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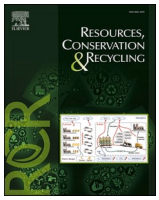

What is modular fashion: Towards A Common Definition

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ABSTRACT

Modular garments are defined as clothing items that can be dis/assembled into multiple parts without having to sew individual parts together. Instead, different parts (e.g., sleeves, collar) can be zipped or buttoned on to the main body. Modular garments have increasingly gained attention as a sustainable design strategy, as they (modular garments) have the potential to extend the lifetime of garments by exchanging modules and thus, also revolutionise business models and the way consumers shop. Although modular garments have gained increased attention, there is currently a lack of what 'modular garments' constitute, and this may differ from modular fashion.

This paper provides a definition of modular garments and modular fashion by reviewing the origin and development of the term *modularity*. Although examples illustrating the concepts of modular garments and modular fashion are exclusive to modular outerwear, this paper provides a conceptual foundation for future research on modular garments and modular fashion.

1. Introduction

Modular fashion has increasingly gained attention, with media outlining that it may be "the next big thing" (Vaid, 2021) or "make sustainability fun" (Webb and Maguire, 2022). Although it only recently has become a buzzword, the concept of modular fashion and more broadly modular design dates to the mid-17th century (Gwilt, 2020). Women's undergarments ('the stays') used to have detachable sleeves that were fastened with ribbons, whilst men's dinner dresses during the Victorian/Edwardian time had detachable collars and cuffs that were assembled with hooks and eyes (Fletcher, 2008; Gwilt, 2020). The original idea of modular design resonates around sustainability principles (Fletcher and Grose, 2012; Gwilt, 2020; Chen and Lapolla, 2021), as it reduced having to wash full garments and saved money by being able to incorporate new trends by simply changing collars/cuffs whilst keeping appearance and functional aspects (Gwilt, 2020). This aligns with the environmental and economic aspects of sustainability.

This conceptual paper explores a common definition of modular fashion by tracking the etymology of "modularity" and distinguishing it from similar terms, such as "modular design" and "modular garments". Increasingly more designers create collections that fit a modular design style and foster sustainability in fashion. One recent example of modular fashion is the collaboration between London-based designer Feng Chen Wang and Nike, which is "breaking all conventions of garment construction to reimaging sportswear staples as highly functional mashups of disparate culture and design elements" (Nike, 2023a). Within their collection, a sportswear jacket can be turned into a skirt, utilising zippers (Nike, 2023b). Yet, modular design and good intentions to promote sustainability often come at a higher price (e.g., Nike Pro-Transform Jacket £459.95). Other examples of modular fashion are 1) Emmanuel Ryngaert's graduate collection, which was inspired by furniture and Meccano toys (Google Arts and Culture, 2016) and is created from circles, squares, and rectangles to construct garments, which are linked together through prefab-specific hole splicing. And 2) COS, which uses zips to create different looks within their Three-in-One Dress (Metziahs, 2023) that can be bought on the high street. What becomes apparent here is that 'modular design' grows in popularity with different types of fashion genre buying into the concept.

Past research (Chen and Lapolla, 2021; Gwilt and Pal, 2017) primarily focuses on the execution of modular fashion and its underlying principles and thus, answering the *how* and *why* of modular design. However, only few studies (Karell, 2013; Koo et al., 2014; Ellen MacArthur Foundation, 2017) currently explore the concept of modular fashion and its potential alignment with sustainability in the fashion industry. These explanations are generally broad and without sources and there is no clear distinction between modular fashion, modular garments, and modular design. Yet, the lack of consensus on meaning hinders the advancement of knowledge and science (Salvador, 2007).

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Specifically, the ambiguity surrounding the definition of modular fashion obstructs the exploration and examination of its viability as a sustainable solution. Thus, a universal definition of modular fashion is needed and must clearly differ from other similar terms, such as modular garments and modular design, which is addressed in this paper.

2. Modularity of modular design

2.1. Modularity

Before addressing how modular design, modular garments, and modular fashion differ and/or align, it is vital to understand what 'modularity' entails and how this can be translated into the fashion design context. Within the literature, *modularity, module, modular product*, and *modularization* are repeatedly mentioned and intertwined and thus, need to be carefully explored (MacDuffie, 2013).

The term *modularity* originated in computer science in the 1980s when discussing different interchangeable/removable parts of a computer (Baldwin and Clark, 2000). Generally, there are two key features associated with modularity: 1) the breakdown of the whole system into either physical items (e.g., modular computer family) or a system (e.g., IBM system/360), and 2) the compatibility of modules (e.g., hardware in physical computers, software in the IBM system/360) (Baldwin and Clark, 2000; Baldwin and Henkel, 2012). It could be said that modules are a part of a larger system that is structurally independent but functions interactively, with dimensions of *modularity* further being distinguished into systematic and structural.

The former (systematic) highlights a process in which the whole (e.g., garment) is broken down into various independent modules (subsystems, e.g., sleeves, collars) and potential connections (e.g., interfaces, such as zips, buttons) (Baldwin and Clark, 2000). Thus, each *module* can be regarded as a subsystem of *modularity*, interacting together through standard interfaces and being organized according to an intrinsic hierarchy. Within the systematic dimension, design rules are established, hierarchies are generated, and modules (subsystems) are identified. Contrarily, in the structural dimension, modularity is seen to have two concrete elements: modules (subsystem, e.g., sleeves, collars) and interfaces (e.g., zips, buttons) that are interconnected. As such, modules and standard interfaces are two essential entities that create *modularity*.

Thus far, the definition of modularity can be summarized as follows (Ulrich, 1994; Baldwin and Clark, 2000; Gershenson et al., 2003; Sako, 2003; MacDuffie, 2013):

- **General Definition:** Modularity is a strategy used to simplify a complex system, product, or problem.
- **System Dimension:** It is a process of breaking down the whole (system) into several modules (subsystems) through interfaces with hierarchy, during which the design rules are involved.
- **Structure Dimension:** Modularity consists of modules and interfaces.

In linking this to the product context, Bonvoisin et al. (2016) define modular products in accordance with the structural dimension as products that are made up of modules and connected through interfaces. Contrarily, Roozenburg (1995, cited in Kamrani and Sa'ed, 2002) discusses modular products considering their functions and suggests that it is the combination of independent modules that fulfil the function as a whole. Thus, a modular product is made up of independent modules with interfaces, and its overall function is achieved by assembling these modules through their interfaces.

2.2. Modules within modularity

It becomes apparent that modules play a key part in defining *modularity*, as they are seen as a standard unit (Baldwin and Clark, 2000; Gershenson et al., 2003; Chorpita et al., 2005; Bask et al., 2010). Yet, there is a lack of agreement on how to define modules (Miller and Elgård, 1998). Some authors focus on structure and define a module as a set of physical components or building blocks (Ulrich, 1994; Newcomb et al., 1996; Gershenson et al., 2003; Hölttä-Otto et al., 2012; Pakkanen et al., 2016), while others refer to modules as a functional unit (Chorpita et al., 2005; Garcia and Trinh, 2019; Piran et al., 2020) or carriers (Bonvoisin et al., 2016).

Within the architecture context where the term module originated, a module was used as a standard measure of length, meaning that each module has the same characteristics to be able to be built into a system and thus, ensure the right property in architecture (Miller and Elgård, 1998). This paper summarizes the key attributes of modules from three aspects:

1) Functionality:

Functionality can either be seen as the function a module possesses (Sanchez and Mahoney, 2001; Chorpita et al., 2005; Garcia and Trinh, 2019) or how modules aid the functionality of modularity and thus are part of a whole (Ulrich, 1994). Within this paper, we refer to *functional modules*, which implies that a module can be utilised with the incorporation of standard interfaces (e.g., zips, buttons, eye, and hook). Here the standard measure of length refers to the compatibility of interfaces, thereby allowing different modules to be connected. For example, sleeve modules will need to have the same interface (e.g., zip, button) as the core of the garment, in order to be attached.

2) Independence across modules, and interdependence within a module:

Modules are structurally independent (He and Kusiak, 1996; Galvin et al., 2020) allowing them to be adjusted without affecting the whole. This independence across modules is secondary to the independence within a module (Baldwin and Clark, 2000). The latter is achieved by interacting, combining, and configuring a module with others through standard interfaces (e.g., zips, buttons) (He and Kusiak, 1996). Here is where the collaboration between Feng Chen Wang and Nike comes into play, in that sleeves and other parts of a jacket can be reassembled to form a skirt. Thus, individual modules are independent, but have an interdependence in that they need to have the same interfaces to be connected.

3) Compatibility:

The compatibility of modules refers to the ability to connect modules through interfaces. If modules have the same interface (e.g., same zip, same buttons/holes) they can be mixed and matched within the same family or even across module families.

Within this section, the link between modularity and modules has been established, which is vital in understanding that there are two different approaches to discussing 'modularity'. The next section centres its attention on modules and their interface.

2.3. Modules and interface: importance for modular garments

To fully understand what modular garments are, it is vital to understand how *modules* and *interfaces*, can be translated within the fashion design context. Niinimäki and Hassi (2011) were one of the first to link a modular structure to fashion design. Within their conceptualisation modules are seen as *detachable parts*. Gwilt and Pal (2017, p.151) further explain that *detachable parts* can be 'replacement, repair or even adaptation' parts of a garment. Examples of *detachable parts* are 'sleeves, front and back panels, collars, and cuffs' (Gwilt and Pal, 2017, p.151).

In assuming that *detachable parts* are the same as modules, a key question that emerges is how many modules does a garment have and

what are the different interfaces and design rules? To address this question, the example of outwear is used. Conventionally, outerwear consists of three to four sections: main body, sleeves, collar and/or hood (Fig. 1). Within 'traditional' garment design (non-modular) each of these modules are stitched together with garment panels, thereby creating a shape that fits the human body (Hinds and McCartney, 1990). Any garment panel, sewing threads and decorations sewn or attached to the finished garment can be seen as subsets of a garment module, known as components. Thus, the definition of *garment modules* in outerwear is summarized as follows:

- Garment modules are detachable parts including the main body, sleeves, collar module and/or hood.
- These garment modules are made up of garment components constructed from garment panels and other elements that are sewn or attached.

It can be said that *modular garments* are not complete garments (Chen and Li, 2018), but rather a collection of modules that can be assembled and disassembled. A modular garment can be understood from three dimensions: structure, function, and system (Table 1). The structure dimension implies that a *modular garment* is made of detachable *garment modules* consistent of different *garment components*. The functional dimension indicates that a *modular garment* not only consists of different garment modules, but each of these modules serves a different function. Finally, from the perspective of a system a *modular garment* can be understood as an entitative subsystem whereby hierarchies exist in terms of decomposing and reassembling garment modules through interfaces.

2.4. Standard interface in modularity

The interface plays a critical role not only in terms of connecting individual modules (detachable parts), but also in terms of the modular architecture. It is argued that interfaces can distinguish non-modularity from modularity (Galvin et al., 2020) because interfaces work like on-off switches that control whether a product or system can be deconstructed or not. The characteristic of being able to deconstruct and reconstruct an item is aligned with a hierarchy and is a key feature of modularity. An interface can also be used as an indicator when assessing the degree of modularity in a product/system (Fixson, 2005). To ensure the highest amount of modularity, standardized interfaces should be used (e.g., same zip length, same button size, same size of hooks and eyes), as this allows compatibility amongst modules and thus, allows for modules to be decoupled and recoupled repeatedly. Therefore, it is the standardization of interfaces that plays a significant role in determining the nature of modularity and in improving the degree of modularity and compatibility amongst modules.

Table 1
Defining modular garments from three dimensions: structure, function, and architecture.

Defining modular garment from three dimensions		
Structure	Function	System
Made up of detachable garment modules (such as the main body, sleeves, collar, or hood) which is the basic unit and is constructed from garment components (such as garment panels and sewing threads)	Achieved by assembling different detachable garment modules that serve different functional roles	An entitative subsystem where hierarchy exists when decomposing and reassembling through the interface between garment modules

Within the fashion context *interfaces* are defined as connections between modules, and thus can be interpreted as the linkage between garment modules (e.g., closure systems) (Baldwin and Clark, 1997, 2000). The properties of the closure system can correspond to those of interfaces. Firstly, closure systems can be used to control the condition of a garment. To explain, closure systems determine whether a garment is open or closed thus enabling wearers to take on or off a garment (Khalil, 2015). Closure structures fulfil the requirement of being an interface for coupling and decoupling garment modules. Moreover, this process is reversible without affecting garment modules' independence both in terms of structure and function.

Secondly, closure assemblies are standardized in specifications but offer various choices to meet different demands on the market. For example, when using a zip as a closure method for one garment, this zip can be any material and/or colour, as long as the size is matchable. Similarly, garment modules sewn together with closure assemblies are

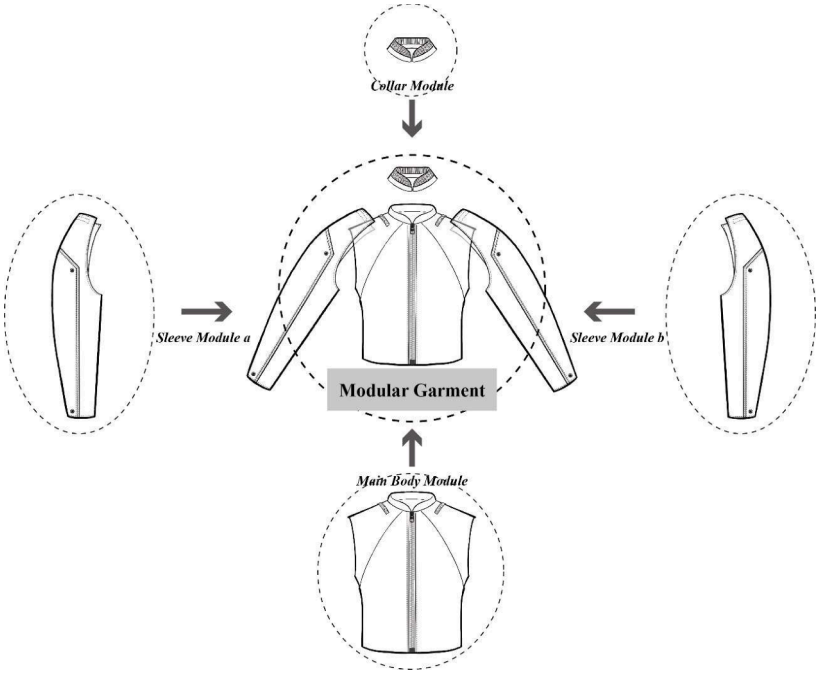

Fig. 1. An example of modular outerwear which is assembled by four detachable garment modules: two sleeve modules, a main body module and a collar module.

standardized and thus, can be mixed and assembled, during which it demonstrates its compatibility and achieves one-to-more mapping. Thus, closure assemblies can be classified as interfaces, as they are deciding how garment modules interact within and across the garment module family.

However, there are various challenges. For example, currently, garment design uses various closure assemblies, including, but not limited to zips, buttons, knots, hook-and-bars, Velcro and loop closures with clothing ties or ribbons. This may have an impact on modularity, as only modules with the same interface can be connected. Unlike in computer science, where interfaces do not necessarily have to endure a lot of tension, tension plays a vital role within the fashion industry context. If garment modules are envisioned to be disassembled multiple times, the closure assemblies (interfaces) need to be robust.

It has to be noted here tension is not the only aspect that needs to be considered in the design process. Linking back to sustainability designers may need to think of environmental benefits and/or drawbacks of different interfaces. For example, zippers are often made from mixed materials that are hard or even impossible to recycle. Buttons on the other hand can be made from plastics and/or animal products, both of which have environmental and ethical implications (e.g., The Cotton, 2024). As such, ties and ribbons may be seen as a more sustainable interface solution, especially from an environmental angle. Yet, it has also been outlined that ties and ribbons, as well as zippers can be challenging to use for anyone with dexterity issues (e.g., Rocket, 2021). Although it is out of scope within this article to explore all challenges associated with interfaces, these need to be considered within the design process. Within this conceptual paper zips are used as examples, as these are currently the most utilised interfaces within the fashion industry (Rahmen and Gong, 2016). Fig. 2 provides a visualisation of zips as closure interfaces.

It is noteworthy to highlight that closure interfaces should align with the following three properties:

1. Standard specification

In order to ensure compatibility, closure interfaces need to be standardised and thus have, for example, the same type, length and size.

2. Having a binary property being coupled and decoupled

For ease of use, closure interfaces need to be simple and solely have two functions, to either attach or disassemble modules.

3. Revisable allowing one-to-more function mapping

Revisable here means that closure interfaces should be compatible across different garment modules, which would allow modules to be used across different modular designs.

Following on from discussing the individual components describing modularity the modularisation process is described.

2.5. Modularisation as a process

Modularization is a process of practising modularity and thus, a design activity (Bonvoisin et al., 2016) where structural changes happen (Miller and Elgård, 1998). The modularization process entails the identification of three factors: the module, the interface, and the modular architecture (Andreasen, 2011; Pakkanen et al., 2016). Modularization involves decomposition and encapsulation, giving rise to the hierarchical structure. This intrinsic process leads to the formation of a cluster of individual modules and interfaces that are broken down from the entirety of the system (Erikstad, 2019). In turn, modules can be encapsulated reversibly through the standard interfaces. During this modularisation process, the *modular product* is created. Fig. 3 showcases the modularization process using the example of outwear.

It is noteworthy to highlight that the modularisation process does not occur randomly; instead, it is carefully designed, and linked to the design rule of modularity (Baldwin andClark, 2000). Total decomposition may be a prerequisite for complete modularity, but complete modularity is rarely achieved (Simon, 1996).

According to the architecture of *modularity* (modularization process, Fig. 3), modular garments can be seen as products or subsystems generated from and controlled under a larger system. Within this paper *modular fashion* is used as an overarching term that encapsulates the individual elements of a modular garment. The current fashion system (design-produce-marketization) may see a revolution through the emergence of modular fashion, as it provides possibilities for designing, manufacturing and marketing garments in a manner of individual garment modules instead of a whole piece of ready-to-wear. Thus, modular fashion can be seen as a new concept that features modularity throughout a product's lifecycle.

Fig. 4 synthesizes the definitions of *garment modules, modular garments* and *modular fashion* through the use of outerwear. As aforementioned, garment modules are constructed of clothing panels and sewing threads. Regarding standard interfaces, these are translated into the fashion design context as closure interfaces, and thus allow the assembling or dissembling of individual garment modules, though, for example, zips. Closure interfaces are two-way (binary) processes in which half of the closure interface is on, for example, the main body and half on the sleeve.

A contribution of this paper is that modular garments are not seen as finished products, but rather as those that are assembled through garment modules based on closure interfaces. Similar to the independence of modules, each garment module is structurally independent, but can interact with other garment modules within or across a garment

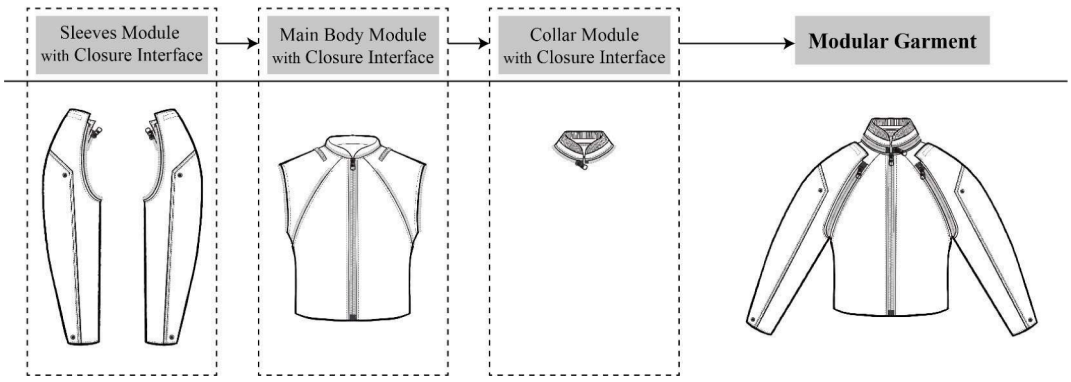

Fig. 2. an example of modular outerwear assembled with three types of modules, sleeves, main body, and collar modules through the standard closure interface. In this example, the closure interfaces used are zips.

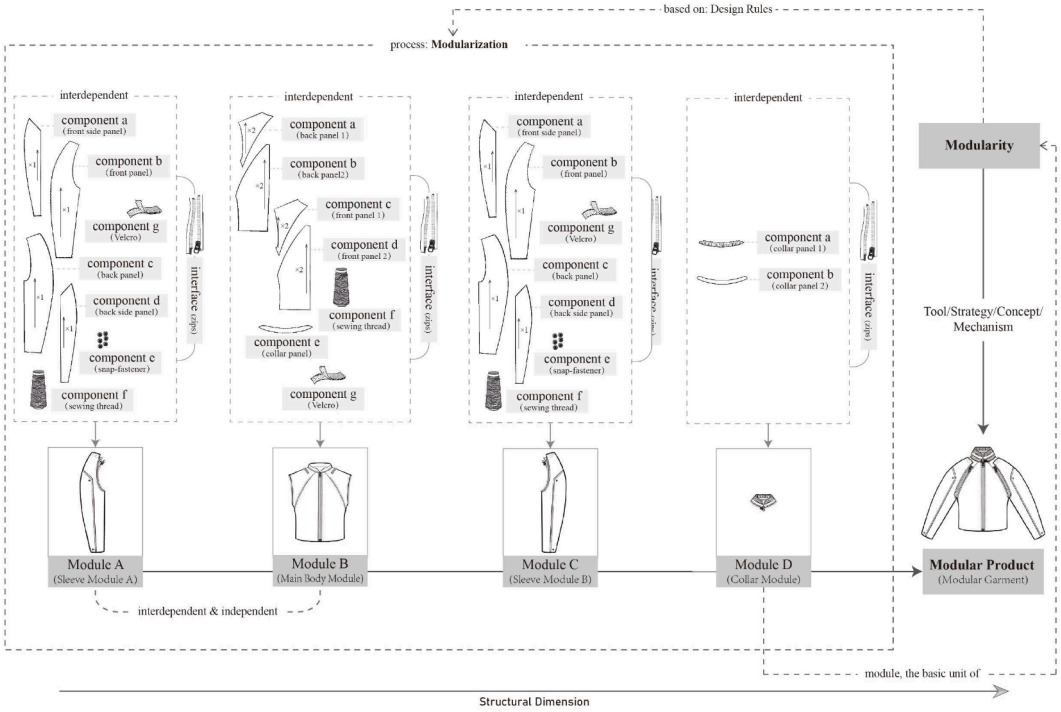

Fig. 3. The relationship amongst terms within the framework of modularity (exampling with a modular outwear): module-as-unit, modularity-as-property (mechanism), modular product-as-production, modularization-as-process, illustrating modularity from a structural dimension.

module family. This compatibility is beneficial from the perspective of closure interfaces that have standard specifications and are reversible and reusable (referring to the two-way separating zips).

Additionally, garment modules can be grouped according to their potential functions. As shown in Fig. 4, *module A* is a group of garment modules that can potentially function as sleeves, while those garment modules grouped in *module B* demonstrate another potential function as the main body. This function grouping allows consumers to quickly target their desired potential function from the multitude of available garment modules, thus being a solution to facilitate consumers' requirement for mass customization.

A key contribution of this article is the clear distinguishing features between garment modules, modular garments, and modular fashion, which is summarised as follows:

- A **garment module** consists of *garment components* and *closure interface(s)*. Garment components are constructed by garment panels and other clothing elements. Garment modules are the basic composition of modular garments. Structurally, garment modules are independent but compatible, being able to interact across the module family through standard closure interfaces. Functionally, garment modules cannot function individually but have potential functions, which are the indications for function grouping.
- Structurally, a **modular garment** is not a piece of a complete garment, but a clothing combination assembled with detachable *garment modules* through standard *closure interfaces* (zips are recommended from the perspective of durability). From a system perspective, garments can be viewed as entitative subsystems where hierarchies exist with the decomposition and reassembling. Functionally, to function as a wearable garment, different garment modules need to be assembled and serve different functions.
- **Modular fashion** can be regarded as a large system where and how modular garments work (modularization) and how design rules are involved. The modular mechanism of modular fashion reveals a concept that features modularity throughout a products life cycle and accommodates modular garments.

3. Link between modular fashion and sustainability

Table 2 provides a summary of key aspects outlined thus far in the article, which is needed to further discuss issues surrounding sustainability.

As suggested in the introduction, the origins of modular fashion and modular design in more general terms can be traced back to the mid-17th century. Whilst the original thought process behind designing garment modules may have had practical connotations, of being able to wash only parts of the garment and/or quickly adapting to new fashion trends, these can be linked to sustainability practices in the 21st century. To explain, one of the biggest problems to date is the expansion of fast fashion. Researchers put forward that extending the lifetime of garments is critical in slowing down the whole fashion industry and developing sustainable fashion that could counteract the negative environmental impacts associated with fashion waste (Cooper and Claxton, 2022).

Modular fashion, as part of the sustainable fashion concept, is seen as a solution and thus, has received more attention as a creative and sustainable design strategy (Chen and Li, 2018; Gwilt and Pal, 2017; Koo et al., 2014). Modular fashion, and more specifically modular garments, features standard modules (e.g., sleeves, collars) (Gwilt and Pal, 2017) that can be assembled to achieve new looks of the same garment with different functions (e.g., long sleeve versus short sleeve t-shirt) (Koo et al., 2014).

In line with what could be observed in the past, modular fashion is regarded as a sustainable design approach that has the potential to increase garment longevity due to the changeability of individual parts and the potential emotional durability (Fletcher and Grose, 2012; Gwilt and Pal, 2017; Y. Chen and Li, 2018). Modular garments enable consumers to be part of the design process, as they can add or remove different modules (e.g., long versus short sleeves), in line with their style and preferences. During this modularization process, an emotional bond between garments and wearers could be created, thus facilitating garment longevity (Koo et al., 2014; Maldini and Balkenende, 2017; Chen and Li, 2018).

Furthermore, modular garments could provide a solution to the

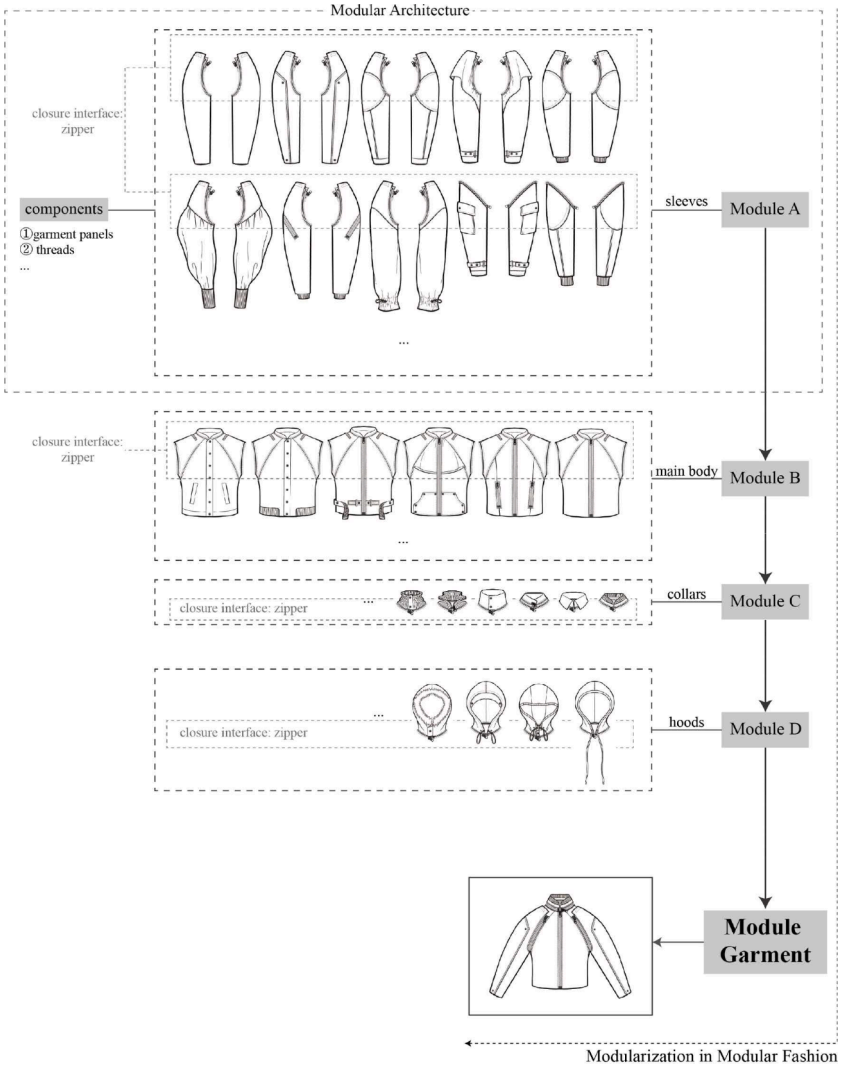

Fig. 4. a conceptual framework of modular fashion exampling with modular outwear.

increased 'fashion appetite' by only replacing parts of a garment rather than its entirety and thus, reduce consumption (Kamrani and Sa'ed, 2002). Simultaneously, this would offer an easier way for repair (Connor-Crabb et al., 2016). Modular garments are adaptable with easy adjustments in the manner of detaching, mixing, matching, and assembling different parts, for example, zipping and unzipping pieces (Chen and Li, 2018).

Given this modular structure and the reversibility, modular garments provide the possibility of an aesthetic upgrade, separate repairs and washing option by removing modules and reassembling them after (Chen and Li, 2018; Connor-Crabb et al., 2016; Fletcher, 2008). Accordingly, the overall consumption might be reduced to only buying a module rather than buying a whole garment (Connor-Crabb et al., 2016). This shifting consumption pattern might lead to a business model revolution (Fletcher and Grose, 2012) and bring along an innovative fashion system.

However, despite the promising sustainable potential of modular garments and the increased interest in the subject matter (Niinimäki and Hassi, 2011; Gwilt and Pal, 2017; Chen and Li, 2018), there is no consensus on the definition of modular garments and/or modular fashion. This is mainly a result of the ambiguity of their etymology, the definition of "modularity". Following on from the previous discussion, this article addresses this issue by defining modular garments based on what "modularity" is and illustrates modular outwear as an example. Nevertheless, if the sustainable potential of modular garments is to be truly exploited, the other key lies in how modular garments can be put into practice over a continued period of time.

Although some companies have started using modular fashion (e.g., Boohoo's detachable shirt (Boohoo, 2024)), this seems to be more of a one-off or comes at a high price, thus, environmental benefits may not be currently measured and/or fully capitalised on. This is evident from the lack of follow-up launches of series garments after marketing their original modular design. Apart from the absence of established theoretical guidance, the unavailability of a mature, compatible and corresponding business model limits the survival of modular garments in a market dominated by fast fashion.

However, there are several challenges in the development of modular fashion as a feasible and sustainable concept. First, it is about how to make universal design rules across the fashion industry. The design rules need to answer a series of key questions about compatibility, such as how to classify garment modules to reduce unnecessary overproduction and how to choose closure interfaces in terms of types, materials and specifications to achieve practicality, compatibility (maximize the assembling of garment modules across brands), and sustainability. This may be especially difficult seen as brands seek to stand out from their competition and may use a diverse range of interfaces. Second, it is about how to make modular fashion a sustainable choice rather than just another trend or fast fashion phenomenon. To explain, there may be a risk of overconsumption of individual parts of the garment and/or increased wear and tear where modules are re/de-

Table 2
A summary of modularity and modular fashion, as well as a comparison between modularity and modular fashion from five aspects: a general definition; structure dimension; system dimensions, properties, and relationships. Additionally, a secondary definition of modular fashion is interpreted from the business perspective. These outcomes are gained by synthesizing different authors 'viewpoints (mainly Miller and Elgård, 1998; *Baldwin and Clark, 2000*; *Gershenson* et al., *2003*; *Fletcher, 2008*; *Sako, 2003*; *Salvador, 2007*; *Niinimäki and Hassi, 2011*; *MacDuffie, 2013*; *Fletcher and Grose, 2012*; *Chen and Li, 2018*).

Modularity			Modular Fashion			
a tool, strategy, concept, or mechanism used to simplify a complex system, product, or problem			overarching term used for the individual elements of modular garments, which can be translated into a concept			
Structure Dimension	**System Dimension**	**Properties**	**Structure Dimension**	**System Dimension**	**Properties**	**Concept**
• its production is ***modular products*** that are made of *modules* and standard *interfaces.* • each *module* is constructed by *components*. • *module* is the basic unit of modularity	• through standard *interfaces, hierarchies* are generated when the whole is decomposed • *modules* are ***subsystems*** within a larger system (modularity)	• *components* are interdependent • *modules* are independent but compatible • *interfaces* are standardized, can be coupled and decoupled, and also reversible, allowing one-to-more mapping • the overall function is achieved by assembling modules through interfaces	• its production is ***modular garments*** that are made up of *detachable garment modules* and standard *closure interfaces*. • each *garment module* (such as the main body, sleeves, collar, or hood) is constructed by *components* (garment panels and other elements such as sewing threads and decorations • zips are competitive choices for *closure interfaces*	• through standard *closure interfaces, hierarchies* exist when decomposition and reassembling • *modular garments* are ***entitative subsystems*** within a larger system (modular fashion)	• *garment modules* are independent but compatible • *closure interfaces* are standardized, can be coupled and decoupled, and also reversible, allowing one-to-more mapping • the overall function is achieved by assembling garment modules having different potential functions	a concept model that features modularity throughout the whole fashion industry stages (design-produce-distribution-selling-end-of-life) and accommodates modular garments
module-as-unit; modular product-as production; modularization-as-process; modularity-as-property			garment module-as-unit; modular garment-as-product; modularization-as-process; modular fashion-as-system/business model			

attached. The latter could lead to discarding garments prematurely. Moreover, the actual choice of interfaces needs to be looked at, as not all materials are environmentally friendly. As alluded to earlier, some materials may be made from finite products (petroleum) or animals (horn), all of which bear sustainability and ethical challenges.

Within this conceptual paper, zips have been used to illustrate how modular garments work. A reason for this choice is that zips are said to be durable and easy to use (Rahman and Gong, 2016). Yet, seems that zips do not only have advantages, they are also made from mixed materials and thus, can be seen as unsustainability.

Despite various challenges surrounding modularity in the fashion design context, it has the opportunity to challenge current practices and could become a viable alternative. Yet this involves collaborations across disciplines and partnerships with consumers, designers and manufacturers beyond existing boundaries (Hur and Thomas, 2011). Modular fashion will bring consumers into the process of modularization and designers will be required to have a more in-depth exploration of garment patterns (Niinimäki, 2013). With the increasing interest shown in the sustainable potential of modular garments (Gwilt and Pal, 2017; Koo et al., 2014; Niinimäki and Hassi, 2011), it would be a worthy attempt for a sustainable future to explore and initiate modular fashion as a new business model, in which modular garments can find themselves a suitable industrial pattern and marketing manner.

4. Conclusion

In this paper identified that it is important to define modular fashion before considering modular fashion as a sustainable fashion solution. To the authors knowledge this is one of the first articles that answers a long-neglected but vital question about what modular fashion is based on reviewing what "modularity" entails, thus setting out a conceptual starting point for future research on modular fashion. This article distinguishes *modular fashion* from *modular garments,* and *modular design*, illustrating conceptual frameworks with modular outwear as examples and interpreting the concept of "module" and "interface" from "modularity" into the context of fashion design.

This article contributes to the definition of modular garments. We outline that modular garments are not complete and wearable items but are clothing combinations assembled with detachable garment modules (e.g., main body, sleeves, and collars) through standard closure interfaces (e.g., zips, buttons, hook and eyes or ribbons with loop closure standard in the specification). This article also contributes to conceptual framework of modular fashion, which is regarded as an overarching term used for the individual elements of modular garments and a concept that features modularity throughout a products life cycle and accommodates modular garments. Within modular fashion, the sustainable potential of modular garments can be explored and put into practice. As such, this article contributes to sustainability and product lifetimes, seeing as modular fashion offers a solution to extend the life of garments, by solely focusing individual modules rather than replacing full items. Developing a definition for modular fashion enables designers and researchers to communicate in the same language and design new processes that could foster stronger collaborations. Although there are still challenges that need to be overcome the concept of modular fashion could be a viable option for the future.

Further areas of research could focus on the refinement and the practice of modular fashion, such as the design rules associated with how to modularize garments and design interfaces, as well as how to build collaborative relationships across the fashion industry. There is a need for future research to answer these questions so that the conceptual framework can be refined to provide guidance for sustainable implementation. Future research should also investigate interfaces used and the implications of using them from an environmental but also accessibility point of view.

Spotlights

- The lack of consensus on defining modular fashion despite its promising sustainable potential and interest increasing.
- Defining modular fashion based on reviewing what "modularity" entails and distinguishing it from similar terms.
- Creating a conceptual framework of modular fashion with modular outwear as an example.
- Promoting industry-academics communication and collaboration with the same language about modular fashion
- Setting out a conceptual starting point for future research on modular fashion as a sustainable fashion solution

CRediT authorship contribution statement

X. Zhang: Conceptualization, Formal analysis, Writing – original draft. **A. Le Normand:** Conceptualization, Supervision, Writing – review & editing. **S. Yan:** Supervision, Writing – review & editing. **J. Wood:** Conceptualization, Writing – review & editing. **C.E. Henninger:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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