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Reconsidering End-User Experience of Circular Product Design

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Abstract: Considering end-users is key in the transition towards the circular economy. Without the participation of the user, the circular economy will not be realized. However, in order to engage, users need to perceive the opportunity of contributing to the circular economy, and the product must include the user through activities that support circular goals. In this paper, the perceptual product experience of circular product design is explored and opportunities for circular user experience are identified.

Keywords: Circular Economy, Circular Design Strategies, User Experience, Perception, Inclusion

1 Introduction

It is clear that the role of end-users in the circular economy is crucial, as their behavior and acceptance of circular business models can significantly impact the success of such models (Lofthouse et al., 2017, Knošková, 2020, Wastling et al., 2018, Camacho-Otero, 2018). There is a need for a more profound consideration of user experience in both research and practical implementation, with a focus on the importance of incorporating the needs, desires, and values of end-users in the circular economy (Lofthouse et al., 2017). Design strategies that encourage circular behavior are critical, as the design of products and services can influence user behavior (Wastling et al., 2018).

Few studies address the end-user perspective, including the user experience of the product, in contributing to circular economy and sustainable behavior. As noted by Lofthouse and Prendeville (2017), “there is a need for a more profound consideration of users in both the research activity and practical implementation of the circular economy, where the real needs, desires and values of the end user are incorporated from the outset, whether as part of research agendas, theories, frameworks or business models.”

Selvefors et al. (2018, p. 2046) state that “much of the discussion regarding product circularity is framed from a production and business perspective”, continuing that a re-framing of circularity from a user perspective is needed, which considers issues of consumption more in-depth. This paper, therefore, focuses on considering the end-user perspective. According to Kirchherr, end-user perspectives are under-researched (J. Kirchherr, personal communication, May 13, 2024). In fact, Camacho-Otero (2019, p. 928) state that “lack of consumer and user acceptance of circular offerings is one of the primary barriers for the transition to a circular economy.” In addressing this issue, Selvefors et al. (2018, p. 2046) suggest an enabling approach, the design of products and services that create preconditions that enable people to circulate products.

Many approaches for sustainable design and life cycle design have been proposed, which take a production, business model, supply-chain innovation, reverse logistics, economic or material-centered focus. However, as the successful implementation of the circular economy depends on user involvement, the end-user experience of circular products and services is essential and has been largely neglected. Addressing this lack, Bakker et al. (2014) call for consideration of “new experiences and relationships with products".

Building on this realization, Aguiar et al. (2022) argue that designers and practitioners need to understand the cycling dynamics of products and what strategy can be applied to each product or component (e.g. reuse, remanufacture, repair and recycle). For example, the study of van Dam et al. (2020) revealed a number of thematic areas where industrial design research contributes to the circular economy, including design for circular production processes, circular consumption, design education, and policy, but none of the 63 articles reviewed address the characteristics of the product itself. As noted by van Dam et al. (2020), “industrial design can contribute to a circular economy by fostering systems changes to achieve durability, optimal reuse, refurbishment, remanufacturing, and recycling of products and materials”, further adding that “a design-driven approach can enable firms to understand, anticipate, propose, and influence new product meanings and languages” (Gallagher et al., 2018).

The report ‘Closing the loop’ (European Commission 2015, p. 6) points out the potential of designing products that are more durable, easier to repair, upgrade, remanufacture, and disassemble (Daae et al., 2018). Furthermore, the report notices that “the choices made by millions of consumers can support or hamper the circular economy”. However, despite the need

pointed out by the European Commission (2015), few studies have focused on how the characteristics of the design of the product contributes to circular economy and sustainable behavior beyond general principles.

In response to the need of user-centered approaches to understand and enable sustainable consumer behavior in the circular economy, this paper thus explores the dimension of user experience of existing product categories. As pointed out by Daae et al. (2018, p. 523), it is paramount that products designed for a circular economy are designed to encourage actors in the economy to behave in the desired way. The end-user's experience of a product contributes to the perceptions and values associated with the product, and it is thus central that the product communicates values which support sustainable behaviour. In this paper, such dimensions of end-user experience are illustrated by two product examples, claiming to offer sustainable and circular products to the consumer product market.

2 Method

Given the overview provided above, this paper aims to answer the research question "How may end-user experience be considered in circular product design?"

The research employs an exploratory approach, aiming to identify concepts and develop approaches which address the research question. As such, the research employed an initial sourcing of material using the AI-based tool Elicit (2024). The tool was asked to "summarise current research on (*topic*) with references to key articles", where (*topic*) included circular economy, the role of end-users in the circular economy, product design principles and strategies in the circular economy, user experience in the circular economy, principles of design for the circular economy, how end-users and consumers can become key actors in the transition towards the circular economy, and the barriers of involving end-users in the circular economy. This phase yielded 31 papers. After a first screening, this phase was supplemented by a qualitative review in which all papers were fully read, followed by sourcing of additional papers to this initial set using snowballing. While some papers were considered irrelevant for the research question treated in this paper, snowballing supplemented additional papers, resulting in a final selection of 48 papers. Additionally, real-world examples of circular product design considering end-user perception and product experience were used to exemplify circular design strategies identified in the literature.

While the literature review contributed by identifying and clarifying dimensions of end-user experience associated with the circular economy, the research furthermore proposes an approach to analyze potential end-user experience using an analysis framework applied to two existing product categories. Two product examples were chosen, which illustrate products employing two circular design strategies as described by Bokken et al. (2016). Product information relating to intended user value was collected using available information from the manufacturers' websites, which was analyzed using the framework of PPE, Perceptual Product Experience (Warell, 2008). The framework and its application on the selected product cases is presented in sections 4 and 5, respectively.

3 User behaviour and the circular economy

Implementing the strategies for circular product design means that users need to change current practices and behaviors into more sustainable ones. Such behaviors include "returning or reselling an item to the retailer or a third party rather than throwing it away, self-repairing products, purchasing something that has been pre-owned or remanufactured, renting rather purchasing items, or paying more for an item that will last longer – and then keeping and using it rather than buying a new one" (Daae et al., 2018).

However, circular behavior may not be supported by the product, and the user may not be aware of the possibilities to engage in the circular economy. Kirchherr et al. (2017a, p. 7) found that the lack of consumer interest and awareness is a "main impediment regarding a transition towards CE". Furthermore, Kirchherr et al. (2017b) highlighted that not enough is known about why consumers would participate in the circular economy or not.

Research suggests that the availability of design approaches that support circular design may be a factor obstructing progress. According to Daae et al. (2018), several authors (Schotman and Ludden 2014, Piscicelli and Ludden 2016, Kirchherr et al., 2017b) highlight the lack of focus on the roles of people's everyday activities and the designs and business models that promote or hinder these. Daae et al. (2018) continue by noting that design for sustainability literature typically has had a limited focus on the use phase (Boks and McAloone 2009) and even less on user behavior. They note that "several studies have provided frameworks and principles for circular design and practice, advocating preservation of resources through long use, extended use and recovery of products (Den Hollander et al. 2017; Bakker et al. 2014), or slowing or closing the loop by advocating sufficiency, designing for disassembly, extending product lifetimes or facilitating access over ownership (Bocken et al. 2016)."

Examples of behaviours that need to be promoted and supported through sustainable product design include fault-diagnosis, repair, cleaning, upgrade, maintenance, refurbishment, self-customizing, disassembly, sorting, and re-purposing

(see, e.g., Aguiar et al., 2022). To support viability and sustainability, such activities should ideally be possible to be performed by the end-user him or herself, or by a provider which allows for affordable and convenient access to so such services. The "right to repair" movement has resulted in legislation in several countries, including the EU and the US, giving consumers increased access to repairs, including the right to repair products themselves (European Commission, 2024).

It is important that the product supports and promotes circular user behavior. Luchs et al. (2012) showed that consumers are faced with trade-off decisions when choosing between a product which is perceived as more sustainable, versus a product which is perceived as having superior functional performance. They argue that "the effective use of product aesthetic design can improve the relative choice likelihood of sustainable products" (Luchs et al., 2012, p. 904) by overcoming the potential lack of confidence in sustainable products. Thus, they highlight the significant importance of product appearance in the design of sustainable products.

Aesthetics is not only a determinant for the perception of sustainability, however. Other perceived aspects also need to be experienced favorably by the user in order to support circular behavior. Several studies (e.g., Bloch 1995, Creusen and Schoormans 2005, Hoegg and Alba 2011) show that product appearance (or aesthetic design) also influences inferences about the product's quality and functional performance. Moreover, a significant body of research has shown that the perception of the product appearance contributes to the user's entire experience of the product, including emotional response (Desmet, 2002), meaning (Krippendorff and Butter 1984, Vihma 1995), understanding of use (Monö, 1997), development of attachment (Mugge et al., 2008), and product identity (Karjalainen and Warell, 2005).

Furthermore, as noted by Aguiar et al. (2022), several authors (including Den Hollander et al. 2017, Sinclair et al. 2018, Sumter et al. 2020) argue that the objective of circular product design is not only to maintain the physical integrity, but also the emotional durability of products in order to ensure that they can be used and reused by different users in multiple cycles. For example, the product must age with grace, evoke attachment, and allow for customization and refurbishment, in order to enhance longer-lasting empathic relationships between products and users over time (Moreno et al. 2016).

4 User perception of circular product design

As shown, research has addressed how circular design principles can be applied to change behavior. However, as noted by Tromp et al. (2011), although this influence plays an important role in the effectiveness of the design intervention, it is rarely discussed how the user may experience this influence.

Lofthouse et al. (2017) states that user choices are not wholly rational but are influenced by a multitude of diverse and complex factors such as socialisation, living conditions, alternatives on offer and the cumulative effects of past choices (Vezzoli & Manzini, 2008). Furthermore, as Daae et al. (2018) point out, "for a circular economy to function successfully, it is not only necessary to have systems in place to enable the various circular goals (reuse, refurbishment, recycling, etc.) but also to increase the likelihood of consumers (or users) to behave in accordance with the goals."

User response to product design is determined by the subjective experience of the product. Temporal, spatial and contextual factors influence the experience, as does goal orientation, psychological and environmental factors. A well-designed product offers new possibilities and extends our mental and physical capabilities. In order to be included in the circular economy and contribute to circular product flows, users need to perceive the opportunity of the circular product offer, and to be equipped with the opportunity to engage through activities that support circular goals.

In this paper, the perceptual product experience (PPE) framework (see, e.g., Warell 2008a, 2008b, Warell and Young 2011) was employed to provide a structure for an initial exploration of perceptual user experience of circular product design. The framework considers product experience as composed of three core modalities; the sensorial, the cognitive, and the affective modes of experience (see Figure 1). The core modes are related to the three different levels of function and processing within the brain: visceral, behavioral and reflective, as proposed by Norman (2004). These three levels prompt distinct responses to products. Apart from the core modes, the PPE framework recognizes that the experience has a dual nature; that is, that the experience can be presentational as well as representational, as suggested by, e.g., Goldman (1990), Greeno and Moore (1993), Vihma (1995) and Visser (2006).

The presentation dimension may be seen as the 'pleasurable' side of the experience, related to the direct, non-interpretative experience, i.e., experiencing the product through explicitly sensory characteristics. The presentation dimension, which is related to Norman's visceral level dealing with automatic, rapid judgements of what is good or bad, is perception based and concerned with product appearance, and how it makes users and observers feel (Komninos 2020). The impression sub-mode is the essential and first part of the experience, becoming aware of a product as a result of it exhibiting salience sufficiently 'different' to stand out and be noticed. Appreciation is about recognition of aesthetic values, related to any of the senses. Emotion is the affective response evoked by the combination of product stimuli, subjective concerns and

appraisal (Desmet, 2002). According to Visser (2006, p.7), emotion is involved in the control of activity and thus influences decision making.

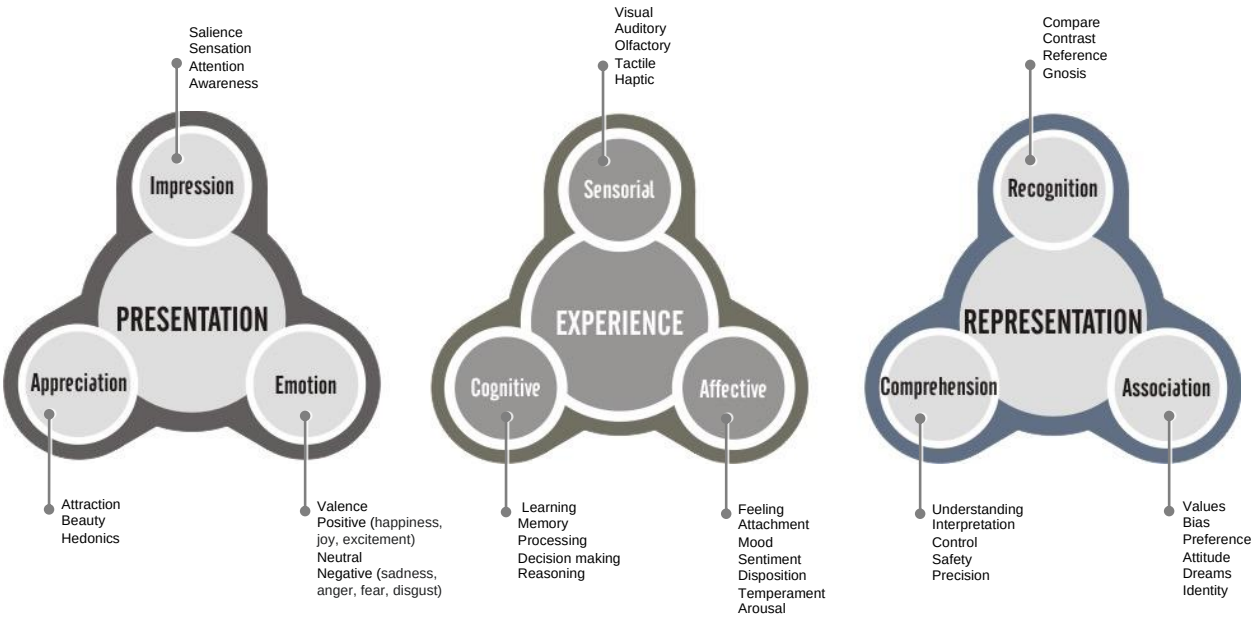

Figure 1. Framework of perceptual product experience (PPE) with core-modes (centre), and the two dimensions of presentation (left) and representation (right) with corresponding sub-modes. Illustrative experiential aspects of each mode are indicated.

In the representation dimension, the product is experienced through user interpretation of appearance, functionality and value. The recognition sub-mode is based on familiarity, resemblance or similarity, and requires previous precedents to compare with, enabling categorization. Through the sub-mode of comprehension, we understand characteristics such as quality and nature of the product; the product describes its operation, expresses its properties, and exhorts certain types of action or even nonaction; it informs and advises about itself. Product understanding, as explained by Monö (1997) through the semantic functions of describe, express, exhort and identify, are associated with this sub-mode. In the association sub-mode, meaning is created and interpreted from external and cultural perspectives such as manufacturer or society, and from personal and social perspectives of the customer or user, who communicates values and preferences through ownership and use of the product.

The representation dimension is related to Norman's (2004) behavioral and reflective levels and the practical and functional aspects of the product, often referred to as usability. The reflective level refers to the congruency with personal values and ideas, and how it contributes to meaning-making. It also influences the behavioral level by rationalizing contextual and environmental information (Komninos 2020).

5 Illustrating perceptual experience of circular product design strategies

Two product examples were used to illustrate how the perceptual product experience may be influenced by circular principles employed in the design of these products. The product examples were chosen to illustrate the two design strategies to slow loops as suggested by Bokken et al. (2016); designing long-life products, and design for product-life extension. Through presentation and representation, the products communicate these strategies in different ways. While the design strategy to close loops may also be considered, in terms of user experience, the two strategies (design for technological and biological cycle, respectively) are here considered to fall outside the realm of the perceived properties of the product as they relate to material characteristics. Note that the third principle of design for dis- and reassembly is also included in the design strategy to slow loops.

As seen in Table 1, the first example is the Fairphone 5, a smartphone which places heavy emphasis on including the user as a key actor in contributing to product-life extension (Bokken et al., 2016), relating to software as well as hardware, offering a 10-year life span. According to Fairphone (2023), the Fairphone 5 comes with a guarantee of at least five major Android OS updates till 2031. It also features a modular design, which allows the user to replace up to 11 parts if broken or outdated, 70% of the materials are either recycled or fairly sourced, and it is produced using 100% renewable energy.

The second example is the Stilride 1, an electric motorcycle which employs a long-life design strategy (Bokken et al., 2016). Designed using a novel technology for thin-walled stainless steel production, it utilizes minimal materials, creates minimal spill or waste, results in a 40% weight reduction, and utilizes 70% fewer components (Stilride, 2023). The design allows for local production minimizing transportation costs. Components are designed to be durable and long lasting, easy to replace while offering precision and quality, resulting in physical integrity and emotional durability.

Table 1 serves to illustrate potential user experiences mapped across the six perceptual modes of the PPE framework. The quotes illustrating value statements from the manufacturers' websites at the time of writing (Fairphone 2023 and Stilride 2023, respectively) are mapped against the perceptual core modes of the PPE framework. Thus, the rows stating "*Proposed user experience*" illustrate the perceived experience of a potential user, mapped against the value statements provided by the manufacturer in the row above.

Table 1. User experience dimensions categorized according to perceptual modalities of the PPE framework, exemplified by two product examples illustrating circular design strategies for designing long-life products and design for product-life extension.

Perceptual experience	**Presentation dimension**			**Representation dimension**		
Core mode	**Sensory**	**Cognitive**	**Affective**	**Sensory**	**Cognitive**	**Affective**
Sub-mode	**Impression**	**Appreciation**	**Emotion**	**Recognition**	**Comprehension**	**Association**
Experience modality	Attention and awareness through salient features or properties	Attraction due to personal aesthetic or instrumental benefit	Affective response evoked in relation to perceived offer	Engaging previous knowledge through similarity or mental connection	Understanding action opportunities and implications	Meaning, attachment, values of personal, cultural or social significance
Example 1	**Circular design strategy: Designing long-life products (Bokken et al., 2016)**					
Fairphone 5 (Fairphone, 2023)	**"A gorgeous, designed for you in every way possible"**	**"A modern European design that is stunning"**	**"Buying a Fairphone device means disrupting the electronics industry for the better"**	**"the Fairphone 5 is not adding to the rapidly increasing amount of electronic waste in the world"**	**"You can easily repair it yourself"**	**"Conscious sustainability choice with environmental and social benefits unmatched by any other smart phone brand"**
Proposed user experience	*Typical smart phone which has additional and unique circular design features*	*I get a phone which is sustainable yet as stylish and modern as any other phone on the market*	*It makes me feel proud and satisfied that I make a contribution to an environmentally and socially sustainable future by choosing this phone*	*I recognise the resource implications avilable in a well established and desirable smart phone form factor*	*Accessible fasteners and tools allow me to upgrade, service and repair at a reasonable cost, prolonging product life time*	*The product communicates to others that I value a conscious choice, care about the environment and identify with the mission of the brand*
Example 2	**Circular design strategy: Design for product-life extension (Bokken et al., 2016)**					
Stilride 1 (Stilride, 2023)	**"Uses a unique recipe of art, design, mathematics, geometry and material science"**	**"Combines cutting-edge design, technology, and sustainability to offer a smooth, fast, and eco-friendly ride"**	**"Our drivers should feel like they're in control, and that they're driving a luxurious and elegant bike"**	**"Avant-garde design that strikingly combines the past with the future. An extraordinary design with its own unmistakable identity" (German design award)**	**"70% fewer components and 40% weight reduction, reduces complexity, facilitates assembly, repair and disassembly"**	**"Pushes the boundaries of just how sustainable a motorcycle can be"**
Proposed user experience	*The unique appearance in durable folded stainless steel makes it stand out among other electric scooters*	*The 'industrial origami´ styling, finish and material qualities makes it look designed for durability and long life*	*I feel awed and inspired by the precision and sense of quality which makes it feel like it will last forever. Its lightness makes me feel satisfied about the use of resources and energy. I will pass this product on to my children*	*I get the classic look, material choice and design simplicity in a product that proposes a new sustainable iconicism*	*Controls are easy to understand and afford an exceptional feedback experience as a classic high-end analog camera, and if necessary, I can change motor and battery on my own*	*I am part of the industrial sustainable revolution*

6 Discussion

This paper serves several purposes. Firstly, it summarizes research in the field of circular user behavior and identifies areas of importance for user experience of circular product design. Secondly, it establishes the connection between circular product design principles and categories of perceptual user experience of product design. The connection between what

we perceive, the experience of the product, and what the product allows, and ideally encourages us to understand and do is critical. The two product examples illustrate potential circular user experiences and relate them to product values as stated by the manufacturers employing two different circular product design strategies.

Engaging people to partake in the journey from the 'linear' economy (make, use, waste) and accept the alternative circular and resource-conserving approach is a critical role for circular product design. However, this transition represents a societal, technological and behavioural paradigm shift, involving moving from seeing 'users-as-subjects' to 'people-as-participants' (Lofthouse and Prendeville, 2018). Realizing the opportunity for engaging in circular product flows implies that users need to become active participants in the circular economy. Incentives are needed on a personal basis, such as economic or social benefits, to make this transition relevant and attractive for the individual consumer. Although we have seen examples such as iFixit, which allows users to upgrade and self-repair their smart phones, this is not the norm for most products. Such solutions require dedicated effort to engage, awareness of possibility, knowledge about approaches, and capability to engage. It requires mental, social and operational capital.

Users must be provided with opportunity to understand that the circular behavior opportunities exist as part of the offering, and how to engage with them, whether through physical product design or service and business model offerings. This requires a fundamental shift in how designers are educated. Lofthouse and Prendeville (2017) note that "industrial designers are recognised as being very skilled at understanding the user, influencing values (Vezzoli & Manzini, 2008), attitudes and perceived consumer/user needs, which means they are well positioned to help change culturally dominant value systems (Wahl & Baxter, 2008)". Still, few design schools start by taking a sustainable, resource-based view towards the design of circular systems.

Most circular examples rely on business models rather than purposeful product design, e.g., models of sharing, renting, and product service systems (PSSs). While PSSs represent strategies towards circularity, they do however not recognize the potential to consider the role of product design and its ability to engage the end user in inclusive and participatory activities. The role of product design towards contributing to the circular economy, i.e., to enable users to become actors of instrumental and symbolic value creation, thus needs further exploration through the employment of circular design strategies.

As noted by Lofthouse and Prendeville (2018), "design places human experiences at the core of its practices (Dunne 2011) and this is acknowledged as an important starting point for meaningful innovation (Verganti 2008)." Hollander et al. (2017) highlight the need for a new set of principles, strategies and methods for circular product design, and argue that "product designers need guiding principles, strategies, and methods to guide the conceptualization and embodiment of their designs." This is emphasized by Aguiar et al. (2022), addressing the need to develop methods, tools and practices for circular product design.

However, new tools for circular design will not solve the sustainability problem. In fact, designing products which are adapted for, and thus become actors themselves in the circular transition, is fundamentally a flawed approach. Technological and economically based approaches tend to favor the opportunity of the technology before the needs of users or society. Sustainable innovation today means addressing the grand challenges we face. Designers, as well as consumers, need to reconsider the concept of need and critically examine whether a product is necessary. Hobson and Lynch (2016) argue for the necessity to address the "deeply embedded" societal issues of overconsumption and consumerism. Merely taking the relative approach (Faber et al. 2005, p.8) proposed by eco-design of improving what is already existing is not sufficient. Rather, den Hollander et al. (2017, p. 518) state that an absolute approach needs to be applied, by opening up the solution space and searching for truly innovative solutions (de Pauw, 2015).

Design thinking-based strategies as proposed by Brown and Katz (2009), starting with need-based investigation, offers an approach for more sustainable product, service and system design which is often radically different to current practices in many technology-based firms. This requires stepping up in system abstraction level, identifying the true needs based on identified challenges, and implementing solutions which meet the requirements of desirability, feasibility and viability of sustainable and responsible innovation.

This paper presents the application of the perceptual product experience (PPE) framework (Warell, 2008) to understand potential user experience of two product examples, chosen because they represent the use of circular design strategies as suggested by Bokken et al. (2016); designing long-life products, and design for product-life extension. While no real users participated in the study, the perceived user experience in each mode is hypothetical. Still, the chosen product cases serve to illustrate that aesthetic and experiential product properties have the potential to evoke attachment and enhance longer-lasting empathic relationships between products and users as suggested by Moreno et al. (2016). Furthermore, as argued by Luchs et al. (2012, p. 904), the cases illustrate how "the effective use of product aesthetic design can improve the relative choice likelihood of sustainable products" by overcoming the potential lack of confidence in sustainable products. Thus, they highlight the significant importance of product appearance in the design of sustainable products.

Future avenues of research should include efforts to empirically understand the experiential response of users to circular product design and the perception of opportunities to engage in circular system activities. Applied design research need to explore and investigate design opportunities and ways to engage the user by equipping them with the opportunity of becoming actors, with a circular participatory design approach to end-user experience and behavior change in slowing and closing resource loops. This requires not only innovative technology and business models, we need to design interventions that invite people to be fully included and engaged as active participants in this transition.

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