Reconfiguring Material Boundaries in Digital Fashion Design: Investigating Artistic Potential and Ethical Challenges of Materialising the Designer's Body in Digital Fashion Design Practices

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ABSTRACT

Research is needed to address the evolving material boundaries of bodies in fashion design, facilitated by digital technology, in order to create meaningful design that goes beyond replicating physical products in the digital realm and responds to the ethical challenges of body datafication. The presented research aims to reconfigure the material boundaries between designer and design by exploring the agential role of digital technology in fashion design through the lens of agential realism theory. Degree projects from undergraduate fashion design students, supervised by the author between 2021 and 2024, were selected as case studies where the designer's body was used as a design material. These cases were analysed through the lens of agential realism theory to:

    i)   destabilise commonly assumed boundaries, purposes, and expressions of material relations in physical fashion

    ii)   ii) ethically examine the designer's involvement at a material level in the design process.

The analysis found that utilising digital technology, uncommon in fashion design, with devices that translate human bodies between digital and physical realms, shifted the designer's perception of their body to a design material equal in purpose and expression to others. This led to designs that more intimately reflected personal narratives and diverse body representations. The analysis also revealed ethical concerns regarding the datafication of bodies, their dissemination, and the emotional impact on the designer. Guiding principles for engaging with digital technology in fashion design, which more closely involve the designer's body, were developed. These principles offer direction for navigating the expanding digital fashion design field, both artistically and ethically.

Keywords: digital materiality, digital fashion, fashion technology, fashion education.

INTRODUCTION

The designer's body in fashion has traditionally been viewed as an external agent acting on materials in the design process, without undergoing modifications itself (Atkinson, 2017). However, the growing proficiency and accessibility of digital technology could disrupt this distinction by enabling the digital translation and modification of the designer's body.

Indeed, an increasing number of fashion design projects now involve digitised human bodies as design materials. One primary driver for this development is that digitising human bodies in fashion design can lead to more cost-effective and sustainable production, with fewer returns due to poor garment fit (Idrees et al., 2023; Javid et al., 2021). Brands like Unspun (Unspun, 2024) and Redthread (Redthreadcollection, 2024) use three-dimensional body scanning technology and online services to create garments based on customer-provided body measurements. Similarly, established CAD garment construction software such as CLO3D and Browzwear allow for the modification or replacement of digital avatars with three-dimensional scanned bodies, enabling the design of garments for a broader range of body types (Papachristou et al., 2022).

In a more artistic direction within fashion, designers and artists have explored digital bodies as design materials in performative contexts. Examples include Heyman's (2024) digital installations featuring modified three-dimensional scanned bodies, Gremmler's animations of digital bodies transitioning into fabrics and back (Magnusson, 2021), and Peacock's (2023) AI-generated digital sculptures of 'fashioned' bodies. Regardless of whether the focus is artistic or commercial, these practices typically exclude the designer's own body (Thiel, 2017). However, digital tools and platforms increasingly promote self-body modifications that are becoming accessible to larger demographics. The widespread use of augmented reality filters on social media, which allow users to modify their facial features or body silhouettes (Javornik et al., 2022; Varman et al., 2021), illustrates the growing familiarity with digital body modifications. This increasing comfort with digital tools inevitably impacts the material understanding of upcoming fashion designers familiar with such experiences, challenging traditional material boundaries in the process (Tepe et al., 2023; Rocamora, 2017; Logaldo, 2016).

Failing to recognise the shifting material boundaries enabled by digital technology would limit digital fashion design practices to mere replication of existing physical ones (Varra, 2021; Salomaa, 2021; Atkinson, 2017) and raise ethical concerns regarding the implications of working with digital representations of the body and their dissemination (Royakkers et al., 2018). Further research is needed to expand material engagement in digital fashion by exploring theories that address the ambiguity, transformability, and temporality of materiality in the digital realm. This would help guide practitioners and educators in navigating a digitally informed design field that

more closely incorporates the designer's body from a material perspective. It could also enable designers to engage in practices that better reflect personal narratives, promote body diversity, and raise awareness of the ethical implications of digital materials, particularly regarding their longevity and accessibility beyond physical limitations.

This paper aimed to reconfigure the material boundaries between designer and design by investigating the role of digital technology in fashion design through agential realism theory. The research addressed two key questions: How does digital technology shift the designer's understanding of their body in relation to design material? What artistic and ethical challenges arise from such design practices? By addressing these research questions, guiding principles are suggested to help navigate and expand material practices in both artistic and ethical dimensions within the evolving field of fashion design.

BACKGROUND

Agential realism was chosen as a theoretical framework to redefine the ontological boundaries of materials in fashion design, providing foundational direction for involving the designer's body as design material both artistically and ethically.

Theoretical framework

Agential realism theory, developed by Karen Barad (2007), challenges the representationalist focus on the relationship between language and reality and rejects the idea of pre-existing entities with fixed properties. Instead, it proposes a relational ontological approach, where specific material configurations of the world shape boundaries, properties, and meanings through their interrelations. In this view, matter is not a static property of things but a dynamic and shifting entanglement of relations.

For Barad, this material ontology unfolds through intra-actions, rather than interactions. While interactions assume that distinct agents exist independently before engaging with one another, intra-actions recognise that agencies only emerge through their mutual entanglements. This shift reframes matter as not a fixed substance, but as a substance in constant becoming: it is a process, not a thing, involving both stabilisation and destabilisation. As a result, Barad shifts the focus from *things* as the basic ontological unit to *phenomena*, as one cannot make sense of things isolated from one another. Building on Bohr's (1963) conception, phenomena are real, physical entities—basic units of reality—formed through the entanglement of objects and their observers. This includes both human and non-human agents, as humans are also emergent phenomena. Therefore, for Barad, reality is composed of things-in-phenomena, rather than things-in-themselves or things "behind" phenomena (p.140, 2007).

To make sense of things-in-phenomena, Barad introduces the concept of agential cuts, which define causal relationships within phenomena by marking distinctions between measuring agencies (effects) and measured objects (causes). Agential cuts allow things-in-phenomena to become intelligible either as objects of observation or as things through which observation occurs. These cuts are not permanent; they can be reconfigured to create different causal structures between measuring agencies and measured objects.

In the context of digital design, Barad's framework allows for a reconfiguration of the material boundaries between designer and design. By adopting a material ontology of things-in-phenomena, these boundaries are not seen as pre-given but as unfolding through specific intra-actions with digital technologies. This approach offers an alternative material understanding in fashion design, where the designer is viewed as equally entangled in the design process as other material components, revealing their materiality and designability through acts of making.

Related research
Research in fashion increasingly draws on concepts and theories more commonly acknowledged in the field of human-computer interaction to argue for redefining traditional material boundaries in response to fashion's digital transformation.

Agential realism theory has been explored in the context of digital fashion to focus on designing phenomena rather than things (Tepe, 2024), treat digital data as material agents akin to physical materials (Tepe et al., 2023), view humans and computational tools as mutually influencing material agents (Alderson-Bythell et al., 2023), and rethink the material boundaries of the fashion model within fashion's imagery system (Petersen, 2020).

In addition to agential realism, researchers have turned to post-phenomenology theories to engage with digital technology in fashion design as a material for garment making (van Dongen, 2019) define material states that are equally composed of digital and physical elements (Ferarello, 2017), and challenge traditional conceptions of the body in fashion using three-dimensional scanning technology (Thiel, 2017).

Beyond fashion, scholars have also used agential realism to explore how the human body, apparatuses, and spaces become diaphanous in the intersection of art and architecture (Jauernik & Tschapeller, 2021), challenge the concept of material mediations in media arts (Cypher, 2018), and question the notion of the human body as having inherent boundaries in performative landscapes (Arlander, 2014).

These examples share a common view that material boundaries are performative rather than fixed. Instead of being pre-existing, they are enacted, dynamic, and

relational, which aligns with the conceptual focus of the research presented in this paper.

METHODOLOGY

Three design cases were chosen and analysed to answer the research questions: How does digital technology shift the designer's understanding of their body in relation to design material? What artistic and ethical challenges arise from such design practices?

Recruitment and procedure

The number of design cases was determined by the number of degree projects the author supervised between 2021 and 2024 that met the criteria for relevance to this research.

Selection criteria:

    i.   The degree students, as designers, incorporated their own bodies from a material perspective relevant to the design process.

    ii.   Degree projects involved the use of digital technology in design processes that went beyond already established use cases in the fashion industry.

    iii.   A variety of devices and software packages were utilised within design processes to navigate the physical-digital spectrum.

Three of the ten undergraduate fashion design degree projects supervised by the author met the criteria and were selected for analysis. It is important to note that the research presented in this paper was formulated after the completion of the degree projects. The degree students had the freedom to choose the focus, direction, and development of their projects, as well as the technology they used and its intended purpose. Furthermore, obtaining consent from the degree students after their graduation to include their projects for analysis ensured that participation was voluntary.

The former students of the selected degree projects completed a six-week course during their first year in the undergraduate fashion design program, in which they learned to utilise various devices, software, and online services relevant to design processes in fashion. These included three-dimensional CAD software such as CLO3D and Blender; three-dimensional scanning technology and applications like Polycam and In3D; augmented reality (AR) tools such as Adobe Aero and Lens Studio, as well as AR-ready devices like smartphones and tablets; and virtual reality (VR) devices such as the Oculus Quest, along with VR immersive sketching applications like Gravity Sketch.

The degree projects were developed over a period of 20 weeks, during which the design students created material samples, upscaled them into collections with a minimum of five to six artefacts or outfits, and wrote a thesis documenting their design process and framing the conceptual approach of their projects. Supervision meetings were held once a week with each student for approximately 30 minutes to discuss conceptual and technical developments.

Design cases

The three selected degree projects that met the selection criteria are discussed to demonstrate their relevance to this research. This is achieved by outlining the design process for each project, the technologies involved, how the designer engaged with their body as design material, and the outcomes of the design process.

Case (C1)

The first degree project utilised digital technology to materialise the space around the designer's body for the development of sculptural wearables. Conceptually and technically, the designer's spatial body—defined as the human body and its surrounding space—was revealed in both expression and function, and materialised using immersive three-dimensional sketching applications in virtual reality. These materialised spatial bodies were made wearable by using lace fabrics and metal constructions in the physical, showcasing the surrounding space as extensions of oneself within the context of a fashion collection (see Fig. 1).

In the first step, the designer captured her surrounding space using the immersive three-dimensional CAD software Gravity Sketch, combined with a virtual reality head-mounted display and hand controllers. Two techniques for materialising the space around the designer's body through movement were explored. The first technique led to abstract form compositions, with scale and proportion determined by the designer's body size (see images A1–A2 of Fig. 1). The other technique involved positioning a digital replica of the designer's body at the centre of the digital workspace, around which forms were sketched and then connected to the digital human body representation (see images B1–B2). In the second step, the materialised body-spaces were imported into CLO3D to create garment patterns by tracing the three-dimensional forms using the *3D pen* tool (see images A4–A5). Additionally, a selection of materialised body-spaces was imported into Blender to create construction plans that a welder could use to translate into metal constructions (see images B4–B5). Finally, in the last step, the digital designs were translated into six garments using lace fabrics hardened with bee wax to maintain their shape (see images A6 and B6).
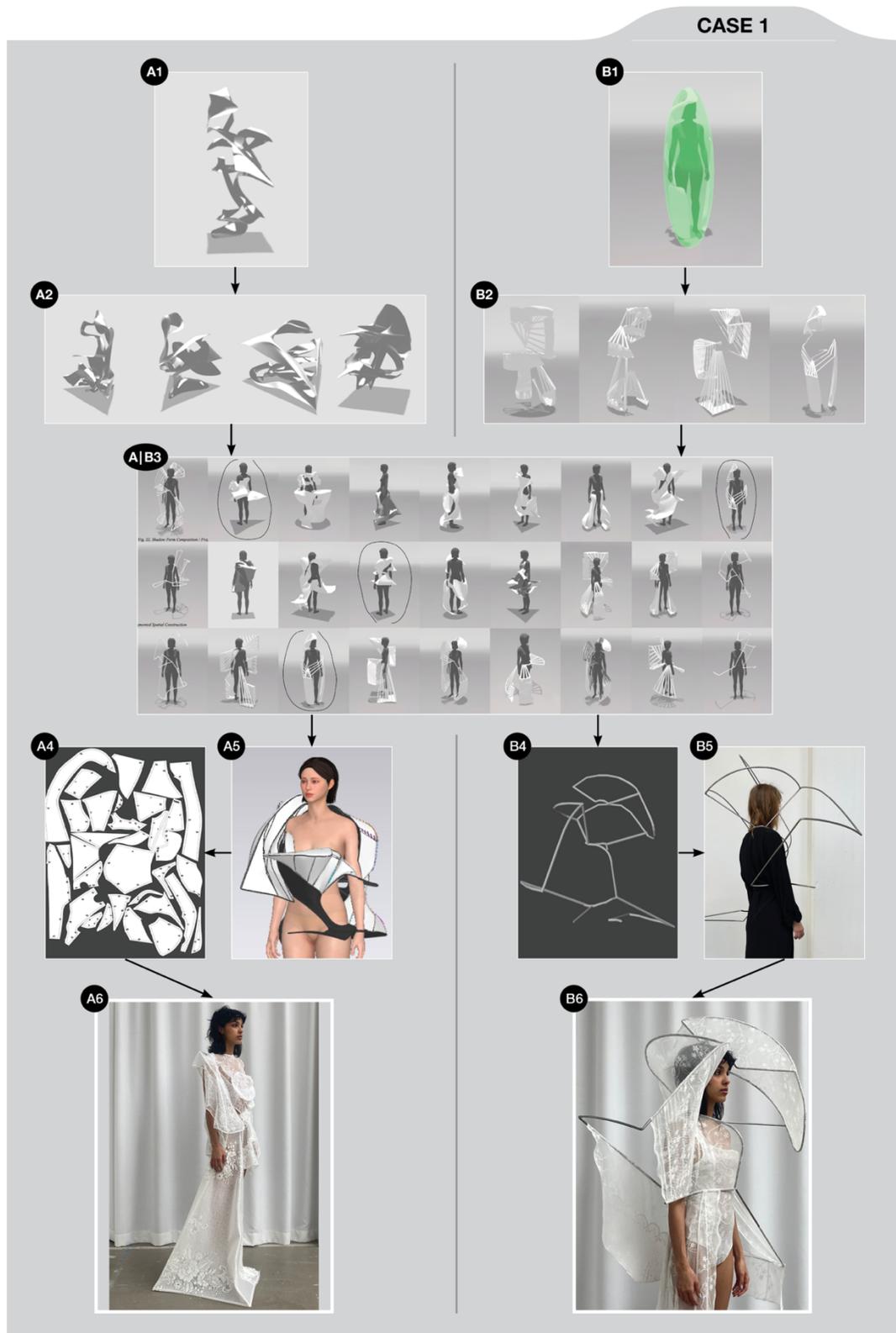
Fig. 1 Display of the design process for Degree Project 1.

Case (C2)

The second degree project consisted of a fashion collection in which the designer utilised digital technology as a tool to engage with her physical body as design material. The design approach was rooted in the conceptual direction of the project: to explore body dysmorphia and gender dysphoria in relation to trans-feminine individuals. The designer addressed this topic from both an internal perspective—her personal experiences as a trans-feminine individual—and an external perspective, examining how depictions of trans-feminine individuals in Western society are often dominated by pornographic media (see Fig. 2).

The designer began the process by using the Human Solutions LS3 body scanner to digitise her body. The body scan was then translated into a digital avatar for CLO3D, and its face was modified slightly to de-personalise the degree of identification with it (see image 1 of Fig. 2). In the second step, the avatar's position was altered in CLO3D, drawing inspiration from how women are portrayed in pornography. In the third step, the designer used an AI image generator to create distorted body images by combining screenshots of the modified avatar with prompts derived from language used to describe trans-feminine women in pornographic media (see image 2). The resulting images served as inspiration for sculpting distorted bodies in Blender in the fourth step. The design process of sculpting bodies was further motivated by the designer's personal struggles with body dysmorphia and gender dysphoria. The sculpted bodies were then imported into CLO3D, where patterns for garment construction were created by tracing the morphological body surfaces with the *3D pen* tool (see images 3a–c and 4a–c). Inflatable physical garments were created based on the developed patterns in CLO3D. Latex was used as the primary material, which was cut using laser cutting devices and assembled with latex glue (see images 5a–c). The process culminated in a collection of five physical garments that mimicked the shape of some of the digital bodies.
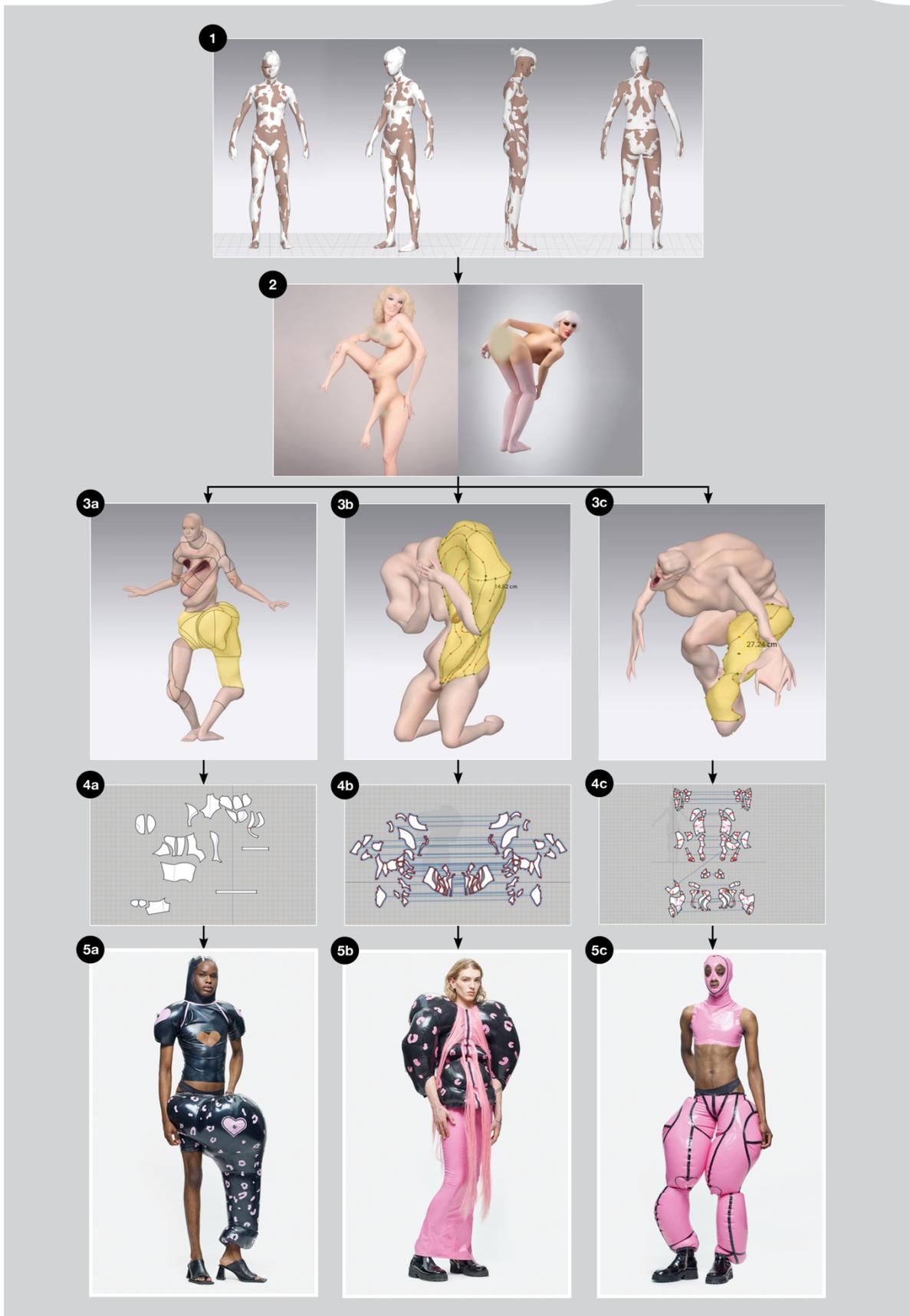
Fig. 2 Display of the design process for Degree Project 2.

Case (C3)

The third degree project transformed the designer's physical body into design material, using digital technology to create 'fashioned' body-like sculptures. Arguably the most conceptual of the three projects presented, this work challenged conventions and expectations within the fashion field regarding which bodies are designed for, the extent to which bodies are designed, and what is considered a design outcome in the context of fashion.

In the first step, the designer digitised his body using a LiDAR-ready iPad Pro in combination with the three-dimensional scanning app Polycam (see image A1 of Fig. 3). Almost completely undressed, the designer moved his body during the scanning process—bending and rotating his torso, hips, arms, legs, and head—resulting in modifications to the body shapes of the digital replica. The body scans were then imported into the three-dimensional CAD software Blender in the second step, where their morphological expressions were analysed in relation to the conceptual direction of the project and the technical possibilities of translating them back into the physical (see images A2a–b). The conceptual criteria included the degree to which the body scans visually expressed recognisable body shapes and textures of the designer's body, while also demonstrating the design potential of the body with digital technology beyond what would be physically possible. The technical criteria narrowed the selection of bodies based on the degree to which they could be translated back into the physical world, excluding, for example, bodies with free-floating shapes. In the third step, the selected digital bodies were projected onto polystyrene blocks in physical space and sculpted to match their digital counterparts through carving (see images A3a–b). Parallel to this sculpting process, the designer scanned surface expressions of his body, such as the skin on his feet, elbows, nipples, and other areas, to create imagery for pattern repeats using Adobe Photoshop (see images B1 and B2). These images were transferred to physical fabrics using a transfer-print process, and the fabrics were coated with bio-plastic to create more human-like surface textures (see images B3a–b). In the final step, the fabrics were applied to the three-dimensional sculptures of the designer's body, with additional coating applied where necessary (see images 5a–b). The result was a collection of sculptures based on morphological alterations of the designer's body, covered in fabrics that resembled the designer's body in texture and surface treatment.
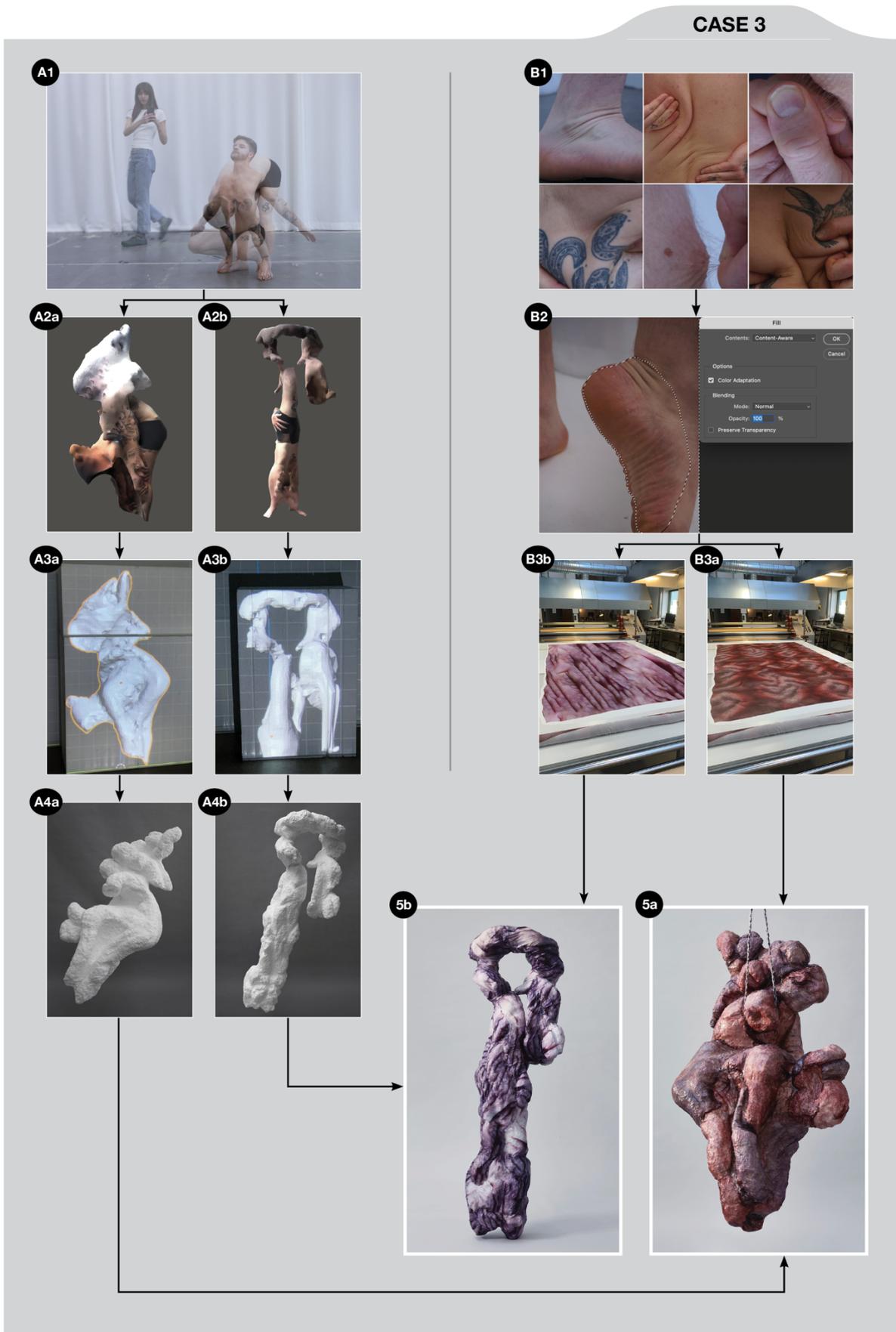
CASE 3

Fig. 3 Display of the design process for Degree Project 3.

Data analysis

The three design cases were analysed using a combination of artefactual and qualitative analysis. For the artefactual analysis, the design process of each degree project was reconstructed from documented imagery provided by the former degree students. Reconstructing the various steps of each design process facilitated a deeper understanding of how materiality was approached at different stages of making, how the role of the designer's body evolved on a material level, and how digital technology influenced the process. Qualitative analysis involved reviewing the written documentation of the degree students' theses, a questionnaire consisting of 21 questions developed by the author, and a design diary written by one of the students. This provided deeper insights into the personal and emotional impact of using one's own body as a design material during the design process. Artefact-based and qualitative data were compared across design cases and reflected against agential realism theory to contextualise the observations with respect to the research questions.

FINDINGS

The comparison of design cases in Section 3.2 helped outline the artistic potential and ethical challenges discussed in Section 4.1, specifically: i) the use of the designer's body as a material, ii) the agential role of digital technology, and iii) the emotional impact on the designer during and after the process. In the following step, design principles were framed by interpreting these insights through agential realism theory, providing guidance for designers. These are presented in Section 4.2.

Shifting material understanding

How digital design practices shifted designers' understanding of their bodies in relation to design material was identified in three focus areas.

Material intra-actions

Comparing the design cases, in relation to the designer's written feedback, suggests that viewing the designer's body as something external shifted its perception, making it more of a design material, less defined by societal norms such as normative body sizes (C1–C3). This allowed for a focus on the uniqueness of the individual body, facilitating the creation of forms and expressions that could not have been fully planned or envisioned in advance. Externalised, the designer's body became a landscape of design possibilities, with landmarks for manipulation and extraction, such as scars, hair, tattoos, etc. (C2–C3). Furthermore, the material boundaries of the designer's body were extended and redrawn by materialising its surrounding space through body movement along a physical-digital spectrum (C1–C3). This helped materialise the intangible, turning space into a morphological extension of the designer's body. The designers' feedback further suggested that their body was

regarded during the design process as a dynamic expression, not a fixed state (C1–C3). This required them to constantly re-evaluate both internal and external conceptions of their bodies in order to engage with them as design materials throughout the process. The designer's body thus became multiple material entities, each with different values and expectations. Its role shifted from that of the designer to a tool, and ultimately to the design(ed) material.

Agential role of digital technology

The design projects and designers' feedback suggested that digital technology was viewed as an 'unbiased' agent, turning digitised material into 'sequences of pixels' beyond fashion-based distinctions (C1–C3). This led designers to experience their body as *just* another datafied material, as digital technology did not discriminate between different material agents in the translation process. This applied equally to three-dimensional scanning technology, image-based generative systems (C2–C3), and movement-tracking virtual reality devices (C1). Digital technology was furthermore considered a dialogical co-designer in how the designer experienced and communicated their body (as) material during and after the design process. This was partly due to the opacity of the algorithms behind the devices and software, which required designers to accept reduced agency and remain open to unexpected material translations. While digital technology was seen as a co-designer more than a mere tool (C1–C3), the designer was described more as a material discoverer than a manipulator (C3), letting go of expectations about the outcome (C2–C3). This created a dialogical design process in which the designer and digital technology negotiated material transformations iteratively.

Emotional entanglements

The designers' feedback suggested that different types and causes of emotional impact were experienced when working with their body as a design material. Identification with the design material based on recognisability of bodily expressions created feelings of attachment and vulnerability (C2–C3). While designers might feel pride in design materials resembling their body, based on positive feedback, they could also feel envious of these materials, as they retain their shape and expression without aging, unlike their own bodies (C3). Additionally, using the body as a design material can evoke dissatisfaction with one's physical body, as designers may create idealised or distorted versions of themselves (C2–C3). However, emotional states toward the body—as both design material and lived body—could shift during the design process. Engaging with one's body as a design material may distort or invert emotional valuation. What the designer initially considers shame-inducing may become particularly valuable for the design process. Unwanted traits, such as scars or an Adam's apple, can become highly valued design features (C2–C3). This revaluation can affect how the designer perceives these traits on their lived body. Generally, however, designers can anonymise or abstract their digitised body early in the process to avoid negative emotional impact (C1–C2). Lastly, while emotional

connection to the design material may diminish after the design is complete, designers expressed distress regarding the 'afterlife' of their digitised bodies. None were aware of the long-term presence of their digitised bodies when contacted post-graduation about why the files were still available on borrowed devices. Emotional distress about potential unauthorised use of their digitised bodies depended more on how closely the bodies resembled the designers, and less on the degree to which bodily expressions were used to create the design.

Framing design principles

Through the lens of agential realism theory, the designers engaged in practices where material configurations shaped the boundaries, properties, and meanings of material agents through their interrelations, rather than assuming these properties were pre-existing or fixed. For the designers' bodies, material boundaries were redrawn by extracting morphological and surface texture expressions to be applied to other materials via digital technology, as well as to materialise space around the designer's body. In line with Barad's theory, matter in the discussed design projects was viewed as a substance in constant becoming, shaped by the continuous stabilisation and destabilisation of material states. Designers recognised their own materiality as things-in-phenomena—equally designable as any other entangled material—rather than external agents acting upon materials from the outset. Digital technology enabled the enactment of material boundaries by merging or separating components in unexpected ways, revealing the designer's body as another 'datafied' material, similar to any other entangled element.

Artistic potential includes:
- Engaging in design practices along the physical-digital spectrum facilitates understanding the designer's body as comprising multiple material entities, depending on the context. This awareness enriches the designer's toolkit by recognising the body as a material in design, equal to any other.
- Intra-action-based design practices that involve the designer's body challenge standardised body types and expectancies, valuing those that deviate from societal and industrial norms, such as size, gender, and ethnicity. This approach revalues the human body on a material level in design, highlighting meaningful expressions in its morphology and surface textures.
- Engaging with one's body as a design material deepens the integration of personal narratives into design practices, offering tools for more tangible communication.

The unfolding of material states through what Barad calls agential cuts, enacted with digital technology, requires awareness and intentionality in engaging with design materials beyond mere production. As discussed earlier, engaging with one's body as a design material evokes emotional responses from the designer that must be considered. Barad argues that the line between subject and object is not fixed and

does not pre-exist specific practices of engagement. Instead, subject and object emerge through these material practices. Designers who engaged with their own bodies as design materials reported various emotional impacts during the design process and the dissemination of outcomes. The entanglement of the designer's body and design materials did not dissolve after the design was produced but persisted beyond the designer's awareness. Files of the designer's body remained on devices due to their lack of knowledge or consideration about the longevity and opacity of the device's algorithms. In an agential realism sense, ethics entails accountability and responsibility for the relational processes of becoming that designers enact with digital technology.

Ethical considerations should include:
- Designers are advised to communicate their perceived material entanglements during and after the design process. Demonstrating accountability for how subject-object distinctions were enacted and their impact on the designer and design outcome helps outside actors understand what bodies were used, how they were used, and how designers have taken responsibility in using and disseminating them.
- Designers must be informed about the longevity and accessibility of their data on devices and software. This can be achieved by designers proactively seeking such information, educators including data handling in curricula, and tech companies making data management details easily accessible through notifications and reminders.
- Designers should clarify how their body-related designs can be used and appropriated by others. They could provide user guidelines when distributing designs and digital body assets, educators could raise awareness about the need for such regulations and how this could be done, and tech companies should offer communication and tracking tools to protect designers' rights.

DISCUSSION

The proposed principles contribute to the evolving field of fashion design by offering guidance for navigating an expanding material practice, both artistically and ethically. Drawing on agential realism theory within the context of digital fashion, the principles presented here advocate for a material ontology defined by dynamism, relationality, and contextuality, rather than pre-existence (Barad, 2007). The design cases demonstrate various ways the designer's body unfolds in multiple roles, functions, and expressions during and after design processes involving digital tools. These findings support material investigations in a digitalising fashion field that reject the notion of material agents having pre-existing roles, purposes, or expressions in design processes (Tepe, 2024), emphasise the materiality of digital data as equally important to physical materials (Tepe, 2023), and acknowledge the mutual influence of the designer and digital tools in acts of making (Alderson-Bythell et al., 2023).

Fashion practitioners and educators can benefit from these principles by fostering transparent communication and heightened awareness regarding the use of digital technology in design processes, particularly when the designer's body is involved as a material. This includes understanding how technological tools function, how body data is generated, interpreted, archived, and shared, as well as communicating which bodies were used, how they were utilised, why their inclusion matters, and how others may engage with them.

Engaging with a shifting understanding of materiality, as outlined in this research, is relevant to both practitioners and educators. It highlights the artistic potential of using designers' bodies to promote body diversity beyond binary gender expressions and idealised body types, and to communicate personal narratives through material form. This perspective contributes to a design field that moves beyond creating digital copies of physical garments (Atkinson, 2017), resonates with digital-native demographics more focused on fashion experiences than products, and attunes to digital body modifications (Javornik et al., 2022; Varman et al., 2021). It also opens possibilities for collaboration with design fields more aligned with digital technology (Salomaa, 2021).

While the research findings have led to the formulation of design principles relevant to engaging one's own body in design processes, the data set was limited in scope. Future research could explore the relevance of the suggested principles in commercial and industry contexts with larger groups of designers, and with a focus on the ethical considerations of digital data management. Ultimately, this research invites a rethinking of the designer's position on a material level, placing them at the centre of the design process through digital technology, and highlights the need for further research to guide stakeholders in leveraging this potential while addressing its ethical challenges.

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