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A review of digital fashion research: before and beyond communication and marketing

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ABSTRACT

This paper focuses on the field of digital fashion and its development by providing an overview regarding fashion design and culture. It is part of a larger research that involved a literature review of 491 relevant papers. From the analysis of this corpus, three main categories were identified: Communication and Marketing, Design and Production and Culture and Society. This study focuses on the categories Design and Production and Culture and Society, which collectively gathered indicatively 48% of the selected literature. It presents its relevant studies and sub-categories, providing a rich and varied map of them and contributing to better design in further research in digital fashion.

1. Introduction

Fashion interacts with many different sectors, including culture, entertainment, finance, and information Communication Technologies (ICTs). As a result of this, it has an increasing societal impact; for instance, during the Covid19 pandemic, many fashion companies contributed to the cause by extending their productions to face masks and hand sanitisers. Furthermore, fashion groups made donations to hospitals and not-for-profit organisations to support local communities around the world (Mckinsey, 2020). The pandemic has also emphasised the key role of fashion as a driver of digital transformation.

Throughout history, technological advancements have shaped the nature of fashion: the first industrial revolution contributed to the mechanisation of fashion manufacture by exploiting water and steam power, the second revolution accelerated fashion production through the invention of electricity; the third one impacted the use of electronics and information technology within the fashion environment. The fourth, the so-called Industry 4.0, contributes to shape the fashion industry through an advancement of digital technologies, such as cyber-physical spaces, Internet of Things, computing tools, personalisation, localisation, and digitalisation of fashion heritage (Kalbaska, Sadaba, & Cantoni, 2018; Nobile & Kalbaska, 2020; Noris,

SanMiguel, & Cantoni, 2020; Permatasari & Cantoni, 2019; Wang & Ha-Brookshire, 2018).

The digital transformation has impacted all the facets of fashion. First of all fashion communication and marketing, through the adoption of digital tools creates a fertile ground for the improvement of business and customer relationships (Noris, Nobile, Kalbaska, & Cantoni, 2021). It had also an impact on fashion design and production, for proposing advancements in areas related to sustainable manufacturing and to the improvement of decision-making processes and HRM systems (James, Roberts, & Kuznia, 2016; Ma, 2010; McQuillan, 2020; Yu, Choi, Hui, & Ho, 2011). It also influenced culture and society, impacting education and human being's everyday life (Chun, 2011; Ebling, 2016; Harris, 2008; Ryan, 2020).

While the areas of fashion communication and of its digital transformation are emerging ones, as it appears clear also from the brief outline above, research on them still requires to be recognised and framed in a consistent way, to yield to a better understanding of the field and to open up to new and better linked research avenues (Cantoni et al., 2020; Lascity, 2021).

To move towards this direction, a corpus of 491 papers were collected through a systematic literature review. From the analysis, three main categories emerged. The category Marketing and Communication

(C&M) contributed highest number of publications (255), hence it was explored separately (Noris et al., 2021). However, to provide a complete overview of all categories a dedicated and in-depth study was developed on Design and Production (D&P) and Culture and Society (C&S), as they occupied nearly half of the studies (236 publications).

2. Literature review

To present the current status of the digital fashion research domain, a literature review was conducted as it is considered an appropriate way to identify the state of the art of a topic and areas of further research (Snyder, 2019).

In July 2019 a systematic literature review of the digital fashion domain was conducted. Five databases were investigated, using the keywords 'fashion' and 'digital' – namely IEEE, ACM, Eric, Springer Link and Scopus – for 1950–2019. The search produced 910 results and 491 of these items were considered relevant for analysis. From the systematic literature review, a classification of the digital fashion field in three categories was reached (Figure 1): (i) *Communication and Marketing – C&M*, which resulted in the highest number of items (255 items), followed by (ii) *Design and Production – D&P* (155 items), and (iii) *Culture and Society – C&S* (81 items). For each category, sub-categories were identified. The category *Communication and Marketing* was further developed in the sub-categories *C&M: Practice, C&M: Enabling Tools* and *C&M: Societal Implications*; the category *Design and Production* in *D&P: Process and Technology Implementation* and *D&P: Product Development*; the category *Culture and Society* in *C&S: Culture, C&S: Education*, and *C&S: Society*.

While it was clear that the category *Communication and Marketing – C&M* included the largest number of published research (51.9% of the relevant documents), covered in Noris et al. (2021). The remaining two categories collected respectively 31.6% and 16.5% of the research literature on digital fashion.

Besides such quantitative balance between the first and the other two categories, it was observed that existing studies might be also organised qualitatively, according to a (chrono)logical framework. *Design and Production – D&P* refers to what happens before an item can be communicated and marketed, be it a physical/digital product or a brand, while *Culture and Society – C&S* refers to the overall context within which fashion acquires its meaning and relevance.

Hence, this study extended and completed the analysis provided by Noris et al. (2021) on its selected bibliographic items, contributing to the advancement of digital fashion research by conducting a literature review of the categories *Design and Production – D&P* and *Culture and Society – C&S*.

3. Results

3.1. Category design and production – D&P

The category D&P refers to 'the (i) creation and (ii) implementation of elements/processes, tangible and intangible, which are devised by humans or machines and contribute to the advancement of the fashion industry' (Noris et al., 2021, p. 5).

The following sections discuss the sub-categories by providing explanatory examples from the studied literature.

3.1.1. D&P: product development

As the term 'product development' implies, this sub-category concerns the development of methods that support the design of products in fashion. The term 'product' refers to tangible and intangible fashion items.

This sub-category discusses novel and advanced methods for developing and implementing tools that automate and enhance the design process, including technologies that advance sketching and drawing thorough computer vision techniques and aided design systems such as 3D models and CAD. For example, the potential of disruptive technologies, to design and

Categories	# of items	Subcategories
C&M – Communication and Marketing	255	C&M: Practices (#119)
		C&M: Enabling Tools (#109)
		C&M: Societal Implications (#27)
D&P – Design and Production	155	D&P: Process and Technology Implementation (#95)
		D&P: Product Development (#60)
C&S – Culture and Society	81	C&S: Culture (#53)
		C&S: Education (#22)
		C&S: Society (#6)
Total	491	

Figure 1. Categories of published research on digital fashion. Source: Noris et al. (2021, p. 6).

produce unique fashion items, was studied by Pasricha and Greeninger (2018).

It also addresses the development of practices derived from the adoption of big data and networks, such as generative adversarial learning and genetic programming that contribute to product creation, including patterns such as fractal patterns, colour forecasting and the generation of various textures. Additionally, it includes research that develops systems for an efficient retrieval of visual information from images and photographs (Dai, 2011; Dongdong, 2012; Gu & Liu, 2010; Kharbanda & Bajaj, 2013; Kuswanto, Iftira, & Hapinesa, 2018; Lee, Lim, Jung, & Park, 2015; Li, Lu, Geng, & Wang, 2009; Liu, Zeng, Tao, & Bruniaux, 2019; Long, Li, & Luo, 2009; Muni, Pal, & Das, 2006). This sub-category presents novel and effective technologies that enable, for example, product customisation or support sustainable fashion (Pasricha & Greeninger, 2018; Wang, Zeng, Koehl, & Chen, 2014). Finally, it introduces technologies that maximise the emotional experience of fashion products through sensors and wearables (Tillotson, 2008; Wakita et al., 2005).

3.1.2. D&P: process and technology implementation

This sub-category discusses the way in which technology advances simplify and enhance the efficiency and effectiveness of the decision-making processes within the fashion industry (Yu et al., 2011). The aim is to enhance operational efficiency, improve products' life cycle (Lee, 2017), ensure high level performance, reduce lead time and minimise the risks through advanced methods such as radio-frequency identification, warehouse management, inventory control and real-time replenishment (Bertolini, Rizzi, Romagnoli, & Volpi, 2017; Bindi et al., 2018; Buckel & Thiesse, 2014; Chen, Luo, & Zhu, 2010; Hauser, Günther, Flath, & Thiesse, 2019; Leitz, Solti, Weinhard, & Mendling, 2018; Pedrielli et al., 2016; Shen, Ding, Wang, & Ren, 2019). It also investigates the development of forecasting models and systems dedicated, which predict the time series sales data of fashion items (Choi, Hui, & Yu, 2011) or find the best pricing for sales (Bruzzone, Longo, Nicoletti, Chiurco, & Bartolucci, 2013; Yu-Chung, 2010).

In addition, the development of digital manufacturing technologies, such as printing methods (Sun & Zhao, 2017) or knitting method technologies (Taylor & Townsend, 2014), which could be adopted to simplify and increment companies' efficiency, is described. Another stream relates to operations, discussing topics, such as resource planning (ERP) development (Siswanto & Maulida, 2016), service quality model advancement (Chan, Choi, & Man, 2016; Choi, Chow, Shen, &

Wan, 2017) and the implementation of innovative robotic technologies to reach higher levels of flexibility (Xu & Lai, 2011).

Within the sub-category, particular attention is given to the improvement and analysis of supply-chain models and strategies tackling issues such as market fluctuation (Zhou & Shu, 2010), agility (Verma, Jain, & Majumdar, 2013), production planning and control (Fani, Bandinelli, & Rinaldi, 2017), or new product development (NPD) models (Takamitsu & Gobbo Junior, 2019). Performance evaluation within the fashion supply chain to increase the level of competitiveness of the company is also considered (D'Avolio, Bandinelli, & Rinaldi, 2017). Technology and data advances enable the implementation of supply chain systems. For example, the availability of large quantities of data – even of 'big' ones – allows the fashion industry to better map its supply chains, and, eventually, to ensure more sustainable ones. This sub-category also includes a series of studies aimed at developing more efficient business models, taking into account specific case studies in the field.

Additionally, it reviewed updated methods of managing human capital, including the development of E-HRM systems (Ma, 2010), the possible contribution of technology for HR practices, such as well-being, social volunteering initiatives and female entrepreneurial activities (Trequattrini, Manfredi, Lardo, & Cuozzo, 2019). It addressed the possibilities brought by the integration of technology and human knowledge (Fan & Qiao, 2010) and its impact on the digital skills, and competencies required by fashion companies. For example, skills to utilise communication technologies (Kalbaska & Cantoni, 2019), skills needed for effective decision-making, such as the ability to source and select appropriate materials, or the ways in which technology can be of use to develop competences and support less experienced designers (Oliveira & Cunha, 2019).

3.2. Category culture and society – C&S

This category included the fields where digital fashion interacts with and contributes to the development of (i) cultures; (ii) education; and (iii) society.

3.2.1. C&S: culture

The sub-category is composed of a number of subjects that according to the literature review dealt with themes such as fashion culture and heritage, history, customs and tradition, religion, art and performances in the digital era.

It showed how fashion digital transformation is related to religion and customs and traditions; some examples are related to the importance to consider the

contribution of digitalisation on the spread of local trends connected to religion, such as modest fashion, to a more globalised fashion environment or it directly refers to the use of religious customs and their impact within the fashion field, for example by utilising digital printed Muslim motifs (Andriana, 2019; Indarti & Peng, 2017). Furthermore, it considered and provided different perspectives proposed on the new ways of preserving fashion as a form of art and heritage for communities (Luchev, Paneva-Marinova, Pavlova-Draganova, & Pavlov, 2013), including the digitalisation of archives for cataloguing collections not only for marketing exploitation but also for cultural dissemination (Martin & Ko, 2011; Takahashi, 2013).

Archives are crucial to protect past designs for the use of designers and the preservation of heritage (Ram, 2015; Takahashi, 2015). This category included papers that discuss the use of innovative and interactive technologies, which improve consumers' experiences and enjoyment at museums and installations (Marfia, Tolic, Mascio, Matteucci, & Roccetti, 2015; Martin & Mauriello, 2013). It also encompassed research that offers overviews of country-specific or geographic-specific areas such as the African continent and their relation to fashion or the Japanese fashion, dress and behaviour (Aziz, Salloum, & Alexandre-Leclair, 2019; Takahashi, 2011). A smaller stream discusses the ethical aspects of digital innovation, such as the issue of data ownership of wearable technologies (Baker, 2017), ethical issues regarding counterfeiting (Pastore & Cesareo, 2015) and the impact of fast-fashion consumption on the surrounding environment, to create a stronger sense of awareness when it comes to sustainable issues among the different fashion stakeholders (Collins, 2019; Perrottet & Nicoletti, 2018; Schor, 2013).

3.2.2. C&S: education
The current sub-category consists of those studies whose goal was to share, examine and further enhance teaching and research strategies to contribute to the development of the field also through an academic and educational perspective. It considered the development of skills and competences within educational institutions derived from all the other sub-categorisations; for instance, the improvement of e-design, communication and marketing and technical skills for the production, the placement and development of fashion products and of the field (Avella, 2018; Lenoir, 2019; Peppler & Glosson, 2013). Specifically, it discussed the improvement of technologies and methods, such as neuroeducation, which support students' learning process through new methods and strategies such as computer-aided instruction and 3D

printing (Cheng, Liu, & Lin, 2015; Choi, 2012; Coelho Lima Júnior & Zuanon, 2019; Kwon, Lee, & Kim, 2017; Wiana, 2018) and it also discussed challenges faced by educators while engaging fashion students in sustainability development and introducing new pedagogical marketing and communication strategies and perspectives (Joyner, Connell, Lang, Ruppert-Stroescu, & LeHew, 2016; Lenoir, 2019).

3.3.3. C&S: society
The last sub-category makes reference to research and studies that presented and took into consideration how the whole digital fashion system can interact with our society. Although this category is smaller than the others, it has been evaluated as a standalone one since it proposes studies that consider the effects of digital fashion on society. Examples are related to the use of fashion Internet of Things and its effects on society or the impact of wearables, their integration in consumers' everyday life and their connection with societal issues such as safety and surveillance (Ebling, 2016; Harris, 2008; Lamontagne, 2014). In this sub-category, the collaboration of fashion stakeholders with external ones was discussed and it contributed to the creation of interdisciplinary studies and to societal development through fashion.

4. Conclusion and limitations

From this study it was identified that there is a substantial pool of research covering the topics related to the *Design and Production* and *Culture and Society*. Even though research on *Communication and Marketing* is the most prolific one, research in the fashion domain is expanding to other topics. For instance, the category *Design and Production – D&P* demonstrates the increased interest of the research field on how manual processes are replaced by digital ones: manual processes of extracting colour palettes have been substituted by automatic ones (Lai & Westland, 2020), or the role and perception of designers and managers regarding sustainable issues, life-cycle, and the effects of digitalisation for pollution (DeLong, Casto, Min, & Lee, 2016).

The category *Culture and Society – C&S* shows instead the impact of fashion on society due to its strong cultural presence (Choi & Lewis, 2018) and it presents topics such as the role of educators in teaching new strategies to designers, to contribute to solve, for instance, sustainable issues (DeLong et al., 2016), to develop the fashion field and to increase its impact on the surrounding environment.

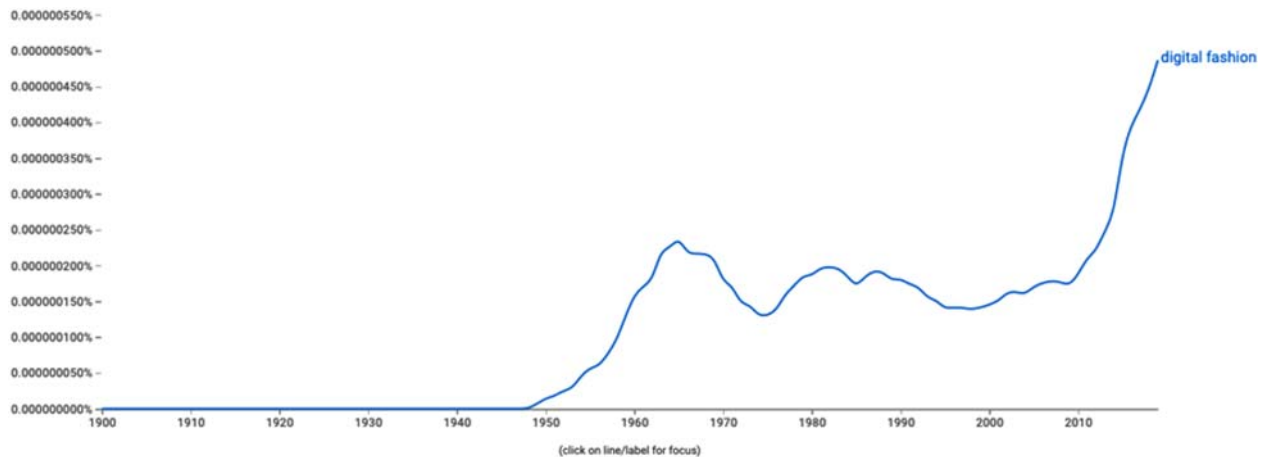Technology advances are impacting the fashion industry as a whole. This emerges from the studies

Figure 2. Ngram Viewer: digital fashion (1900–2019).

which cover a great number of topics and highlight the changes that are occurring in the fashion industry. The fashion industry is benefiting from such advances in multiple ways.

From the current literature review the following definition of digital fashion is suggested: Digital fashion involves all those processes that include (i) marketing and communicating tangible and intangible products; (ii) the development and implementation of processes that support the advancement of the industry; (iii) the effects of digital advances on society.

From this study, it emerges that the field of digital fashion could benefit from further research. As shown by Figure 2, the interest in digital fashion is growing.

Additionally, the recent pandemic has accelerated the digitisation process of fashion. However, it also represents a challenge, as it involves many changes for the industry which needs to adapt to the new technologies and also their impacts on society. This research has some limitations. In particular, it considered only those studies that were conducted and published before July 2019. The pandemic of Covid19 could have accelerated the process of digital transformation of companies and increased the interest in developing new research studies and studies within the field. New research topics within the sub-categories could then have emerged since the collection of the data on which this study is based. Future research could advance the field by analysing more in-depth effects of emerging technologies on society, for example the effects of artificial intelligence, 3D printing technologies, phygitalisation and haptic technologies.

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