WEARING DIGITAL BODIES: designing and experiencing dress as poly-body objects at the intersection of the physical and the digital

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Abstract

Advances in digital and augmented reality (AR) technology create opportunities for more body-diverse methods of designing dress. However, while the clothing industry uses such technologies to explore digital venues in promoting its designs, most designs are made to resemble physical garments for the same body types. This research aimed to investigate alternative morphological relations between the physical human body and digital dress to enable more body-diverse design practices within the field of fashion. A three-day workshop was conducted with undergraduate fashion design students to critically examine the hypotheses of this research. The students were tasked with using three-dimensional scanning, computer-aided design (CAD), and AR technology to design digital dress-related designs for different body shapes and sizes. The performative act of projecting digital dress onto a physical body created wearable poly-body dress expressions, the morphological qualities of which were experienced by the participants simultaneously physically and digitally. The participants described their experiences as turning the body and dress into designable poly- body expressions, and changed their perception of the body in relation to dress. In addition to walking around 'inside' the designed items, i.e. using them as pieces of clothing to cover the body, the participants were also able to walk around 'inside' of and interact with designed itemsas they would an architectural space. The fashion system can benefit from artistic investigationsof digital and AR technology for creating dress alternatives that may contribute to a more diverse and inclusive appreciation of body-dress expressions.

1. Introduction

The digitisation of design methods of academia and industry for creating dress has changed how designers experience and interact with the body and dress. More specifically, the integration of three-dimensional scanning technology (Daanen & Psikuta, 2018: 245–248), three-dimensional computer-aided design (CAD) software (Jhanji, 2018: 279–284), and Augmented Reality (AR) editors (Rhee & Lee, 2021: 6–10) have contributed to a shift in designing, constructing, and experiencing dress away from the physical and towards the digital.

It is argued by both academia and the clothing and fashion industry that the inclusion of digital technology in the design of dress is desirable, partly because it would facilitate a more sustainable production and distribution processes for dress and dress-related products (McQuillan, 2020: 90–92). Brands are increasingly offering production-on-demand services by advertising their designs through digital twins (Atacac, 2021), producing garments that are made-to-measure based on three-dimensional body scans (Unspun, 2021), and promoting an alternative vision of fashion that exclusively takes place in the digital (The Fabricant, 2021). These developments in digitisation are needed for sustainability reasons and to expand clothing and fashion-related experiences towards new venues such as virtual worlds. However, dress and dress-related products are still designed, constructed, and promoted based on traditional methods and techniques and physical production processes, which regard the body as an unchanging and loosely involved factor in the design process. Moreover, translating physical design processes for creating dress into the digital has led to similar representations of body types and body expressions (Atkinson, 2017: 148). Designing dress by combining technologies such as three-dimensional scanners, CAD software, and AR editors has the potential to break with common traditions that regard the human body as an object that remains unchanged throughout the design process. Artistic explorations with these technologies could lead to the emergence of alternative body-dress expressions that may regard the human body in its morphological qualities as a transitional design material. The presented research follows Koles and Nagy's definition of 'transitional materials' as ones that bridge digital and physical spaces, which in turn allow the boundaries of one's body in relation to the outer world to be redefined (2016: 283, 290). Exploring the body as a transitional material from an artistic perspective using AR technology may be relevant to designers working in the clothing and fashion industryas it may facilitate a more diverse representation and appreciation of body types and shapes.

The artistic design research presented in this article was intended to contribute to this discourse by challenging the prevalent design practices and methods of designing body-dress expressions that are commonly seen in the fashion industry and academia. In particular, this research investigated alternative morphological relations between the physical human body and digital dress within a workshop, engaging with digital and AR technology to examine the idea of more body-diverse design practices.

2. Related Studies

The usage of digital innovations in fashion has led to idealised body types that mitigate the limitations of the physical and real (de Perthuis, 2008: 169–170; Reaves et al., 2004: 141– 142).

Especially digital-born models and computer-generated influencers are designed to express idealised fantasies of body-types and beauty standards (Baumgarten et al., 2021: 153–161). This has resulted in increasing dissatisfaction with regard to body perception among young people (Gurrieri & Drenten, 2019: 104).

The design of digital bodies for digital spaces has been investigated from a user perspective with regard to its effects on self-expression. It has been argued that digital bodies are as designable as digital garments when avatar-creation editors are used (Freeman et al., 2020: 3–6; Taylor & Unver, 2007: 368–370). In this context, researchers have investigated the implications of designing digital body alternatives for self-expression that deviate from human morphology (Cooper, 2007: 129–130). Despite the possibilities they offer, avatar- creation editors for digital gaming environments often facilitate the creation of idealised body stereotypes, instead of providing a more diverse range of body shapes and sizes for self-expression (Yee, 2014: 104–106).

Researchers who focus on the limited and potentially harmful aspects of modifying the human body through digital technology suggest alternative ways of using technology to engage with and design for the human body (Smitheram, 2015: 242–252). Further examples are Kat Thiel (2015: 165–171), who three-dimensionally scanned a fully dressed human body and developed physical clothing items based on alternative body measurements; similarly, Tepe and Saleem (2022: 4–9) challenge the prevalent body-textile paradigm in fashion by using motion-capturing technology to generate alternative body shapes to design dress for.

3. Method

In this section, the initial explorations and observations are discussed; the purpose and development of the workshop are then presented, and this is followed by analysis andevaluation of the findings of the research.

3.1 Experimental process

The experimental framework of this research was based on initial explorations using three-dimensional scanning, CAD, and AR technology (Fig. 1). The intention was to disrupt established understandings of the human body, and to design dress by exploring the body in terms of its morphological qualities as a transitional material for design at the intersection of the physical and the digital.

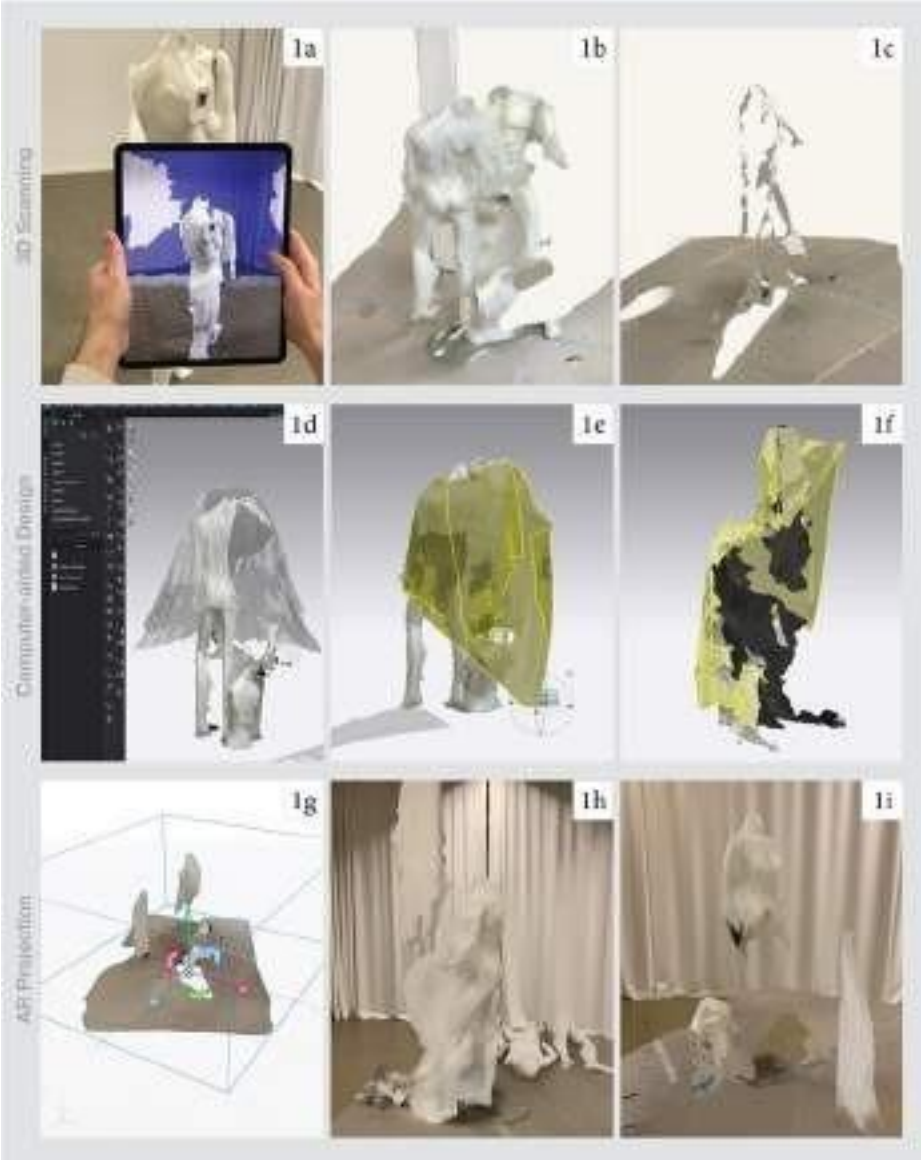

Figure 1: Images 1a–c show the three-dimensional scanning process, Images 1d-f show the digital draping process, and Images 1g-i show the body scans projected in the physical space

Three-dimensional scans of draping mannequins were made by either arranging multiple mannequins such that they were merged during the scanning process or scanning them from one side, which resulted in fragmented scans. As can be seen in Figure 1, the draping mannequins partly merged with walls, pillars, and other draping mannequins in unforeseen ways (see Fig. 1b) or appeared to be hollow, or even invisible, when looked at from certain angles (see Fig. 1c). In the next step, selected three-dimensional scans were imported into the CLO3D software package to explore the idea of designing dress based on these alternative digital bodies. As shown in Fig. 1e-f, it was possible to drape textiles on the digital bodies and create patterns in a manner similar to how one would normally work with the software. However, it was necessary to rethink how to construct or drape on those as they deviated significantly from regular human body shapes. Projecting the body scans into physical space

using AR technology suggested potentials for alternative functions and expressions of dress, which were worthy of further investigation (see Fig. 1h-i).

The observations raised the following questions: What alternative expressions and functions can be derived from and with body shapes when designing dress with digital and AR technology? How can these alternative expressions promote a more diverse representation of body types when creating dress?

3.2 Workshop

The initial explorations and research questions guided the development of a three-day workshop that was conducted with undergraduate fashion design students.

For the duration of the workshop, all of the participants had access to digital and AR technology such as an iPad Pro equipped with the three-dimensional scanning app Polycam; this allowed them to three-dimensionally scan each other's bodies. They also had access to computers and laptops with the CLO3D software package, which they used to design and digitally construct dress, as well as AR editor software such as Adobe Aero and Spark AR, with which they created digital content that could be experienced in the physical space.

The overall procedure of the workshop was guided by the initial explorations as discussed above. Three activities were planned that correlated in terms of the order and execution of and technology used during the initial explorations. On Day 1, the participants were tasked with scanning the bodies of those who voluntarily agreed to be scanned using the iPad Pro. On Day 2, all of the participants imported the scanned bodies into the CLO3D software package and designed dress using them. On Day 3, the participants converted their designs into AR content using the Adobe Aero or SparkAR software packages, allowing smartphone users to experience their designs in relation to their own bodies by projecting the designs in the physical space.

3.3 Data analysis

Images and digital three-dimensional objects were used to reconstruct the participants' design processes. This allowed analysis of how the scanned bodies influenced the participants' design processes when they were used to design dress and dress-related expressions. More specifically, it allowed various morphological qualities of the scanned bodies to be identified, supporting the emergence of alternative dress designs by visually suggesting different relations to the body.

The participants' behaviour when interacting with the digital designs in the physical space were recorded using photography and videography. This facilitated analysis of the alternative functions and expressions of dress from a body-related perspective.

Cross-sectional comparisons between the participants' design processes and behaviour when engaging with the digital designs through their physical bodies facilitated identification of disruptive patterns in terms of the design process, which led to the emergence of dress-related expressions for alternative bodies.

4. Findings

The findings of this study suggest expression and interaction possibilities in relation to alternative bodies for the design of digital dress. This chapter is structured in three sections, which align with those of the workshop (see Section 3.2). The first section focuses on the artistic potential of digitising the physical human body. The second focuses on the inherent potential of the scanned bodies as materials for design, and how they could be used to design dress. The third focuses on the interaction possibilities between the physical body and the digital dress-related designs that emerged as a result of the use of bodies as materials for design.

4.1 Creating bodies to digitally design dress

The participants created 53 body scans during Day 1 of the workshop that featured alternative morphological body qualities. These were the results of four identified scanning techniques: *One-Body-Scanning* was similar to traditional three-dimensional body-scanning techniques, and digitised the physical body in the most precise way (see Fig. 2a-c), while with *Poly- Body-Scanning*, multiple human and non-human bodies were placed close to each other or intertwined with each other (see Fig. 2d-f). For the *Fragmented-Body-Scanning* technique, the physical bodies of the participants were scanned from one angle (rather than the scanner moving around the body to create a full-body scan), which resulted in hollow-seeming

shapes that only showed a fragment of the actual body (see Fig. 2g-i). The *Moving-Body-Scanning* technique involved the participants moving their bodies during the scanning process, which resulted in multiplied and morphed bodies that fragmented the body and partially repositioned body parts such as the head and hands (see Fig. 2j-l).

By comparing the scanning techniques, the following morphological alterations were identified: bodily movement during the scanning process was identified as altering the bodies to the greatest extent during scanning. This was particularly evident when the results of the One-Body-Scanning and Moving-Body-Scanning techniques were compared. Requiring the scanned person to remain still resulted in morphological expressions that appeared to be relatively static and solid, with smooth surfaces. In contrast, three-dimensional body scans that involved two people moving their bodies independently of each other created digital bodies that seemed to be hollow and split in unusual ways, with fragmented surfaces and textures. Body scans that did not scan the entire body, as was most obvious in the case of the Fragmented-Body-Scanning technique, created alternative morphological expressions by making bodies that were only visible from one perspective seem hollow (see Fig. 2g-i). Some of the scanning techniques resulted in larger-than-life digitised bodies, as in the case of the Fragmented-Body-Scanning and Moving-Body-Scanning techniques. In the case of the former,three-dimensionally scanning the body using mirrors fragmented the body and merged it with the surrounding walls (see Fig. 2g-i) and, in the case of the latter, multiplied and morphed body parts due to unanticipated spatial alignments (see Fig. 2j-l).

Figure 2: Examples made using the One-Body-Scanning technique (2a-c), Poly-Body-Scanning technique (2d-f), Fragmented-Body-Scanning technique (2g-i), and Moving-Body-Scanning technique (2j-l).

4.2 Digitally altering body shapes to design dress

The scanning techniques discussed above revealed visual and morphological expressions of the human body that suggested alternative ways of approaching the body in the following design processes. This resulted in two approaches to using the digitised bodies to design dress: *using body scans as digital dress* and *using body scans as alternative bodies for designing dress*. The structure for displaying the Design Examples 1-4 as seen in Fig. 2 a-c, d-f, g-i, and j-l respectively, was also applied in Fig. 3-6 since the same designs were used throughout the design process.

4.2.1 Using body scans as digital dress

This section presents the designs made by the participants who approached the scanned bodies as design materials for creating dress that did not require digital textile materials (see Fig. 3). The scans were either placed on the body of an avatar in the CLO3D software package or separated into pieces which were then placed on an avatar. In all of the examples, the bodies were used to cover the avatar in a manner similar to how various types of dress are generally used. This approach worked better with body scans consisting of full bodies (see Fig. 3a-c) or that provided three-dimensional material that could be easily related to the scale of the human body (see Fig. 3j-l). In spite of this similarity, the digitised bodies also exposed the digital body in that they revealed parts of the wearing body as a result of their morphological expressions (see Fig. 3a-l). This was particularly the case for the examples shown in Fig. 3a-c. In contrast, the body scans that altered the morphological expressions of the physical body by fragmenting it (see Fig. 3d-f), making it seem hollow (see Fig. 3g-i), or moving body parts (see Fig. 3j-l) had less resemblance to the wearing body, making it easier to regard them as dress-related designs.

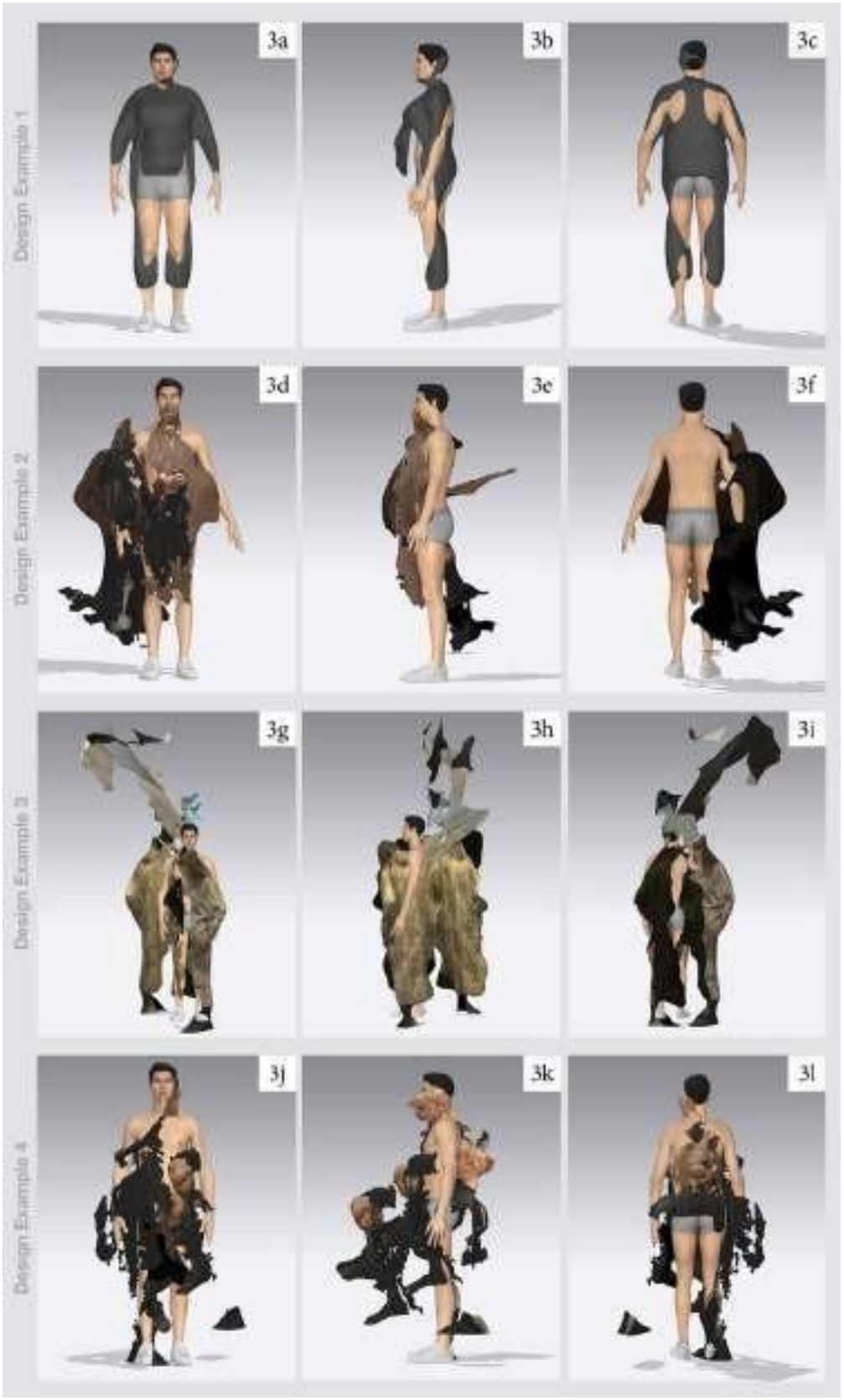

Figure 3: Four design examples that were created by placing scanned human bodies on a digital avatar.

4.2.2 Using body scans as alternative bodies for designing dress

This section presents the design examples made by the participants who interpreted the digitised versions of the body as reference objects for designing dress by draping digital textileson them (see Fig. 4). All of the design examples shown in Figure 4 were created using a digitaldesign process for dress that was similar to industrial design processes in the sense that digitaltextiles were used as materials for draping and designing dress on an avatar. However, the morphological qualities of the digital bodies chosen for Fig. 4d-f, Fig. 4g-i, and Fig. j-l required that the participants find alternative starting points for constructing and draping dress. Some of the chosen alternative bodies consisted of more than one head (see Fig. 4d-f and Fig. 4j-l), had heads that were located on different parts of the body than is normal (see Fig. 4g-i and Fig. 4j-l), or had shoulder and arm positions that merged with other body or non-body parts (see Fig. 4d till Fig. 4l). Furthermore, unlike most types of dress, some of the inherent morphological expressions of the bodies suggested that openings be aligned vertically instead of horizontally. This is particularly evident in Fig. 4d-f and Fig. 4g-i. In the case of the former, the back of the dress was left open due to the fact that the digital body used was concave, resulting in a digital dress that a wearer would walk into from behind to put on, rather than putting it on from above, as with a T-shirt, or from below, as with trousers (see Fig. 4d-f). The design example in Fig. 4g-i suggests a similar approach in that it had an opening at the back that a wearer would walk into. However, this design decision was influenced by the size of the body that it was draped on, which resembled more an architectural space than a human body.

Figure 4: Four design examples that were created by using the scanned bodies as a body on which textiles were draped.

4.3 Projecting body-shape-related dress onto the physical body

The design outcomes of Section 4.2, which were developed by following one of two design approaches, suggested how the participants might interact with them once they were projectedon their bodies in the physical space. *Wearing digital bodies as dress* focuses on the emerginginteraction potentials of the designs presented in Section 4.2.1, and *Wearing digital textiles thatwere formed using alternative bodies* does so with regard to Section 4.2.2.

4.3.1 Wearing digital bodies as dress

As can be seen in Figure 5, the digitised bodies described in Section 4.2.1 were projected onto the bodies of some of the participants, creating the experience of wearing dress to varying degrees. The bodies shown in Fig. 5d-f and Fig. 5j-l created the most relatable experiences of wearing dress for the participants from a visual perspective, due to the fact that they resembled common types of dress to a greater degree than the other designs. The bodies projected onto the participants' bodies of Fig. 5a-c were not altered enough in terms of their morphological expressions, which led to the experience of wearing body-objects rather than dress-related expressions. Furthermore, the visually apparent morphological differences between the digital body and the physical body created a tension for the participants that was difficult to relate to experiences of dressing. Some of the participants described looking at themselves from the front or back and feeling that they had two bodies at the same time (see Fig. 5a and Fig. 5c). However, seeing themselves from the side, as in the case of Fig. 5b, changed the perception of the projected body and made it seem more like a designable object, as the space or gap at waist height separated the physical and digital bodies visually. As compared to the other designs, the design shown in Fig. 4g-i had the least impact on the participants' perception of wearing dress. Here, the spatial relation between the physical body and the digital body was too loose to create an immersive experience. The participants described the relation between the design projected on their body and the body itself as fragmented.

Figure 5: The designs that were created by using bodies as dress were projected onto the participants' bodies.

4.3.2 Wearing digital textiles that were formed using alternative bodies

In a manner similar to that described in Section 4.3.1, projecting the digital designs onto physical bodies influenced how the participants perceived their own bodies in relation to the designs, albeit for different reasons. The designs described in Section 4.2.2, which consisted of digital textile layers that remained in the shapes of the bodies they were draped on, were used during this iteration. Observation of how the participants interacted with these designs helped in identifying four alternative body-dress relations, which led to an understanding of the potential functions of digital dress in relation to a physical body. Body-Dress Relation 1 was observed as a result of Design Example 1, and involved participants with smaller bodies than those that were scanned; this resulted in the participants experiencing the digital dress as a layer that surrounded their body and as a space to move in to equal degrees shown in (see Fig.6a-c). The space between the digital textile layer and the physical body was not felt to break the sense of immersion of wearing the dress, provided it moved in accordance with the body. Instead, the digital layer allowed the participants to explore the body shape of somebody else from within the dress by moving inside it (although this was only possible to a limited extent in order for the two bodies to be lined up). In connection with this, Body-Dress Relation 2 wasdiscovered through the observation that the emerging interaction between physical body and digital dress transformed the dress into a garment or architectural space, as seen in Fig. 6g-i and Fig. 6j-l. In the case of the design example shown in Fig. 6g-i in particular, the participants‘wore’ the textile layer, which visually expressed the body it was shaped by, as a dress and asan architectural space, depending on where and how they stood inside the dress and whether the dress moved in relation to their bodily movement. Body- Dress Relation 3 was directly connected to Design Example 4, as it was observed that the design influenced how the participants decided to wear the digital dress, requiring them to change their body posture in accordance with the openings for the head and arms in the textile (see Fig. 6j-l). The result wasthat some of the participants knelt down to use the opening at hip height for their head, or heldtheir arms perpendicular to their heads when standing upright. While a similar logic accounts for Fig. 6d-f, this example also led to Body- Dress Relation 4, in that the design changed howthe participants experienced and engaged in the process of dressing and undressing. The wideopening in the back of the design motivated the participants to step inside it from behind ratherthan walking through the digital textile layers, allowing the participants to ‘dress’ in a mannermore similar to entering a room than wrapping an object around one’s body.

Figure 6: The designs created by shaping digital textiles after the alternative bodies were projected onto the participants' bodies.

5. Discussion

Explorations of the human body in both the physical and digital worlds revealed alternative approaches to the morphology of the human body that are relevant to the process of designing dress. The findings suggest that digitising the human body changed the participants' understanding of both the morphology of the body and its use as a material in the design of dress. Informed by this change in understanding, one of two distinctive directions were taken by the participants: a focus on the digitised body as a design material, and on the digitised body as a reference body for draping digital textiles on. Consequently, alternative qualities of the physical body were considered in relation to the design of digital dress. Understanding the morphological qualities of the digital body as a material with which to dress the body, as discussed in Sections 4.2.1 and 4.3.1, changed how the participants perceived their own bodies through the shapes and expressions that were projected onto theirs. Due to the inherent qualities of the digital bodies, which were projected onto the participants' bodies as dress- related designs, the participants' bodies were exposed rather than covered. This led to a disruption of the commonly perceived distinction between body and dress. In contrast, draping digital textiles on the digital body, as discussed in Sections 4.2.2 and 4.3.2, provided the potential for alternative body-dress interactions. The participants explored the body shapes of others through the digital textile layers, which became spaces that they existed in and were surrounded by, similar to architectural spaces. This led to experiences of walking inside dress, and to alternative experiences of dressing and undressing by walking inside and outside dress.

Digital and AR technology enabled alternative body-dress expressions, but also constrained the physical body in various ways due to its limitations. This was particularly evident with theAR devices, as the participants had to constantly hold their smartphones in order to see the designs projected on their bodies or ask somebody else to hold these while looking at the screen.This dependency on smartphones in order to experience digital dress in relation to the physical body felt unnatural and restrained the participants in their movements. Future research could include AR headset devices that combine digital content and physical space without limiting or strongly influencing body position and movements.

By placing this research in a wider context, the human body can be regarded as a transitional design material when it is experienced via digital and AR technology. Following Koles and Nagy's definition of the body as a transitional material, this would allow the boundaries of one's body to be redefined in relation to the outer world (2016: 283, 290). Considering this from a designer's perspective may contribute to an appreciation of a more diverse range of bodies in terms of shapes and sizes, and lead to a different understanding of the body during design processes. In this context, technology – which is primarily developed for industrial purposes – has the potential to disrupt the norm by facilitating the design of alternative body-dress expressions at the intersection of the physical and the digital (Daanen & Psikuta, 2018: 245–248; Jhanji, 2018: 279–284; Rhee & Lee, 2021: 6–10; Atkinson, 2017: 148). Exploring the intersection of the physical and the digital in terms of body-related design disciplines such as fashion may improve our understanding of the role and importance of the body with regard to design, particularly when it is present and engaged with in multiple realities simultaneously.

Conclusion

The morphological qualities of the human body were investigated as transitional materials for designing dress using digital and AR technology. The findings suggest that using the digitised human body as a material for design can contribute to an appreciation of a more diverse range of bodies in terms of shapes and sizes, and inclusive representation of these when designing at the intersection of the physical and the digital.

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