stores. Luxury brands and retailers, such as Dolce Gabbana, Tommy Hilfiger, Etro, Selfridges and Dundas World, participated in the event (Figure 4) (Hirschmiller, 2022a).

Some brands and retailers offered purchasable NFT wearables for avatars to use in the Decentraland metaverse, and others arranged virtual try-ons of clothes from their physical collections. Some brands used their spaces to increase brand awareness through exhibitions or by showcasing collections with direct links to their websites. The fashion brand Imitation of Christ took the opportunity to show support for Ukraine with anti-war installations and banners (Hirschmiller, 2022a). The second edition of Metaverse Fashion Week took place in March 2023, this time with advanced features, such as interoperable wearables and cross-metaverse teleportation. Thus, the NFTs purchased in Decentraland could be used in multiple metaverses, and brands had the opportunity to run fashion shows in three virtual spaces simultaneously (Hirschmiller, 2022b).

Avatar Fashion Shops for Social Networking: Meta and Ralph Lauren

Today, social media platforms are entering the metaverse business by opening fashion shops. Meta defines an avatar as a digital expression of a person's personality/personalities that conveys individual characteristics, such as the sense of fashion. As a step toward the Metaverse, the company started to offer customisable avatars for their social media platforms. To allow additional personalisation, Meta recently launched a store that offers purchasable digital clothes from luxury brands, such as Balenciaga, Prada and Thom Browne. The company believes that avatars can enable more meaningful connections with friends, family, co-workers and other people (Meta, 2022).

In 2021, Ralph Lauren launched a virtual social networking app in partnership with ZEPETO. Users can interact with each other through personalised 3D avatars in the virtual world of Ralph Lauren, featuring the Madison Avenue Flagship Store, Ralph's Coffee Shop and Central Park in New York City. The app includes a digital fashion collection consisting of 12 purchasable outfits. Ralph Lauren believes that virtual worlds are essential platforms for reaching the next generation of consumers. The company also created a customisable Bitmoji collection for Snapchat and was the first luxury brand to partner with G2 Esports to dress players on a long-term basis (Ralph Lauren Corporation, 2021).

Figure 2. Afterworld: The Age of Tomorrow by Balenciaga (Hitti, 2020). Courtesy: Balenciaga 2021.

Fashion x Gaming: Balenciaga and Burberry

The gaming industry, with more than three billion global players and a market value of $184 billion in 2022, has become a targeted platform for fashion businesses. The gaming industry has a long history of building communities and is transforming into a digital extension of the real world (Amed et al., 2022, p. 57; McDonald, 2023).

One of the fashion brands that stands out in this field is Balenciaga. Their fall 2021 collection was released as a video game, *Afterworld: The Age of Tomorrow*. The photorealistic outfits captured on real-life models and the scenery in the dystopic Balenciaga world (Figure 2) were created by Epic Games with volumetric capture and a 3D virtual design tool (Hitti, 2020; Maguire, 2021).

The game is set in the near future, presenting a vision of the future of clothing. The creative director of Balenciaga, Demna Gvasalia (Hitti, 2020), imagines multifunctional, long-lasting clothes that are worn until they fall apart (Hitti, 2020).

Balenciaga continued implementing VR in the company's business strategy. They were the first luxury brand to partner with the gaming company Epic Games, designing four purchasable skins for the popular game Fortnite. Epic Games had revenues of $5.1 billion in 2020, driven by Fortnite and its 400 million global users. Fortnite is monetised with the in-game currency V-Bucks, with which users can purchase skins, accessories and emotes (actions). To keep Balenciaga skins accessible for all players, they were priced at 1000 V-Bucks, which is equivalent to about $8 dollars. According to Alan Cooper, director of product and consumer communications at Epic Games, the motive of fashion activations in games is to increase market awareness among the digital audience. (Maguire, 2021)

Another luxury brand that has explored the opportunities of gaming is

Figure 3. Blankos Block Party featuring Burberry. Courtesy:Burberry, 2022.

Burberry, which has been partnering with Mythical Games since 2021 by launching NFT products for the multiplayer game Blankos Block Party (Figure 3). Mythical Games uses blockchain technology and NFT tools to enable players, creators, artists, brands and game developers to become stakeholders and owners in a new universal ecosystem of gaming. Burberry has created two limited-edition characters as NFTs, which players can purchase, upgrade and re-sell within the game. They have also launched NFT collections of accessories, which players can apply to any character they own in the game. Blockchain technology is used to provide players with proof of verified ownership and authenticity (Burberry, 2021).

Rachel Waller, Burberry's vice president of channel innovation, believes that virtual worlds provide endless opportunities to connect with customers in more valuable ways. She also sees similarities between gaming and luxury in terms of fantasy and creative expression (Burberry, 2022). Indeed, the opportunities of NFTs in gaming and virtual worlds are extensive. To

Figure 4. Iridescence, digital couture by The Fabricant (M.C., 2021). Courtesy: The Fabricant, 2021.

enter this new market, brands need a strategic mindset and a willingness to create partnerships. High-quality content requires a variety of expertise, either in-house or through third-party collaborations (Amed et al., 2022, p. 60).

The Fabricant Offers the First Digital-Only Garments

The phenomenon of digital fashion attracted headlines in 2019 when The Fabricant created and ultimately sold Iridescence, the world's first digital-only couture dress (Figure 4). The dress was auctioned on the NFT platform Portion and sold for $9500 (The Fabricant, n.d.-a.).

Amber Jae Slooten, co-founder and creative director of The Fabricant, sees the dress as a look into the future where we are no longer bound to physical space. Following their success, the company has since helped other brands make their own digital products and created a marketplace where anyone can co-create, sell and buy NFTs. The Fabricant's mission is to develop a new fashion industry in which everyone can participate and profit. The Fabricant has received a total of £10.7 million in funding to support the development of their metaverse wardrobe (Rydzek, 2022; The Fabricant, n.d.-a; The Fabricant, n.d.-b).

One of The Fabricant's most remarkable collaborations was with Adidas and model Karlie Kloss. In 2021, they launched a competition for 3D creators to make their own digital version of the WindRdy parka jacket (Figure 5) (Amed et al., 2022, p. 59).

Figure 5. The winning look of the NFT design (Dobrosielski, 2021). Courtesy: The Fabricant, 2021.

The top 20 creators who made it to the finals had their designs auctioned on the NFT platform KnownOrigin and displayed in the Metaverse Fashion Week. The winning look was sold for $2,515 (Decentraland, 2021; Dobrosielski, 2021).

Luxury Brands in the NFT Marketplace: Gucci, Dolce & Gabbana

Numerous luxury brands are exploring the NFT market. Gucci launched a series of $11.99 NFT sneakers in collaboration with fashion-tech company Wanna, and Dolce & Gabbana created Collezione Genesi, a nine-piece digital collection alongside physical couture (Figure 6) (Li, 2021; UNXD, 2021).

Collezione Genesi was designed by Domenico Dolce and Stefano Gabbana and auctioned on UNXD. A crown received the highest bid of 423.5 wETH (Ethereum), equivalent to $560,102. The whole collection was sold for a remarkable $5.7 million. This success reflects a transition toward the Metaverse, where luxury items are part of the ecosystem (Amed et al., 2022, p. 60; Njuguna, 2021; UNXD, 2021).

Marketing of Luxury Digital Fashion: Influencers for DressX

Digital fashion has also been implemented in online retail luxury fashion. In 2021, Farfetch launched a pre-order campaign together with digital fashion company DressX to promote sustainability. Pre-order looks from the newest collections were digitised and used in editorial photoshoots and by influencers with the idea to avoid the environmental impacts related to the production of physical clothing. Farfetch stated that they saved 346,698 litres of water and 2,515 kg CO2,

Figure 6. Collezione Genesi by Dolce & Gabbana (UNXD, n.d.). Courtesy: Dolce & Gabbana, 2021).

Figure 7. Safiya Nygaard wearing digital clothes (Nygaard, 2021, August 28; Nygaard, September 1).

representing 97.86% of the CO2 emissions produced by a similar campaign in the physical space (Retail Technology Innovation Hub, 2021).

Daria Shapovalova, co-founder of DressX, identifies two major groups of customers in the digital fashion market: Millennials and GenZ. Millennials who consume luxury goods understand the concept of digital fashion and use it to elevate their social media profiles, while GenZ are on platforms like Snapchat and TikTok, where video-based content including filters is the most common communication tool (Amed et al., 2022, p. 58).

Influencer Safiya Nygaard performed an experiment in which she wore digital clothes for a week on her social media. She wanted to understand the concept and to see people's reactions without revealing that the outfits were digital. She purchased several digital outfits and accessories from DressX, with prices ranging from $35.00 to $1,050.00. When purchasing a digital fashion asset, the customer needs to submit a pre-outfit photo in form-fitting clothes, which the digital item will be added on. Nygaard discovered that DressX also does modifications free of charge if the customer is not satisfied with the result (Nygaard, 2021).

Nygaard was pleased with most of the work but noticed some bad-quality editing that made the products look unrealistic. The reactions on her social media were generally positive. Some people believed she was wearing physical clothes,

while others realised that they were edited (Nygaard, 2021).

The Fabricant: Facilitating the NFT Ecosystem

The Fabricant has created their own marketplace of digital fashion that emphasises co-creation. The platform uses blockchain technology and has an integrated co-creation design tool. Anyone who signs up on the site can trade, buy and sell NFTs that are co-created on the platform. Figure 8 illustrates the royalties on primary and secondary NFT sales on the platform (The Fabricant, 2022).

Royalties are divided among all who are involved in the co-creation of the item. The marketplace uses the cryptocurrency FLOW tokens, which requires a Blocto wallet and a subscription to the third-party company MoonPay for currency exchange (The Fabricant, n.d.-b). There are many different NFT marketplaces and platforms, each with their own royalty structures and fees.

YOONA: Automating Design with AI

The creation of digital fashion can also be automated with AI-based design software (Figure 9). Anna Franziska Michel, founder and CEO of YOONA Technology, stated in an interview that more than 70% of successful collections are created based on historical data, performance analysis or through modifications of bestselling products from their own company or competitors (DressX, 2020).

YOONA is a B2B technology solution that analyses data and creates success-oriented automated designs. The technology is based on generative adversarial networks (GANs), an AI-based tool that generates images of any kind. The user can input the desired data, such as performance analyses, images, technical illustrations, trends and mood boards. The technology then analyses the input data and generates unique images, which the user can select and save (DressX, 2020).

Figure 8. The royalties on primary and secondary sales (The Fabricant, 2022).

Member	Primary Sale (% of sale amount)	Secondary Sale (% of sale amount)
Garment Creator	30%	3.33%
Material Creator	30%	3.33%
CoCreator	30%	3.33%
The Fabricant Studio	10%	5%
Owner		85%
TOTAL	100%	100%

Figure 9. AI-generated metalook (DressX, 2023, January 20).

There are several factors to consider when pricing a digital fashion NFT, including the quality, complexity and utility of the product. A small quantity and availability limitations can trigger consumer demand and justify a higher value. Another factor that must be considered is royalties. A high percentage of secondary sales may seem desirable for the creator but can drive away costumers if their intention is to invest and resell the items (Ginsburg, 2022).

To succeed in the digital market, Ginsburg, a write for NFT Now (2022), emphasises the importance of building connections, seeking collaborations and getting integrated in the digital fashion community through physical and digital events. Amber Slooten points out that the NFT market is experimental, and thus success cannot be guaranteed (Amed et al., 2022, p. 60, as cited in Nanda, 2021).

Risks and Challenges

Digital fashion can be seen as a solution to the environmental and social impacts related to the production, use and disposal of physical clothing. However, digital fashion does have its own sustainability challenges, as the validation of NFT transactions on the blockchain consumes considerable energy (Amed et al., 2022, p. 60). Robert Triefus predicted that some of these issues will be solved as the understanding of cryptocurrencies progressively improves (Williams, 2022, p. 62).

In the beginning of 2023, headlines focussed on Hermès and NFT artist Mason Rothschild due to a trial concerning trademark infringement. Hermès sued Rothschild for releasing an NFT collection of MetaBirkins, digital replications of the iconic Birkin bag. Rothschild argued that artists are allowed to make interpretations of existing objects. The 'Rogers' test, which functions as a standard in cases of trademark infringement, forbids the use of trademarks only if it has no artistic interpretation to the underlying work or if it explicitly misleads consumers to identify the work as the original source or mark. This lawsuit is likely to have an influence on how the law of intellectual property is applied to digital assets and NFTs (Rossow, 2023).

As digitalisation reaches new heights in the fashion industry with digitised business models and processes, proper data management and cyber security become fundamental aspects for businesses. Cyber-crimes have increased significantly in the past few years due to accelerated e-commerce and digital platforms increasingly sharing sensitive data. To minimise the risks of cyber-attacks, companies must establish clear standards for the collection, use and storage of data (Amed et al., 2022, pp. 97–99). The consequences of improper data handling are severe and can cost businesses tens of millions of dollars (Amed et al., 2022, p. 99 as cited in IBM, 2021).

Metaverse Fashion Business Opportunities

Metaverse virtual fashion designers are not the ones making the biggest profit from their work, as the ideal and culture of the Metaverse are more focussed on decentralised values. Instead, the benefactors of the revenue streams seem to be big businesses with established brands. However, 'born digital' fashion brands and community-based groups are blooming, and thus an opportunity for smaller designers and producers is emerging (i.e. Särmäkari, 2022; The Fabricant n.d.-a). The 'middle layer' is the XR-design professionals organising and supporting the business and offering 3D modelling services. More in-depth studies are needed to understand the producer economy in more detail. Digital fashion design communities have managers and agents for designers, but their role is unclear. The key player in this case is The Fabricant, which offers an NFT marketplace for digital fashion. The platform even offers an integrated co-creation design tool called Fabricant Studio. Direct business is possible for anyone who signs up on the site, and NFTS that are co-created on the platform can be traded, bought and sold. The direct earning opportunity for content creators are the royalties on primary and secondary NFT sales (The Fabricant, 2022). Meanwhile, the business benefits for The Fabricant seem to be the fees, advertising and investor funding. In April, 2022, The Fabricant raised $14 million to clothe metaverse avatars (https://www.ledgerinsights.com/blockchain-fashion-house-the-fabricant-raises-14m-metaverse-avatars/).

Appendix 1

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