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Behavioral change for the circular economy: A review with focus on electronic waste management in the EU

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ABSTRACT

In recent years, electrical and electronic products (e-products) have been central to the discussion of resource sustainability due to their growing demand, use of critical resources, and challenges in managing the resulting waste stream (e-waste). As such, the concept of circular economy, which seeks to 'design out' waste by better products, practices and business models, is deemed to be very relevant for e-products. The nature of circular systems mandates a collective effort of businesses, consumers, and governments. While the techno-economic sides of the circular economy have attracted large attention in recent years, the role of consumer behavior – a critical factor in defining the long-term success of 'sustainable production and consumption' initiatives – remains less explored. In this context, this paper explores the potential of integrating lessons from behavioral sciences to facilitate circular economy in e-waste management. It offers a review of prominent behavioral theories and their application in the context of sustainable consumption and pro-environmental behaviors. Finally, the paper identifies opportunities for behavioral interventions in improving e-waste management and in achieving a more circular economy.

1. Introduction

1.1. Background

Electrical and electronic products (e-products) have been one of the focus areas in the discussion of resource sustainability mainly due to a) their growing demand, b) the use of critical resources, and c) challenges in properly managing the end-of-life (EoL) for e-products (known as e-waste) (Breivik et al., 2014; Habib et al., 2015). E-waste is a fast-growing waste stream globally, which with the current trend, is expected to double by 2045 (Parajuly et al., 2019). E-waste is also a mixture of valuable resources and toxic substances that demands careful handling. E-products have evolved to become complex and ubiquitous in everyday lives but e-waste collection and management systems have not caught up – largely failing to ensure proper handling of e-waste. This entails potential risks of resource losses and negative impacts on environment as well as human health (Wang et al., 2016b).

Governments and other actors have taken actions to tackle the growing e-waste problem. In Europe, for example, the Waste Electrical and Electronic Equipment (WEEE) Directive sets targets for collection and subsequent processing of e-waste for material recovery (European Parliament, 2003). The Directive mandates all member states of the European Union to facilitate separate collection of and resource recovery from e-waste. More importantly, the system based on Extended Producer Responsibility (EPR) principle has made producers responsible for their e-products with the aim of improving recyclability and encouraging the integration of EoL aspects during product design (Atasu, 2018). For more than two decades, concepts such as 'design-for-recycling' have also been in circulation (Kriwet et al., 1995) and more recently, the European Ecodesign Directive has begun to set design requirements for energy-related products to include all stages of product lifecycle, including product EoL (European Parliament, 2009).

The results of these collective efforts, however, have not been satisfactory. Despite relatively well-established waste management infrastructure in place, European countries only collect about one third of the generated e-waste under the official collection systems with significant quantities going to non-compliant waste management channels (Balde et al., 2015). As for products themselves, little evidence of design supporting EoL resource recovery exists. Classic design flaws are still found even in modern e-products (Parajuly et al., 2016). Due to their

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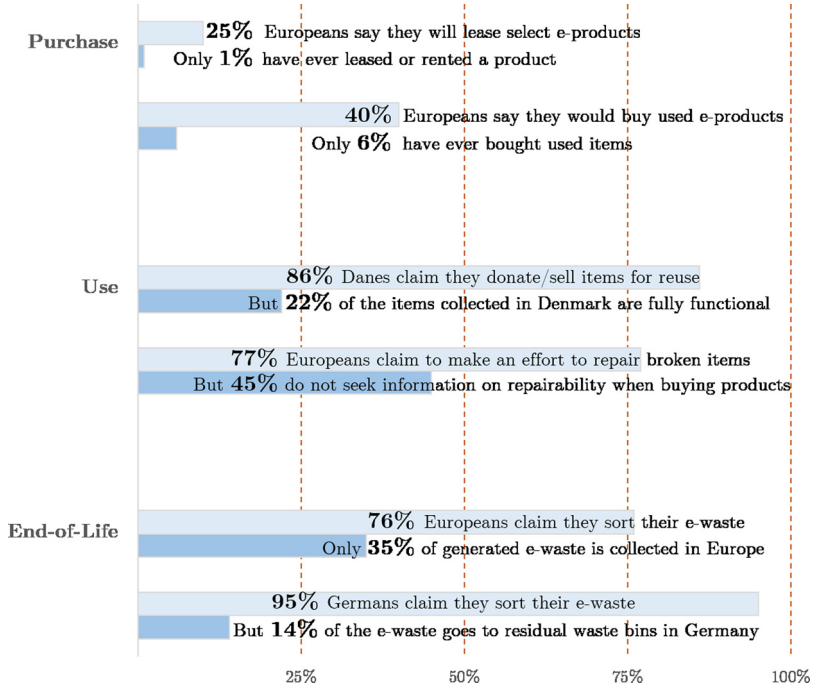

Fig. 1. Examples of gap between people's claim and actual practices [sources: (Baldé et al., 2017; Cerulli-Harms et al., 2018; European Union, 2014; Huisman et al., 2017; Parajuly and Wenzel, 2017)].

complex material composition and design, many e-products are not compatible with material recycling processes, which results in resource losses. As the recycling techniques try to catch up with the ever-advancing product design, 'Design-for-EoL' has not been the priority. Overall, the lack of progress is disappointing – considering how much policy development and technological research has taken place.

In recent years, the concept of circular economy is deemed increasingly relevant in addressing the e-waste problem. Circular economy aims to 'design out' waste through optimization of products and materials cycles by keeping them at their highest utility and value (Ellen MacArthur Foundation, 2019) with the help of cleaner and renewable technologies, innovative business models, and policies supporting them (Ghisellini et al., 2016). Such an optimization can be realized through better-designed products and business models that allow a) product lifetime extension, b) reuse of products and components, and c) efficient material recovery from the EoL products. To begin with, the vision of EPR-based e-waste management system was in line with that of a circular economy as it was believed that by making producers responsible for EoL collection and treatment, they would be incentivized to re-organize business models and product designs to reduce their EoL costs. The implementation however, has been limited to simply collection and subsequent material recycling processes with collective schemes offering no incentive for individual actors to improve resource recovery. Preparation for reuse of EoL products, which would conserve the embodied energy and many critical raw materials that are lost during recycling, is almost non-existent (Coughlan et al., 2018; Parajuly and Wenzel, 2017).

In the academic discourse on environmental sustainability, the consumption side of the product lifecycle has not always received equal attention as the production side. Most common carbon management frameworks use production-based rather than consumption-based accounting (Sudmant et al., 2018). The latter approach assigns emissions to the consumption point of goods and services, which may provide a better guide for climate policies (Steininger et al., 2014). This practice, however, is not surprising given the 'linear' nature of current economic systems in which production, consumption and EoL management of consumer goods are isolated in many regards. In a circular economy, more focus is on the consumption (or use) of artifact as the goal is to maximize the usefulness and hence the utility of resources (Ellen MacArthur Foundation, 2013). In this regard, the techno-economic aspects of the circular economy concept has been extensively studied in recent years. However, like in the sustainability debate, the role, motivations, and drivers of end users' behavior in a circular system has not been equally examined. The social and behavioral elements linked to consumption of everyday goods, and how they need to be adapted to enable regular people to facilitate the success of a circular system, remain largely unexplored (Camacho-Otero et al., 2018). In the midst of discussions on technicalities of improved e-waste collection and recycling rates, users' important role in sustainable production and consumption of e-products seems to have been neglected (Otto et al., 2018).

1.2. Consumer behavior in a circular economy

End-users of e-products (consumers) are directly involved in the three key stages of a product lifecycle: purchase, use, and EoL management. Users' behavior and decision making during these stages have direct implications to the success of not only the most preferred options in a circular economy (reuse and repair), but also subsequent resource recovery (recycling) at the product EoL. Investing in more durable products and/or engaging with circular business models (purchase), opting for repair and reuse of functional broken products (use) and timely and proper disposal of products with no reuse potential (EoL management) are examples of such consumer behaviors.

Because of their interactions to everyday lives, circular strategies seeking to boost resource efficiency (including infrastructure, products, business models and policies) will not succeed without the consideration of public acceptance and adaptation (Cherry et al., 2018; van Weelden et al., 2016v). There are technological as well as economic challenges (in terms of infrastructure and incentives) to implement a perfect system allowing all users and businesses to engage in the circular economy. While many stakeholders are driven by monetary rewards and legislative requirements, certain transactions rely on users' behaviors (e.g., exploring reuse options, selling second hand, returning

instead of stockpiling, and recycling instead of wrongly discarding). Such behaviors have considerable impact on EoL collection and resource recovery, and on the success of a circular system for e-products.

The majority of Europeans are aware of the environmental issues linked to our consumption model and the importance of effective use of resources (European Union, 2014). Many of them also claim to participate in waste sorting, and to be willing to try reused items or alternative business models such as leasing (Cerulli-Harms et al., 2018). The practices however, do not reflect the claims made by the people. Some examples of the gap between people's claims and their actions during purchase, use and EoL of e-products are offered in Fig. 1. These examples are based on limited available data on consumer behavior and not all of them may be directly comparable to reflect the gaps, nevertheless, they offer a useful insight. For example, at the product EoL, 76 % of Europeans claim that they sort their e-waste but only 35 % of the generated e-waste is collected under official collection systems in the EU. It implies that part of the sorted e-waste is either stockpiled at homes or collected through unofficial channels. Moreover, these gaps are the outcome not only of consumer choices, but also of available e-waste disposal options and collection systems that are often beyond consumers' control.

Many environmental problems are rooted in human behavior, and behavioral changes are therefore needed to utilize the potential of technological innovations helping environmental sustainability (Steg and Vlek, 2009). The efficacy of intervention strategies to promote pro-environmental behavior relying on information campaigns is limited mainly because of the fact that environmental literacy do not necessarily translate into sustainable actions (Frisk and Larson, 2011). Human behavior is understood to be linked to both intrinsic as well as extrinsic attributes (Martin et al., 2017). In the context of sustainable consumption behavior, intrinsic attributes include knowledge, motivation, beliefs, habits, values, attitudes, intentions and other psychological variables whereas extrinsic attributes include social and cultural norms, monetary implications, and contextual variables such as infrastructure and institutional constraints (Jackson, 2005; Knussen and Yule, 2008; Young et al., 2009). This paper explores the possibilities and barriers in integrating behavioral insights in sustainable production and consumption initiatives.

2. Method

2.1. Scope

We study the potential for utilizing behavioral insights in the context of circular economy and e-waste. For this, we review prominent behavioral theories, models, and intervention tools that are linked to sustainable consumption and pro-environmental behaviors. The goal is to identify opportunities for implementing behavioral interventions in properly managing e-waste, and in a larger context, in achieving a more circular economy by promoting circular business models, product lifetime extension and material recycling.

2.2. Literature review

We begin with an attempt to understand existing theories on human behavior and behavioral change from different fields of study including social and behavioral sciences, economics, and psychology. We then closely analyze the literature where these theories are applied in the context of environmental and resource sustainability in order to a) create an overview of behavioral theories linked to sustainable production and consumption and b) collect examples of behavioral interventions in the context of e-products and circular economy. Google Scholar was used as the primary search tool for the publications using different combinations of keywords including 'behavior', 'circular economy', 'consumer', 'consumption', 'e-waste', 'pro-environmental', 'sustainable', and 'theory'. However, the search was not limited to these terms and a snowball technique was used to identify all relevant literature within the scope of this paper. Since the literature in the field of behavioral change for circular economy is limited, we expand our scope beyond the academic publications. We include academic literature (e.g. peer–reviewed articles, conference proceedings, books chapters, etc.) as well as other publications (e.g. reports, popular science books, case studies, etc.) in our review. In total, 115 publications were reviewed. A list of reviewed publications on pro-environmental behaviors, linked to waste management in general and specifically on e-waste and circular economy, along with their scope is provided as Supplementary Material.

3. Behavioral change

The complex nature of human behavior is explained by several theoretical frameworks from varying fields of study. More than 80 different theories of behavior and behavioral change exist across the field of psychology, sociology, anthropology and economics (Darnton, 2008; Davis et al., 2015). Widely used in the sector of public health, the use of theory-based behavioral intervention is limited when it comes to promoting pro-environmental behaviors. Most common theories (and models) of pro-environmental behaviors can be grouped as moral, rational choice, and economic models (Turaga et al., 2010). In addition, nudging and community-based social marketing are two popular intervention strategies that make the use of cognitive biases and social influences, respectively (McKenzie-Mohr, 2011; Thaler and Sunstein, 2008). The following sections briefly unpack these theories and intervention tools, an overview of which is illustrated in Fig. 2 below.

3.1. Rational choice theories

Attitude and subjective norms are the main constructs of rational choice theories (Kaiser et al., 1999). The theory of planned behavior (TPB) is one of the most popular psychological theories used in the research of pro-environmental behavior (Botetzagias et al., 2015). It suggests that pro-environmental behaviors are the result of 'rational choices' made with the goal of maximizing personal benefit (Bamberg, 2013). Centered on an individual's 'intention' to perform a certain behavior, the TPB suggests that such intentions can be predicted from attitudes toward the behavior as well as subjective (social) norms and perceived behavioral control, and the actual behavior is the result of these intentions combined with individual's perception of behavioral control (Ajzen, 1991). Assuming intention to be the most important factor in behavioral change, the framework of TPB advocates for 'goal-directed' behavioral interventions for promoting pro-environmental

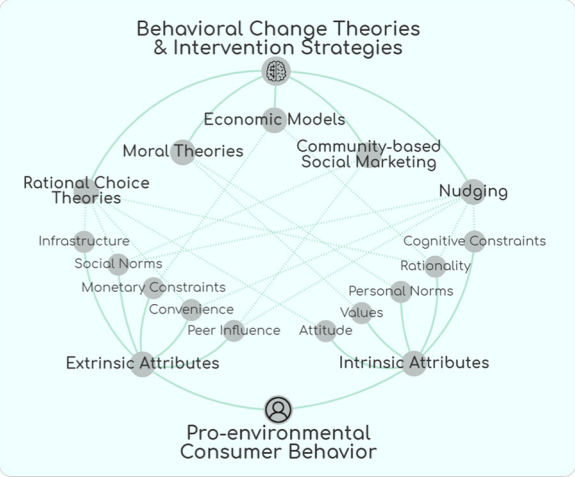

Fig. 2. Elements of pro-environmental consumer behavior and their connection to the main theories and intervention strategies for behavioral change.

intention, and thus, behavior (Botetzagias et al., 2015).

Past research have tested the effectiveness of this theory in the domains of circular economy and e-waste management. The TPB has been used as a framework to study, for example, determinants of consumers' e-waste disposal behavior intentions in China (Wang et al., 2016a) and Vietnam (Le et al., 2013), willingness to participate in formal e-waste recycling in Nigeria (Nduneseokwu et al., 2017), intention-behavior gap in e-waste recycling in Brazil (Echegaray and Hansstein, 2017), and young adults' e-waste recycling behavior cross-culturally in China and India (Kumar, 2019). In addition, The willingness to participate in e-waste recycling with a points reward system (Zhong and Huang, 2016) and through online e-waste recycling platforms (Wang et al., 2019) were also investigated in China. The TPB has also been used to analyze the key variables underlying the consumers' purchase intentions of remanufactured e-products (Jiménez-Parra et al., 2014).

The outcome of these studies, which rely mostly on questionnaire surveys for data collection, are mixed. While some suggest that environmental awareness is the most important predictor of e-waste recycling behavioral intention (Wang et al., 2016a), others point to perceived behavior control (Le et al., 2013), attitude (Kumar, 2019), and social norms (Echegaray and Hansstein, 2017). This suggests a potential indirect influence of external factors (possibly demographic and socio-economic factors) in determining e-waste recycling behavior, which may challenge the generalized applicability of the TBP. The famous 'intention-behavior gap' – the fact that only few intentions translate into behaviors – is another source of skepticism against founding behavioral change interventions on the TPB (Bamberg, 2013).

3.2. Moral theories

Moral norms – descriptive and prescriptive – are a strong driver of pro-environmental practices as well as policies (Davis et al., 2018). People in general value environmental quality and accept the responsibility to care for it, and environmental campaigns can benefit more from appealing to people's 'positive self-concept' than their 'economic self-interest' (Bolderdijk et al., 2012). Behavioral change driven by intrinsic motivators may also be longer lasting than external (e.g. financial) rewards that seem to dilute the 'purity' of an altruistic act (van der Linden, 2018v). Altruistic values are positively linked to pro-environmental norms. Beliefs about environmental impacts and the effectiveness of one's action come into play between values and norms. These beliefs and norms, and thus the readiness to perform certain action, can be shaped by information (Stern, 2000).

The value-belief-norms (VBN) theory is arguably the most popular of moral theories in investigating pro-environmental behavior (Bronfman et al., 2015; Janmaimool and Denpaiboon, 2016; Lopez-Mosquera and Sanchez, 2012). It provides a social-psychological framework for examining normative factors promoting sustainable attitude and behaviors, which links personality elements, beliefs about human-environment relations, and the sense of moral obligation to pro-environmental behaviors (Stern et al., 1999). The theory suggests that pro-environmental behaviors are more likely to appear when people value the collective wellbeing over personal interest.

The relationship among variables of the VBN theory has been empirically studied and verified in different settings for addressing varying environmental behaviors (Turaga et al., 2010) but examples from the e-waste and circular economy domains are limited in both number and scope. The VBN theory was used – in combination with other theories – to evaluate residents' willingness to participate in e-waste in USA (Saphores et al., 2012) and to examine consumers' perceptions towards reuse and recycling of e-products in Finland (Yla-Mella et al., 2015). However, the available studies do not evaluate the constructs of VBN theory using statistical analysis and are inconclusive regarding the significance of moral constructs in defining e-waste and circular economy related behaviors.

3.3. Economic models

In economics, pro-environmental behaviors are modeled as the 'private provision of public goods' (Saphores et al., 2012). Unlike psychological theories, the approach of economic models assumes individuals to be utility-maximizers whose behavior can be influenced through incentives (Nnorom et al., 2009). Individuals' stated willingness to pay (WTP) for environmental improvements has been widely used as a metric for pro-environmental behavior. Willingness to pay for better management of e-waste and waste in general has been studied in Asian, African and South American countries, where proper infrastructure as well as the 'polluters-pay' philosophy are yet to fully develop (Dwivedy and Mittal, 2013; Nnorom et al., 2009; Wang et al., 2011). There are also examples, though comparatively fewer, from other regions including Northern America and Europe (Nixon et al., 2009; Saphores et al., 2012). Willingness to pay a premium for greener and remanufactured products have also been studied for different categories of e-products (Atlason et al., 2017; Michaud and Llerena, 2011; Saphores et al., 2007).

WTP may vary with socioeconomic factors (demography, education level, income, etc.) (Turaga et al., 2010; Yin et al., 2014). Although affixed to the economic value of outcome of the investment, WTP also reflects some degree of altruistic motives and moral values (Guagnano, 2001; Nunes and Schokkaert, 2003). Some have even suggested that environmental attitude and values are stronger predictors of WTP than socioeconomic characteristics (Nixon et al., 2009). However, the marketplace behavior of consumers are not always consistent with their attitude or ethics (De Pelsmacker et al., 2005). Hypothetical bias is also a pronounced issue, which suggest that the WTP preference may vary between hypothetical and real settings but findings are not conclusive (Aadland and Caplan, 2003; Carlsson and Martinsson, 2001).

3.4. Community-based social marketing

Social marketing exploits the evidence that people are more likely to follow what others do (Liebig and Rommel, 2014). It is a strategic planning process that uses marketing principles and techniques to influence behavioral changes that benefit society and the individual (Salazar et al., 2019). Social marketing is compared with education and law as one of the three major tools for behavioral change with the claim that the toolbox of social marketing has more options than other theories and frameworks for behavioral change. A merger of knowledge from psychology and social marketing, community-based social marketing (CBSM) is proposed as a pragmatic alternative to traditional information-intensive campaigns for behavioral change (McKenzie-Mohr, 2000).

The tools used by CBSM include communication, incentives, norming and social diffusion. The CBSM has been studied in the context of, for example, fostering sustainable behavior (paper reduction, commingled recycling, purchasing environmentally preferred products) at a university (Cole and Fieselman, 2013), and promoting waste recycling behavior of households (Haldeman and Turner, 2009; Linder et al., 2018) and of tailgaters in a sporting event (Martin et al., 2015). We did not find any examples of CBSM used in the context of e-waste and circular economy.

The CBSM approach is based on social psychology and the idea that behavioral changes are effective when pushed by 'real' people and at community levels (McKenzie-Mohr, 2011). It provides a five-step guideline for behavioral change interventions – selecting behaviors, identifying barriers and benefits, developing strategies, piloting, and implementation and evaluation. Social concern for status is a key trigger for consumption, and therefore interventions based on social influence may be effective in changing consumer behavior (O'Rourke and Lollo, 2015). The resources (in terms of time and money) required for the interpersonal communication in the CBSM programs has been highlighted as the major issue in implementing this behavioral change

strategy (Haldeman and Turner, 2009).

3.5. Nudging

Nudging is based on the assumption that humans are not exclusively rational beings and do not always act based on their knowledge and intentions because their decision making is often not mindful and can be influenced by heuristics and biases (Thaler and Sunstein, 2008). People's failure to always make rational choices works against the goal of behavioral change frameworks based on the utility-maximization assumption (e.g. economic incentives). To address this, two concepts – choice architecture and libertarian paternalism – have been proposed by behavioral economists (Sunstein, 2015). Based on these two concepts, a 'nudge' helps people without compulsion, but 'paternalizes' them with a gentle push towards the 'right choice' (Leonard, 2008). In recent years, 'nudging' has been increasingly used as an umbrella term and is known as a low-cost solution for promoting pro-environmental behavior (Ölander and Thøgersen, 2014).

Contrary to other approaches that seek to completely change a behavior, nudges rely on subtle ques to influence on how people act – without them even noticing it. Nudging evolved from the field of behavioral economics, which unlike conventional economic theories, suggests that a) material payoffs are not the sole driver of human behaviors, b) social norms and context are important motivators, and c) cognitive limitations lead to irrational decisions (Carlsson and Johansson-Stenman, 2012). An example of these elements coming into play is the significant difference between 'willingness to pay' and 'willingness to accept' reported by empirical studies (Horowitz and McConnell, 2002).

Nudges have been tested and reported to be effective in reducing food waste (Kallbekken and Sælen, 2013) and plastic waste (Rivers et al., 2017), and promoting more expensive green energy (Ebeling and Lotz, 2015). In the context of e-products, research examples include use of nudge to promote more durable products (Cerulli-Harms et al., 2018) and to encourage repair, leasing and purchase of 'greener' mobile phones (Stefansdotter et al., 2016). In both cases, the experimental trials based on simulated situation produced promising results for nudges but their implementation in real-world setting is not known.

Nudging is seen as a more rational approach to efficiently address individual behavior in environmental policies (Gsottbauer and van den Bergh, 2010). There are examples of investigations commissioned by governments as well as non-governmental bodies, mainly focusing on the policy aspects of user behavior. However, the initiative of implementing evidence-based intervention is still in its infancy. Nudges can be an attractive policy tool because of their low implementation cost (Momsen and Stoerk, 2014) but there is not enough evidence to claim that the process of designing effective nudges is inexpensive. Nudges are context-specific, and not all nudging strategies are equally effective to tackle a particular behavior. For example, 'defaults' are proven to be an effective nudge strategy for promoting green energy, while 'priming' – another nudge strategy – is found to have no or even negative effect (Momsen and Stoerk, 2014). A thorough methodological approach is therefore required to come up with the right nudging strategy. There are also controversies and critics of behavioral interventions based on nudging, which is accused of being manipulative and unethical and nudges are even argued to be unfit for tackling society's 'major ills' such as climate change (Goodwin, 2012).

4. Relevance to the circular economy

Transition towards a circular economy is not possible without a fundamental change in consumer behaviors regarding green purchase, adaptation to new business models and acceptance of product upgrading that involves repair and remanufacturing (Planing, 2015). This will require addressing not only the extrinsic attributes (e.g. infrastructure and incentives), but also intrinsic attributes (e.g. values and personal norms) of human behavior (Fig. 3). Conventional approaches to addressing this issue include initiatives such as information campaigns, economic incentives, and stricter regulations, whereas the use of behavioral insight in such initiatives are still rare. We can draw from literature that despite imperfections, behavioral theories and intervention tools are useful in addressing these social and psychological factors in order to drive pro-environmental practices. This conveys an optimistic message on the potential for integrating behavioral strategies along the different lifecycle stages of e-products to achieve a more circular economy.

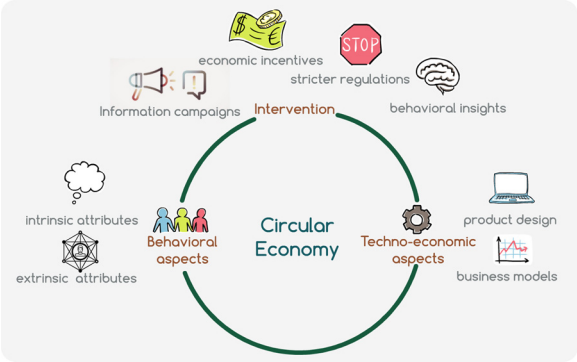

Fig. 3. Elements of behavioral and techno-economic aspects of the circular economy and potential intervention tools for behavioral change.

4.1. Challenges and opportunities

The gap between circular economy principles and consumer practices may be bridged with the help of behavioral insights without significantly altering the product lifecycle systems. Behavioral strategies may be used to promote, for example, purchase of 'green' products or alternative business models (such as leasing). Similarly, strategies may seek to encourage product reuse and repair for product lifetime extension during the use stage. Finally, at the end of a product's life, behavioral interventions can be designed to motivate users and to facilitate timely and proper disposal for better management of e-waste. The understanding of the socio-economic and psychological factors influencing human behaviors can help designing effective strategies to engage individuals and businesses in a more circular economy. The opportunities and challenges in implementing behavioral insights during purchase, use, and EoL management are summarized below.

4.1.1. Promoting green products

Displaying expected product lifespan as a label on e-products can influence purchase decisions and the influence may vary across different products (EESC, 2016). When designed properly, such labels can be used as a behavioral intervention to achieve the desired outcome (e.g. promoting 'greener' products). Users were less likely to choose the most energy-efficient television set when the European energy label was changed from a scale of 'A to G' to the scale of 'A^{+++} to D' (Ölander and Thøgersen, 2014). This is an example of 'framing', a nudging strategy, with undesired outcome (Schubert, 2017), which may be avoided by carefully using behavioral insights in the process of designing interventions.

Designing 'green' labels for e-products based on lifecycle impact assessment could be a challenging task given the multiplicity of product models and features in different e-products, which makes it difficult to compare two items. Research also suggests that not all product types are equally associated with ethical issues for consumers. In one study, consumers associated food items most strongly to ethical issues (including environmental) whereas brown goods (i.e. consumer electronics such as TV and stereos) were considered to have the weakest links (Wheale and Hinton, 2007). Such an issue may pose as a barrier to

promoting green e-products because they do not receive equal attention from consumers as, for example, organic food products during purchase. In addition, purchase of e-products occur much less frequently compared to other everyday consumer items. This makes it more challenging to develop buying 'green' e-products as a pro-environmental habit in consumers.

4.1.2. Circular business models

Consumer habits and routines formed by linear business models serve as a behavioral barrier in changing the status quo in consumption practices. A transition towards the circular economy will require leveraging the power of both rational (e.g. economic) as well as non-rational (e.g. moral) motives in order to change consumer habits (Planing, 2015). This applies for mainstreaming of alternative business models such as leasing for consumer e-products as well as for creating demands for refurbished and remanufactured products (Bittar, 2018; van Weelden et al., 2016v).

Despite the potential economic and environmental benefits of business models based on remanufacturing and/or product-service system, their adoption in industries are not widespread (Linder and Williander, 2017). Remanufacturing is especially less common for consumer products – an issue that cannot be solved by traditional 'green marketing' approach without considering behavioral aspects of the buyers (Vogtlander et al., 2017). In addition, the design of products and business models needs to expand beyond the physical characteristics in order to encompass the human aspects of consumption (Wastling et al., 2018).

4.1.3. E-waste management

The recast of WEEE Directive has set a new minimum e-waste collection target of 65 % (based on the weight of e-products put on the market during the three preceding years) (European Parliament, 2012). Many countries in Europe are struggling to meet this new target whereas stockpiling of used e-products in households has been a major factor contributing to the lower collection and recycling rates (Nowakowski, 2016). Improper disposal and stockpiling of EoL products can be partly attributed to the lack of flexibility and convenience of the official e-waste collection systems offered to consumers. Factors such as behavioral costs and environmental motivations at the individual level are therefore important, which may be influenced more effectively by social enticements than more costly structural improvements (Otto et al., 2018).

The nature of e-waste poses additional challenges in designing behavioral interventions compared to other product and waste categories. In some countries, recycling behavior has become a social norm and people may be stigmatized for not recycling their household waste (Thomas and Sharp, 2013). However, e-waste is a relatively new stream of waste that is usually not discarded with other household waste. E-waste is perceived as valuable and clean, which helps to discount the urgency factor of waste disposal – partly explaining why people don't mind stockpiling EoL products at home (Casey et al., 2019). Behavioral interventions aiming to improve the e-waste collection situation need to take into account these nuances within the waste collection practice.

It is worth mentioning here that the main objective of the WEEE Directive is not only to facilitate recycling, but also to prevent the generation of e-waste, for example, by the means of reuse. The Directive also emphasizes that the recycling and any other form of resource recovery should occur in a manner that the overall lifecycle impacts of e-products are minimized. It is therefore important to ensure that behavioral interventions applied to improve e-waste collection is matched with collection and resource recovery infrastructure that are aligned with the goals to preserve, protect and improve the quality of the environment and human health.

It is also important to consider the variations in different geographical, cultural and techno-economic settings that have significant influence on consumer behaviors. E-waste recycling behaviors can vary because of different financial and social enticements in different countries. Structural conditions such as convenience of recycling and the nature of EoL management systems across different countries and regions also come into play (Kumar, 2019; Otto et al., 2018). Moreover, recycling behaviors are shaped by personal norms that vary with people's knowledge and beliefs about environmental impacts as well as cultural norms that vary with ethnicity and collective values (Saphores et al., 2012). These issues, together with the more complex nature of e-waste, need attention in the designing of behavioral interventions to facilitate a more circular economy.

4.2. Policy implications

The role of users and impacts of their action in a circular economy have been largely ignored in policy interventions. The European action plan for the Circular Economy (European Commission, 2015) touches upon the need for public awareness campaigns to change behavior, but it does not address the well-known knowledge-action gap or the psychological and social aspects of consumption in a circular economy. Two other key European interventions covering e-products – WEEE and Ecodesign Directives – do not include end users in their scopes. On the bright side, although policies traditionally have been focused on 'regulatory' tools like taxes and permits, behavioral elements, and the fact that they can be facilitated with business models and infrastructure, are increasingly becoming part of the toolbox for policy making (OECD, 2017).

Despite the ongoing debate on ethical issues, nudges are becoming increasingly popular in recent years. Changing defaults, one type of nudging strategy, has proven its strength as an alternative to economic incentives and has been the go-to tool for behavioral interventions at policy level (Ebeling and Lotz, 2015; Tannenbaum et al., 2017). The evidence in the favor of nudging for environmental policies is strong, however, the application of these insights is not straightforward and needs to address the complexities of behavioral interventions to be a success (Moseley and Stoker, 2013). Nudges are known to be cost-effective (Thaler and Sunstein, 2008), can be designed and implemented in different forms and they can easily be combined with other theoretical frameworks of behavioral interventions (Linder et al., 2018). Nevertheless, there is no one-size-fits-all behavioral solution to varying problems across the product lifecycle and therefore they require customized interventions.

Finally, although everyday consumers play an important role, a transition towards the circular economy is not possible without the behavioral changes of structural actors. Besides reuse, repair and recycling, the circular economy envisages alternative models such as access models or product-service systems that are focused more on fulfilling customers' need than on selling more products (Reim et al., 2015). To achieve this, a collaborative approach from markets, institutions and policy makers is crucial, which requires changes in behavior of structural actors, namely businesses and governments (O'Rourke and Lollo, 2015). The lack of collaboration among stakeholders in the product lifecycle has been identified as a significant barrier in building a circular system for e-products in the EU (Parajuly, 2017). A proactive role of businesses and governments is therefore needed to negate the institutional barriers such as inertia and bureaucracy.

5. Future research

There are behavioral scientists/economists and environmental psychologists, and then there are engineers and policy makers. There is a gap between the behavioral research and the understanding of the techno-sphere of e-products' lifecycle. This serves as a major barrier in designing behavioral interventions to promote circular economy for e-products. An awareness of behavioral elements and strategies, combined with product lifecycle system knowledge, will allow designing

effective interventions. Behavioral interventions without the knowledge of techno-economic aspects of circular economy and e-products may produce insufficient or even opposite results. Behavioral insights alone are not enough, for example, to realize that the change in purchasing behavior can yield better environmental results than recycling of products (Byerly et al., 2018) or to identify the intangible product properties that shape the reuse of e-products (Makov et al., 2018). On the other hand, techno-economic models alone are not enough to realize that the factors (e.g. values and environmental attitudes) behind waste reduction and reuse practice may not be the same as those driving the success of structured recycling schemes (Barr et al., 2013).

The nature of target behaviors can be different: some meant to last for a long period, while others may be one-off. Interventions should try to address behaviors considering the most relevant attributes linked to them, which may be based on part or the whole of one or more behavioral theories. Although solid evidence of its success are not sufficient (Kosters and Van der Heijden, 2015; Vetter and Kutzner, 2016), nudging may carry a unique potential among the available frameworks as a 'novel' instrument for behavioral interventions especially at the policy level (Stefansdotter et al., 2016). Nudges can also be used by other stakeholders to promote actions particularly in situations where less frequent decision-making is required. The potential use of nudging in the context of e-waste and circular economy deserves further investigation.

It is important to emphasize that people's behaviors are linked to a whole array of infrastructural opportunities and are dictated by their surroundings. Therefore, behavioral change interventions are not only about changing individuals' consumption habits, but also about creating favorable environments to perform certain actions. Although potentially helpful in drafting effective policies and designing cost-effective infrastructure for public involvement, use of behavioral insights in technological solutions for environmental problems is not widely practiced (Allcott and Mullainathan, 2010). And even when such initiatives are taken, not having a thorough understanding of user behaviors and the science behind behavioral interventions may lead to poor application with disappointing results and loss of resources used in the initiative (Davis et al., 2015).

Systematically identifying target outcomes first, and then designing behavioral interventions to achieve those context-specific targets may be a more realistic strategy than seeking to permanently alter general consumers' attitudes and behaviors concerning circular economy. Identifying right points of intervention in the product lifecycle will require a thorough system understanding of product lifecycle and the related techno-economic aspects, whereas designing effective intervention will require socio-behavioral insights. More interdisciplinary research is needed in order to investigate the rationale behind users' actions and the significance of user behaviors in product lifecycle and to explore possibilities of matching and influencing those behaviors through interventions.

In the context of facilitating a more circular economy for e-products, we recommend that the future research should particularly focus on the following aspects of consumer behavior.

a Empirically understanding the challenges (intrinsic and extrinsic attributes of consumer behavior) to encourage their participation in the adoption of more circular business models, repair/reuse practices and proper collection of e-waste: For example, understanding why people tend to stockpile used e-products at home instead of discarding them in proper and timely manner.
b Establishing a systematic and methodological approach to design and test effective behavioral intervention tools for promoting desired consumer practices. Given the promising prospects of the 'nudging' strategy, design and testing of better choice architecture could be a focus.
c Integrating behavioral elements into national/regional policies on e-waste and using behavioral change strategies in the design of EoL management infrastructure (e.g. collection systems) and business models that seek to facilitate reuse and repair of e-products.

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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Appendix A. Supplementary data

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