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Repair of electronic products: Consumer practices and institutional initiatives

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ABSTRACT

Electronic waste, or e-waste, is the fastest growing category of waste in developed countries and a threat to the environment and human health. The extension of electronic products life cycles could reduce the use of finite resources, the emission of pollutants, and the amount of waste disposed of in the landfills, delaying the impacts of disposal and product replacement. Consumers' decisions affect the environmental impact of a product since deliberate consumer effort is necessary to extend and fully explore the potential life cycle of a product. The objective of this article is to investigate current consumer practices in the repair of electronic products. To achieve this goal, we analyze recently published research presenting surveys and case studies about the repair of electronic products. The literature review identified a range of barriers and motivations that influence the decision to repair. We also examined how institutional initiatives to address product reparability, such as governmental directives, are responding to consumer practices. Our results emphasize the need for an environment that promotes and enables more sustainable behaviors. We discuss the necessity to consider not only technical aspects but also intangible aspects in public perception, such as the role of perceived obsolescence in the search for a more circular economy.

1. Introduction

Electronic waste (e-waste) became the fastest growing category of waste in developed countries and a matter of concern in developing countries (Balde et al., 2015), and is expected to double by 2050 (United Nations University 2019). Technological advancements and marketing cause consumers to search for more modern electrical and electronic equipment (EEE), promoting obsolescence, shortening the service time of products, and generating tons of electronic waste (Babbitt et al., 2009; Sabbaghi et al., 2015; Kumar et al., 2017). Moreover, the increase in the demand for electronic devices driven by the digitalization of daily activities, such as the trend to work from home (Islam et al., 2021), and the highly specialized and short-lived equipment used to mine cryptocurrencies (de Vries and Stoll, 2021), are other examples of activities with the potential to increase the generation of e-waste. E-waste presents a challenge because, although it is a valuable source of precious elements such as Gold (Au), Platinum (Pt), and Silver (Ag), these are amalgamated with several other substances that are toxic and hazardous to human health (Arya and Kumar, 2020) (Fig. 1).

The product life cycle includes all phases from inception to retirement, including production, use, and end-of-life handling (Keoleian and Menerey, 1994). Extending the life cycle of electronic products is key to sustainability and should focus on increasing the service time of the product, i.e., the period of active use (Zhilyaev et al., 2021). According to Cooper (2010), increased life cycles could reduce the use of finite resources, the emission of pollutants and the amount of waste disposed of in the landfills. Moreover, prolonging the service time of products would not only delay the impact of the disposal but would also delay the impact of product substitution (Manzini and Vezzoli, 2008)(Sabbaghi et al., 2016).

Life cycle extension is one of the core ideas of Circular Economy (CE). Circular Economy is a strategy that focuses on the planetary boundaries, looking to improve the management of resources, the production and use of products, and what happens to the materials after disposal (The Ellen McArthur Foundation, 2019). It seeks a gradual transition to an economic model decoupled from the consumption of finite resources through the implementation of a regenerative system. There are different approaches to CE, but they are generally related to the design of products with reduced envi-

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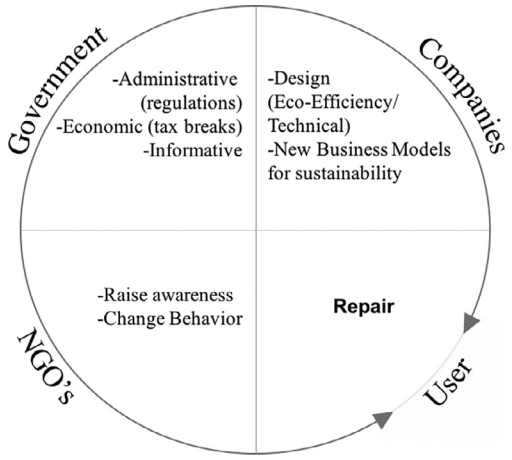

Fig. 1. The role of the main stakeholders in sustainable consumption.

ronmental impact, extended life cycles, and the return of the product or its materials to the system by the end-of-life.

Product repair is a crucial part of the CE, and an important topic on waste and resource management in many countries (McLaren et al., 2020; Laitala et al., 2021). Repair seeks to correct problems and failures of the product to return it to normal operation (Watson, 2008). It has a greater potential for reducing environmental impact than recycling and remanufacturing because it is closer to the direct reuse and perpetuation of the original product (Wieser and Tröger, 2018). In addition, Lepawski et al. (2017) argue that, from the perspective of the workers who handle the product, repair, reuse, and repurposing are better options than recycling since these may enhance their well-being, skills, and training.

Researchers often discuss repair as a question of business models and design. Modularity and Ecodesign are examples of strategies to prepare the product architecture to be more easily disassembled and repaired. They guide the development of more appropriate fastening technologies and prevent failures from affecting the whole product (Sonego et al., 2018). However, the role of consumers and consumer practices in repair is frequently underestimated (Jaeger-Erben et al., 2021). Consumer involvement is crucial to the conquest of regenerative cycles since deliberate consumer effort is necessary to repair and extend the life cycle of a product. The decision to repair is dependent on the consumer's choices and perceptions (Terzioglu, 2021). Therefore, if the practice of repair can benefit the environment, then consumer behavior must be studied to determine how it can be encouraged.

This paper investigates current consumer practices regarding the repair of electronic products. The investigation of consumer practices could lead to a better understanding of what is required to promote and enable product repair and to alert about the responsibilities of all stakeholders involved in the process. To achieve this goal, we analyze recently published research presenting surveys and case studies about the repair of electronic products. We also examine how institutional initiatives, such as governmental directives, are responding to consumer practices. The contribution of this study can be summarized in two points. First, it reviews consumer practices regarding the repair of electronic products, discussing barriers and motivations related to the repair process. Second, it presents the initiatives from governments, companies, and non-governmental organizations to promote repair, discussing the relationship between these initiatives and consumer practices.

A better understanding of consumer practices is a way to guide the development of stronger and proactive, and not only reactive, strategies and policies to address the issue of repair. These policies must seek to mitigate the barriers to repair encountered by consumers and work on the motivations that lead them to seek the repair. Furthermore, the survey of initiatives by stakeholders to promote repair is a way to discuss different strategies already put in place to address consumer practices and to disseminate best practices that can be replicated in different contexts.

This paper is organized as follows. Section 2 describes the methodology used in this study. Section 3 presents an overview of the current state of repair as well as consumer practices categorized into motivation and barriers to repair. Section 4 presents the initiatives gathered in the second stage of our review and relate these to the consumer practices presented in Section 3. Finally, Section 5 presents our conclusions.

2. Method

We performed a systematic review on the Science Direct Database, considering the time interval from 2011 to June 2021. The review was conducted to identify articles presenting surveys and case studies with consumers about the repair of electronic products. The search string consisted of the word "repair" combined with any of the following terms: "EEE"; "ICT"; "mobile phones"; "smartphones"; or "consumer electronics"; and it was carried in the title, abstract and keywords of the papers in the database.

We have only considered papers contemplating quantitative or qualitative information collected from consumers in our analysis. The first screening considered the title and discarded the papers that were not linked to the research subject. The second screening considered the abstract, and the third was performed reading the text. The search resulted in 88 papers, ten of which passed the inclusion criteria. In a second step, we screened the references of the ten papers, finding six additional papers that met our inclusion criteria. These were also included for analysis. Finally, in the third step, we identified the journals "Journal of Cleaner Production" and "Resources, Conservation, and Recycling" as the two main publication venues in the field, based on their occurrences in the two previous steps, and conducted a search for the term "repair" in these journals. We identified two more papers matching our inclusion criteria, resulting in a total of 18 papers selected for analysis. These papers are listed in Table 1.

We should point out that these papers do not consider the same products and context. Moreover, some of them have a broad scope, discussing other topics besides product repair. In this review, we only analyze the questions and findings relevant to the repair process, with a focus on the repair of electronic products. We grouped our findings into motivations and barriers to repair, which were identified through an aggregative approach, used to categorize the findings presented in the studies (survey answers, for example), and tabulated them in a spreadsheet.

To complement the academic aspect of this study and to help draw a more contemporary picture of the repair problem, we performed a search in the Google search engine using the same word string as before. We used a multi-layered strategy, including snowballing and cross-referencing, to gather existing initiatives from companies, governments, and NGOs, which are important stakeholders in sustainable consumption (Mont and Plepys, 2008), that deal with product repairability. We favored articles published in newspapers and reports from NGOs and governmental institutions. These initiatives and practices are presented at the end of the discussion section (Table 4).

3. Results

(Sabbaghi et al., 2016) and Wieser and Tröger (2018) argue that research focusing on consumer behavior towards repair is scarce. In addition, Mashhadi et al. (2016) noted that only a few academic

Table 1
Papers analyzed in this revision.

Authors	Journal	Method, country	Products analyzed
Cox et al., 2013	Resources, Conservation and Recycling	Qualitative discussion groups with users *United Kingdom*	Household appliances, electronics, apparel, furniture.
Scott and Weaver, 2014	Journal of research for consumers	Survey with users via IFixit and MTurk *United States*	Products in general
Hennies and Stamminger, 2016	Resources, Conservation and Recycling	Survey with users *Germany*	Washing-machines, laptops, kettles, TVs, hand mixers.
Mashhadi et al., 2016	Journal of Cleaner Production	Survey with IFixit users *United States*	Computers, tablets, smartphones, cameras, videogames, household appliances.
Sabbaghi et al., 2016	Resources, Conservation and Recycling	Survey with Ifixit users *USA*	Electronics, small home appliances, large home appliances, vehicle, clothing, furniture.
Pérez-Belis et al., 2017	Journal of Cleaner Production	Survey with users *Spain*	Vacuum cleaners, hand blenders, coffee makers, juicers, kettles, irons, sandwich makers, hair dryers, toasters, heaters.
Bovea et al., 2017	Journal of Environmental Management	Survey with stakeholders *Spain*	Vacuum cleaners, hand blenders, coffee makers, heaters, juicers, irons, sandwich makers, hair dryers, toasters.
Bovea et al., 2018a	Waste Management	Survey with users *Spain*	MP3/MP4, video camera, photo camera, mobile phone, tablet, e-book, laptop, hard disk drive, navigator-GPS, radio/radio alarm clock.
Wieser and Tröger, 2018	Journal of Cleaner Production	Quantitative and qualitative research with users *Austria*	Mobile phones
Sabbaghi and Behdad, 2018	Resources, Conservation and Recycling	Survey with users *USA*	Mobile phones
(Borthakur and Govind, 2018)	Journal of Environmental Planning and Management	Survey with users *India*	Mobile phones and computers
Blake et al., 2019	Sustainability	Survey with users *New Zealand*	Small Household Appliances; Large Household Appliances; Information and Communication Technology; Handheld Devices; Phones; Audio Visual Equipment; Lighting Equipment; Electrical Tools; Toys, Leisure and Sporting Equipment; Batteries; and Medical Equipment
Rodrigues et al., 2020	Waste Management	Survey with users *Brazil*	26 categories of EEE (ICT, small and big household appliances).
Laitala et al., 2021	Journal of Cleaner Production	Survey with users, *Norway*	Household Appliances, Mobile Phones and Clothing
Rogers et al., 2021	Resources, Conservation and Recyling	Survey with users, *United Kingdom*	Motor vehicle, bicycle, expensive tools, large electronic, large white good, small electronics, furniture, clothing, small appliance
Jaeger-Erben et al., 2021	Journal of Cleaner Production	Survey with users, *Germany*	Washing machine and Mobile Phones
Terzioglu, 2021	Journal of Cleaner Production	Cultural probes method, users	Products in general (answers to electronics were considered)
Woidasky and Cetinkaya, 2021	Journal of Cleaner Production	Survey with users, *Germany*	Computers

references explored product repair as an eco-behavior; and according to McLaren et al. (2020) and Laitala et al. (2021), little attention was given to the role of repair in the CE research.

The analyzed papers showed that a high percentage of consumers do not repair: 90% for household appliances in Spain (Bovea et al., 2017; Pérez-Belis et al., 2017); 66% for mobile phones in Spain (Bovea et al., 2018a); 66% for mobile phones in Austria (Wieser and Tröger, 2018); 75% for mobile phones in Germany (Jarger-Erben et al.,2021); 55% for mobile phones in Norway (Laitala et al., 2021). It is important to note that, when we consider the time intervals in the surveys or only products currently in use, some respondents did not experience the necessity to repair. Woidasky and Cetinkaya (2021), discussed that 80% of all current computers worked flawlessly and, consequently, did not require repairs.

The price of repair services has grown much more than the price of new products over time (King et al., 2006). New production methods and technology, outsourcing of manufacturing activities, and other efficiency improvements decrease the price of new products (McCollough, 2019). However, as economies advance, the costs of labor are increasing, especially in developed markets (Cooper, 2010; McCollough, 2019), which drive the price of repair up relative to the cost of new products.

In fact, the cost of labor is a factor that could impact the search for repair in developed and developing countries. However, there is a knowledge gap between developed and developing countries. Even though developing countries play a significant role in the global e-waste stream, very little academic research about extending the life cycle of electronic products has been carried (Borthakur and Govind, 2018). From the 18 papers analyzed, only two were carried out with customers in developing countries (Borthakur and Govind, 2018; and Rodrigues et al., 2020).

When considering the same country, the economic context of the respondents can influence the search to repair. (Borthakur and Govind, 2018) found that the low-income group has the highest willingness to repair (93,7% of respondents) since they try to maximize the product life. In Brazil, the media reported a significant increase in the repair of electronic products during the recent eco-

Table 2
Barriers to repair.

	Cost	Time	Lack of Information	Convenience	Obsolescence	Quality of repair	Negative Prior experiences
Cox et al., 2013	•						
Scott and Weaver, 2014	•			•			
Hennies and Stamminger, 2016							
Mashhadi et al., 2016				•			
Sabbaghi et al., 2016			•	•			•
Pérez-Belis et al., 2017	•	•	•				
Bovea et al., 2017			•			•	
Bovea et al., 2018a	•					•	
Wieser and Tröger, 2018	•	•	•		•		
Sabbaghi and Behdad, 2018	•						
(Borthakur and Govind, 2018)	•						
Blake et al., 2019	•						
Rodrigues et al., 2020	•			•	•	•	
Laitala et al., 2021	•				•		•
(Rogers et al., 2021)	•	•	•			•	
Jaeger-Erben et al., 2021	•	•			•		
Terzioglu, 2021	•	•		•	•		
Woidasky and Cetinkaya, 2021	•	•	•	•	•		

Table 3
Motivation to repair.

	Extended use of appliances	Emotional Attachment	Personal data	Environmental Reasons	High quality	Positive Prior experiences
Scott and Weaver 2014		•				
(Sabbaghi et al., 2016)						•
Hennies and Stamminger, 2016	•					
(Sabbaghi et al., 2017)		•	•			
Pérez-Belis et al., 2017	•					
(Wieser and Tröger, 2018)		•				
Laitala et al., 2021		•		•	•	
(Rogers et al., 2021)					•	
Terzioglu, 2021		•	•	•	•	

nomic recession faced by the country (Jornal Globo, 2016). In a survey in the city of São Paulo, Brazil, Rodrigues et al. (2020) found that 50,6% of the interviewed declared that they always repair damaged EEE, while 30,6% declared that they sometimes repair; reinforcing the idea that socioeconomic and cultural factors influence the search to repair. This is consistent with the findings of Scott and Weaver (2014), that the search for repairs is higher during economic slumps, highlighting the importance of the economic perspective on repairing. Moreover, Laitala et al. (2021) argue that to save money, some consumers are more likely to attempt a repair by themselves.

Repaired products can be associated with poverty (Terzioglu, 2021) as repair is seen by many as an act of necessity (Rogers et al., 2021). Rogers et al. (2021) discuss the tension between a sense of shame of those who repair because they cannot afford to replace a product; and repair as a luxury choice of those who have the skills and the free time. This discussion shows how individuals from different socioeconomic groups may perceive the repair of products. This reinforces the need for sustainability studies that consider all the stakeholders, as well as the role of the consumers and the consequences of their behavior.

3.1. Barriers

Consumers play a critical role in determining the environmental impact of a product since their decisions define the end of the useful life of the product. Therefore, to promote longer product life cycles, it is important to consider what discourages product repair from a consumer perspective. Table 2 presents the barriers found in the reviewed papers. These barriers are discussed in more detail below (Table 3).

3.1.1. Cost

Cost is a major barrier to product repair. According to Pérez-Belis et al. (2017) and Bovea et al. (2017), high cost is the reason behind almost 80% of non-implemented repairs. The problem of cost considers not only the repair service price but also the price of a new product and the extra time that the repair can guarantee. In a survey conducted in India, (Borthakur and Govind, 2018) found that 68.1% of respondents consider buying a new product in the face of the repair cost.

In general, cheaper products are more easily replaced because the cost of repair is almost the same as the cost of the product, and sometimes even higher. Therefore, more expensive products are more likely to be used for longer before needing repair and more likely to be repaired (Scott and Weaver, 2014; Hennies and Stamminger, 2016).

In a survey carried out in New Zealand, (Blake et al., 2019) found that repair costs also affect large household appliances such as washing machines. This was an unexpected result considering the high cost of replacing these items. However, the qualitative section of the survey demonstrated a preference for buying cheaper products, with a short life cycle, instead of better products, which are expected to have a longer life cycle.

3.1.2. Time

The repair of products can require a long waiting time, depending on the complexity. The time will impact the final cost of repair since it forces the consumer to stay without the product or to find a replacement (Svensson-Hoglund et al., 2021). McCollough (2019) discusses that from a financial perspective, as incomes increase, the time spent on repair or waiting for a technician may be better used working. According to the author, the time

constraint is a major reason that influences the decision to repair or replace in wealthy nations.

3.1.3. Lack of information

The lack of repair manuals and of information about the causes of failure, as well as where to take the product for repair, are also barriers to repair. Many consumers do not know about the repair possibilities or where to take their malfunctioning products to be repaired. As the consumers are "in the dark" considering the product architecture, they could fail to make simple and quick repairs due to the lack of information. Pérez-Belis et al. (2017) observed that almost 22% of the consumers surveyed did not have any idea about the causes of the failure of their products. Repair knowledge could lead to better purchases and better care since the customer is more aware of the product architecture and potential causes of failure, prolonging the product service life and, in the long run, the demand for higher quality products (Laitala et al., 2021).

Wieser and Tröger (2018) found that, based on assumptions about the state of the repair sector, consumers have a skeptical view towards the repair of mobile phones, leading to the impression that their phones cannot be repaired. In a survey about circular economy and product design, Bovea et al., 2018b) found that only around 30% of respondents believe that repairability is very important in product design, and only 40% considered the inclusion of repair information on product labels to be very important.

3.1.4. Convenience

Access to parts, tools, and information is key to carrying out repairs. The price and limited access to spare parts are among the main factors that inhibit the repair process. To enable repair, spare parts must be available during the entire life cycle of products, including after the end of production (Sabbaghi et al., 2017). As emphasized by Kim et al. (2017), companies must decide how many spare parts will be produced in the final production run to meet future demand. This decision may be difficult, since the demand for spare sparts is influenced by consumer decisions and is, by nature, intermittent. Boylan and Syntetos (2009) present an overview of methods to forecast the demand for spare parts. The unavailability of spare parts could lead to the use of non-original parts or parts recovered from ancient models, influencing the quality of the service and the consumer's perception of repair.

In many cases, companies are not spreading information regarding the repair of their products. The lack of transparency affects the repair business, making it impossible to carry out repairs. This issue can derail the service and compromise its quality as repairers are required to take actions based on conjecture (Sabbaghi et al., 2017). As pointed out by Sabbaghi et al. (2017), manufacturers prefer to hold formal training courses for repair businesses, instead of making the repair information public for everyone. They could also offer their own repair service and deny the supply of parts to non-official repairers (Türkeli et al., 2019). This practice could hinder access to repair services and raise its price. To increase the search and implementation of repairs, it is important to empower consumers and independent repair businesses, sharing information and ensuring access to required parts and tools. According to Van Nes (2010), to enhance repairability, repair should be so simple that consumers can perform it themselves, or it can be done by a relatively cheap and low skilled workforce.

Many products are designed to be disposable and not repairable (McCollough, 2019). In a survey with independent repair shops, Türkeli et al. (2019) report that 58.8% of respondents in the Netherlands, 71.42% of respondents in China, and 69.2% of respondents in Poland agreed that mobile phones are becoming more difficult to repair. This issue requires independent repairers to constantly seek new knowledge and qualifications to be able to continue repairing electronic devices.

Modularity is a key strategy to Circular Economy, preparing the product for easy disassembly and allowing maintenance, repair, and upgrades (Sonego et al., 2018). Researchers point out the tendency toward more integral products, leading to the difficulty to repair (Sabbaghi et al., 2016, 2017; Bovea et al., 2017; Wieser and Tröger, 2018). This argument is supported by the 2017 Greenpeace Guide to Greener Electronics, which also points to the tendency toward more integral products. This tendency runs in the opposite direction of the sustainability discussion.

3.1.5. Obsolescence

The decision between replacement or repair is also influenced by obsolescence, the real or perceived loss of value that will lead to the end of the product service life. Den Hollander et al. (2017) categorize obsolescence into 3 groups: absolute, when physical or functional problems are the cause of the end of active use; technological, when there are no more compatible systems available (software) for the product; and perceived, when psychological and social factors influence the products' end of life.

According to Zhilyaev et al. (2021), absolute obsolescence is not the main driver for the end of service life of products, and many functioning products can be found in storage. Sabbaghi and Behdad (2018) present an example of perceived obsolescence. In their survey, they found that consumers were less likely to repair old phones. In such context, the product may be perceived as obsolete, regardless of its technological state, and the purchase of a new one feels justified. The authors also discuss technological obsolescence, arguing that companies focus on offering services to their newer models, discontinuing service offerings for older models.

3.1.6. Quality of repair services and negative prior experiences

The expected quality of repair services and unpredictability of results can also influence consumer behaviors. They could mistrust the quality of the repair and the repair service (Rogers et al., 2021). This barrier is linked to convenience, which was discussed above, and to the access to private data stored in the product, which we discuss below. Additionally, past experiences can influence consumers, either positively or negatively (Sabbaghi et al., 2016); high cost, long wait time, poor quality of repair, among other issues could reinforce the perception of replacement as the most viable option.

3.2. Motivation

In addition to the extra usage time that can be gained by repairing a product, other reasons can also lead users to seek repair. Motivation to repair go beyond economic reasons and can also be related to personal perceptions about the products. Bobba et al. (2016) argue that durability is a complex issue that is influenced by psychological aspects, product characteristics, obsolescence, and technological changes.

3.2.1. Extended use of appliances

Successful repairs can lead to an extended use of products. Pérez-Belis et al. (2017) and Bovea et al., 2018a found that the repair extended the life cycle of the analyzed products, in some cases, by more than four years. But it is important to note that repair does not necessarily extend the life cycle of products in every circumstance. For instance, Hennies and Stamminger (2016) have found that the repair did not extend the life cycle of some of the analyzed products (laptops and electric kettles). Moreover, Jaeger-Erben et al. (2021) discuss the non-significant role of repair in prolonging the use time of mobile phones and washing machines. In their survey, it was not possible to predict the lifetime of washing machines, whereas the lifetime of smartphones was related to novelty and attractive offers.

We note, however, that their findings apply to the products and context where the survey was conducted and may not be generalized to other products or contexts. Indeed, this is an interesting subject, which could be further investigated, and which could help to consolidate the knowledge on the potential to extend a product life cycle through repair.

3.2.2. Emotional attachment

Consumers may feel attached to their products due to positive and affective memories or the perception of high performance compared to new products in the market. Gifts and products with a long history could hold a special meaning for the user (Terzioglu, 2021). The emotional attachment could contribute to the decision to repair, even when it is not profitable from an economic point of view (Laitala et al., 2021). According to (Velden, 2021), emotional attachment can extend service time and slow down the circular movement of materials.

3.2.3. Personal data

Products such as smartphones, computers, and cameras contain stored data that is important to the owner. According to Sabbaghi et al. (2017), data recovery is one of the main reasons to repair an electronic product: any product that contains data storage is precious to the consumers, and they will pay more to repair the device. However, Sharpe et al. (2018) also discuss that confidence and trust in service providers can play a role since they may have access to sensitive and personal data. This can lead to the tendency to destroy or store the product to protect confidential information.

3.2.4. Environmental reasons

Many consumers do not link their consumer habits to environmental problems (Thang and Bhamra, 2009; Mont and Plepys, 2008). In the Eurobarometer 2017, 66% of the respondents felt that the consumers are not doing enough to protect the environment. In the same interview, 35% of the respondents answered that the most effective way to address environmental problems is to pursue new technological solutions through investment in research and development. Although they recognize that individuals do not do enough, the respondents still attribute more importance to technological solutions (35%) than changes in consumer habits (26%).

(Sanye-Mengual et al., 2006) emphasize that proper communication is an important factor to situate the consumer as an agent responsible for the environmental impact of a product. In fact, Cox et al. (2013) observed that, typically, environmental concern was not among the factors motivating actions to increase the lifetime of a product. In the literature consulted in this review, environmental concern was viewed by consumers as a motivation to repair only in Laitala et al. (2021) and Terzioglu (2021).

3.2.5. High quality products and positive prior experiences

High quality products are more likely to be repaired. This idea converges to the product typology presented by Cox et al. (2013). The authors argue that there are three different types of products: workhorse, investment, and up-to-date, and that this typology influences the search to repair.

Workhorse products are valued for their utility and are expected to be reliable and to have a long life cycle (larger home appliances, for example). The repair of workhorse products considers the additional lifetime acquired by the repair, how much it will cost, and the inconvenience. Investment products are, in general, more expensive purchases (high-quality electronics, for example). This category of product is more likely to be repaired due to the high initial investment and, in some cases, the emotional dimension linked to this kind of purchase. Finally, up-to-date products are strongly linked to self and social identity. These products are more likely to be updated due to changes in trends and technology than due to malfunction, i.e. to be directly discarded for fashion reasons.

Positive repair experiences influence future consumer decisions. Successful repairs can improve the perceived quality and reliability of the product, which could lead to recommendations to others and repurchase from the same brand (Mashhadi et al., 2016).

4. Discussion

Individuals are not rational and independent decision-makers. They exist and engage in a complex spatial, temporal, social, political, economic, and cultural system (Rogers et al., 2021). Thus, in addition to evaluating their practices, it is also necessary to understand the system in which they are inserted and what other stakeholders can do to encourage the repair of products. The main players in sustainable consumption are governments, companies, consumers, and non-governmental organizations (Mont and Plepys, 2008).

Rogers et al. (2021) discuss a recent surge in support for repair in Europe and North America, through policy, legislation, and economic incentives (e.g. tax deductions). In addition to issues related to product design and consumer perceptions, there are legal mechanisms that limit participation in repair activities such as intellectual property, contracts, consumer laws, tax laws, and chemical laws (Svensson-Hoglund et al., 2021).

The stakeholder's initiatives presented in Table 4 (not limited or specific to electronic products) are examples of how these players are acting to promote and present repairability as an appealing option to consumers.

Most initiatives from governments and companies focus on absolute/technological obsolescence, with proposals to improve durability and repairability, and extended warranties. Studies exploring absolute and technological obsolescence are also more abundant (Zhilyaev et al., 2021). This is consistent with the findings presented in the results section, as many of the barriers encountered by consumers would be alleviated with easier and cheaper repairs and easily accessible information.

These government initiatives attempt to counter planned obsolescence, which is the practice of deliberate planning and design of products to make them fail early, stimulating repetitive consumption (Maitre-Ekern and Dalhammar, 2019). The Greenpeace Report of 2017 cites Apple and Samsung as companies using planned obsolescence; Apple was fined in France and Italy, accused of deliberately slowing older phone models with their system updates to sell newer ones; Samsung was also fined in Italy for planned obsolescence (Svensson-Hoglund et al., 2021).

The use of modularity and Ecodesign could facilitate product repair. However, per se, they do not guarantee an extended life cycle. A business model that allows and promotes product longevity is required, together with the consumer decision to repair. It is necessary to understand the relational, social, moral, and cultural implications of business models and assess who wins and who loses in different approaches to product repair (McLaren et al., 2020). For example, Product Service Systems (PSS) is widely discussed as a possibility to encourage repair. PSS can deal with the issue of reliability and quality of the repair and stimulate employment in the repair sector (Rogers et al., 2021). However, this centralized model creates the threat of a monopoly, where companies are the sole responsible for decisions related to repair and can take small repair shops and informal workers out of business, and preventing the democratization of repair at the user level (Svensson-Hoglund et al., 2021; Rogers et al., 2021: McLaren et al., 2020).

Moreover, the focus on technical and functional aspects of products is not only characteristic of the repair market but is

Table 4
Stakeholder's initiatives to promote repair.

Stakeholder	Initiatives
Governments	
Administrative	**Ecodesign Working Plan 2016–2019** (European Union): contributes to the Circular Economy Action Plan by promoting durability, repairability (design for repair, availability of spare parts and manuals), upgradeability, ease of reuse, and recycling. (European Commission 2016; Rreuse 2015). **Directive on Waste Electrical and Electronic Equipment** (WEEE) 2012/19 (European Union): it extends producer responsibility to encourage design and production considering easy repair, upgradability, reuse, easy disassembly, and recycling. (Bocken et al., 2016; Rreuse, 2015; Directive 2012/19/EU, 2012) **Action Plan for the Circular Economy** (European Union): It supports circular economy on every step of the value chain – production, consumption, repair, remanufacturing, and waste management. It also encourages the design of more durable and easy repair products, covering the availability of repair parts and repair information). (Cases i Sampere, 2015; European Commission, 2015) **Directive 2009/125/EC** (European Parliament) It consists of eco-design requirements for energy-related products, promoting the extension of the product lifetime through the availability of spare parts, repairability, modularity, and upgradeability. (Cases i Sampere, 2015; Directive 2009/125/EC, 2009)
Economic	**Tax breaks for repair** (Sweden): Reduces the cost of repair by reducing the VAT on certain types of products. Allows the deduction of 50% of the labor cost of domestic appliances repair from the taxes. Tax products that are difficult to repair and recycle. (Durand, 2016; The Guardian, 2016; European Commission, 2017; Rogers et al., 2021)
Informative	**Label of excellence for durable, repair-friendly designed electrical and electronic appliances (ONR 192,102) (**Austria): a label of excellence for durable and repair-friendly products (covering aspects such as nondestructive disassembly, availability of parts for ten years, free access to repair documentation…) (Durand, 2016) **Blue Angel Standard** (Germany): ecolabel of the German federal government since 1978. It provides environmental information to help consumers choose environmentally friendly products (easy of repair and open availability of the repair manual are requirements). (Cases i Sampere, 2015; blauer-engel.de) **Cradle to Cradle Certified** (USA): certification for products made for Circular Economy. The certification is based on 5 categories: material health, material reuse, renewable energy and carbon management, water stewardship, and social fairness. (c2ccertified.org) **Nordic Swan** (Nordic Countries): ecolabel established in 1989 (Denmark, Finland, Iceland, Norway, and Sweden). It provides information to help consumers in choosing more sustainable products and services. (https://www.nordic-ecolabel.org/)
Companies	
Design (Eco-efficiency/technical)	**Modularity:** facilitates repair (Cheng 2012; Gu and Sosale, 1999; Umeda et al., 2008; Yan and Feng 2014) and disassembly of products (Go et al., 2015; Gu and Sosale, 1999; Umeda et al., 2008) due to structural and functional independence, interface and minimization of interaction between modules and external influences (Stewart and Yan, 2008). **Ecodesign**: is a proactive approach that guides product development towards the minimization of environmental impacts throughout the entire life cycle (Johansson, 2002). Luttropp and Lagerstedt (2006) discuss that repair and upgrades, longer life cycles, use of simpler materials and use of the fewer joining elements as possible (use screws, geometric locking, etc.) are part of the golden rules of Ecodesign.
New business models	**Sustainable business models:** "a sustainable business model aligns interests of all stakeholder groups, and explicitly considers the environment and society as key stakeholders" (Bocken et al., 2014). There is a discrepancy between private and public benefits, and sustainable business models are created to generate value for the company, customers, and society (Lüdeke-Freund, 2010). Bocken et al. (2016) cite Patagonia and Fairphone as companies with sustainable approaches: *Patagonia:* their Common Threads Initiative, described as a partnership between customers, company, and eBay, seeks to stimulate repair and recycling of products, and the reduction in consumption patterns (buy only what you need). They offer a website in collaboration with iFixit to teach customers how to repair their products and inform customers about the importance of repair and reuse. *Fairphone*: the modular smartphone allows easy repair, upgrade, reuse and recycling. Besides the long-lasting design, the company also uses fair materials (Fairtrade gold) and a transparent approach to supply and manufacturing processes. **Sustainable Product Service Systems:** provides solutions to satisfy customers without the ownership of physical products (focus on the user needs). As the manufacturer retains the ownership of assets, this approach could enhance product longevity and durability and encourage the design of products considering upgradability, repairability, and improved end-of-life management. Maintenance, repair, and recollection are performed by the manufacturer rather than a third party. (Fargnoli et al., 2012; Bocken et al., 2014; Tukker, 2015)
NGOs	
Raise awareness and change behavior	**Repair Association** (USA): Is engaged in passing the Fair Repair legislation at the state level in the USA. It requires companies to sell replacement parts and tools, and to make repair documentation available to anyone. (Rreuse, 2015; Repair.org) **IFixit (IFixit.com) (**USA): a wiki-based site to share step-by-step repair guides to help people to fix their products. The manuals are made by individuals who share their technical skills. In a partnership with Greenpeace, IFixit publishes the "Reparability Scores" to inform people how easy a specific product is to repair (for example smartphone repairability score, tablet repairability score…). (Rreuse, 2015; Mashhadi et al., 2016; Sabbaghi et al., 2016) **Rreuse** (Belgium): represents social enterprises active in reuse, repair, and recycling. It is engaged in policies to make repair activities more competitive and argues for repair-friendly design, spare parts availability, and free access to repair information. (Rreuse, 2015; rreuse.org) **Repair Cafes:** Repair cafes are free meeting places where people can find tools, materials, and the help of volunteers to repair a variety of products. The site Repaircafe.org offers a list of more than 1400 repair cafes worldwide. (Cases i Sampere, 2015; repaircafe.org; The Guardian, 2018) **The Restart Project** (London): a social enterprise that encourages people to use their electronics longer. It promotes community events to help people to repair their electronics and inform the consumers about repair and resilience. (European Commission, 2017; therestartproject.org) **Greenpeace:** Through Rethink-it.org, Greenpeace informs the consumer about the product's repairability and promotes a petition to end planned obsolescence. (rethink-it.org; greenpeace.org)

also observed in the discussion of Circular Economy. Much of the CE discourse focuses on recycling, technological solutions, and end-of-pipe thinking, perpetuating the idea of indefinite economic growth and ignoring the challenges of overconsumption (Velenturf and Purnell, 2021)(Alvarado et al., 2021). Ideas related to the reduction of consumption compete with the ideas about economic growth, which are part of the status quo (Alvarado et al., 2021). As discussed by Klein (2014), it is easier to embrace policies to consume green than to encourage people to consume less. Consuming green is safely within the market logic (Klein, 2014) since both producers and consumers can continue with the existing practices, however with reduced impact (Velenturf and Purnell, 2021). Therefore, a new perspective on CE and repair that also addresses overconsumption is needed.

Initiatives such as the Repair Cafes are in line with a new perspective on repair, creating a space for people to engage with change and share experiences. Community repair is focused on sustainability and sharing, offering people a way to participate in the circular economy and to gain more knowledge about the products and their care, strengthening emotional attachment (Velden, 2021). The role of attachment, care, and trust is emphasized as a major motivation to repair (McLaren et al., 2020; Zhilyaev et al., 2021). The repair can signify a connection with an object, creating a unique narrative and an opportunity for self-expression (Rogers et al., 2021). Scott and Weaver (2014) discuss a creative perspective on repair, presenting it as a tool to empower consumers to show their innovativeness and express their values. Repair is a way of co-creating and redefining value, creating attachment, social innovation, and resistance to consumerism (McLaren et al., 2020). Taking care of your products must be associated with positive experiences, increasing recurrence in the future (Ackermann et al., 2021).

As seen in our results, there is evidence that perceived obsolescence plays a decisive role in the life cycle of products. Zhilyaev et al. (2021) showed that physical durability was not the main cause for the end-of-life service of ICT products in Denmark, while Makov and Fitzpatrick (2021) argue that a discussion focused on the technical aspects is unlikely to bring the desired extension in products lifespans. Moreover, several studies discuss the high number of electronic products stored in garages and attics, many of which are still functional (for example, Ylä-Mella et al., 2015; Wilson et al., 2017).

Jaeger-Erben et al. (2021) discuss that, if novelty and innovation remain the motor of our consumption and production practices, the availability of repair services and social support for repair will not be sufficient. Repair is ineffective against perceived obsolescence because of the discrepancy between what the consumer perceives and the actual functional performance of the product (Makov and Fitzpatrick, 2021). Moreover, minor modifications in the appearance of products can trigger the desire for an upgrade, even if the functionality is not significantly altered. It is important to consider the subjective characteristics, especially the role of branding, in the value that people attribute to the products and that make them look more worthy of repair. In this sense, we can see the importance of NGO initiatives, changing the perspective of repair and raising awareness against conspicuous consumption, fostering emotional attachment and care to extend the use of products, and informing consumers about the actual environmental impact of consumerism. This shows that, in addition to reducing the barriers to repair, it is also necessary to work on motivations, seeking broader solutions and slowly changing consumer habits. Moreover, Zhilyaev et al. (2021) emphasize the need for repair policies that also consider subjective and intangible issues, in addition to technical and functional ones.

Repair and maintenance are not only linked to a material issue, but also political and social values and systems (McLaren et al., 2020). Repair has transformative potential and, in addition to contributing to sustainability, it can also be an agent of more egalitarian social relations. There is the need for a transformation in consumption, which includes the rethinking of values, material needs (Korsunova et al., 2021), quality of life and social connections (Friant et al., 2021), and a debate about human needs and wants in a context of sustainable development (Velenturf and Purnell, 2021).

5. Conclusion

We conducted a literature review to investigate the current consumer practices regarding the repair of electronic products. As presented in our results, consumers face many barriers that discourage the search for repair.

Circular Economy is a major topic of discussion in academia, with a large body of research, theoretical discussions, and methods addressing the problem. However, current solutions are focused on the technical and functional requirements, which are only part of the problem. To achieve the necessary change towards sustainability, it is not sufficient to consume sustainable products, it is also necessary to consume less. To incentivize the search for repair and further increase the lifespan of electronic devices, it is very important to facilitate repair through design, new business models, and access to information and parts. Moreover, repairing is an opportunity to communicate values to users and raise awareness through increased knowledge about the products, how they are made, how they should be maintained, and the actual impact of their disposal. Our study concludes that it is not only important to reduce the barriers to repair, but also to work on the motivation, encouraging product attachment and a new perspective that resists consumerism.

The contribution of our paper is to highlight the consumer and discuss their role in achieving a more circular and sustainable economy. More than enabling and promoting product repair through technical and functional adjustments, our results suggest that it is important to consider more subjective issues, especially the role of obsolescence in the decision-making process of consumers.

However, literature addressing repair as an eco-behavior is recent, and we found a relatively small number of studies given the novelty of the subject. Our outreach is also affected by the limitations of the consumer studies, such as sample size, convenience sample, and the locations where the surveys were applied. Studies that take into consideration different socioeconomic contexts, the entire life cycle of products, and all stakeholders in the system are paramount to better understand how to promote repair in the context of a circular economy.

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.

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