

## Behavioural rebound effects and secondary benefits of sustainability-oriented design: two sides of the same coin?

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**Abstract:** Despite the growing body of research on the role of rebound effects (RE) in offsetting potential environmental gains, understanding of secondary benefits (SB) remains limited. SB are induced behavioural or systemic changes triggered by sustainability-oriented design that strengthen, rather than offset, potential environmental gains. To address this gap, this study aims to uncover the underlying behavioural mechanisms with the aid of a systematic literature review. A total of 59 relevant articles has been selected, resulting in the identification of 17 behavioural SB mechanisms. The mechanisms are clustered into five categories: identity, consistency, efficacy, goals, and motivation. For each mechanism, a definition, explanatory quote, moderator list, and source overview is provided. Although each mechanism is unique, similarities in mediators and moderators suggest an interconnected rather than isolated nature. An evaluation of the research trends indicates an increased number of examined interventions. Nevertheless, limitations regarding the diversity of interventions, the intention-behaviour gap, and self-report bias remain. After interpreting the results, potential connections between SB and RE mechanisms are addressed. This study concludes with three recommendations for research to develop a comprehensive understanding of SB mechanisms. Ultimately, this understanding could contribute to achieving the full environmental potential of sustainability-oriented design and preventing RE.

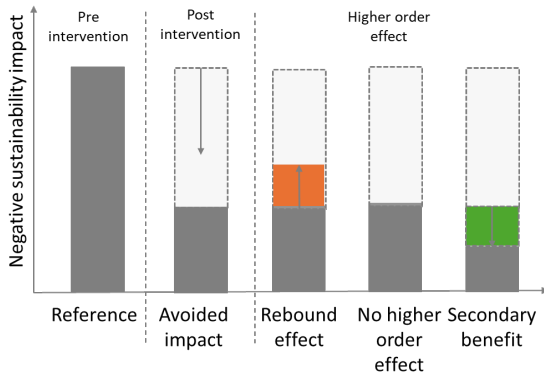
### Introduction

Currently, the full environmental potential of sustainability-oriented design remains unrealized due to the occurrence of rebound effects (RE). In this paper, sustainability-oriented design is defined as the process to design interventions (i.e., products, services, or systems) with lower resource consumption, implemented by actors such as designers and engineers. RE are induced behavioural and systemic changes triggered by these interventions, offsetting ca. 47% of the potential sustainability gains, in some cases even resulting in a net-negative impact (i.e., a backfire) (Andrew & Pigosso, 2024). Despite growing recognition of the importance of RE, understanding of the underlying causal structures leading to RE (i.e., mechanisms) is still limited (Guzzo et al., 2024), with a prominent focus on the economic rather than behavioural (e.g., social, psychological) mechanisms (Exadaktylos & van den Bergh, 2021; Santarius & Soland, 2016; Sorrell et al., 2020). Behavioural research tends to focus on the “moral licensing” mechanism, explaining

how the adoption of a sustainability-oriented intervention (e.g., refurbished laptop) can result in moral credits or credentials, creating the perception of entitlement to perform subsequent environmental questionable behaviour (e.g., not turning the laptop off), ultimately increasing resource consumption (Merritt et al., 2010; Tiefenbeck et al., 2013).

Contrary to RE, a topic remaining relatively unexplored is the occurrence of secondary benefits (SB), which are induced behavioural or systemic changes that reinforce, rather than offset, potential sustainability gains (Figure 1).

In this study, an environmental impact is defined as negative when it contributes to exceeding the safe operating space of the planetary boundaries (Rockström et al. 2009).

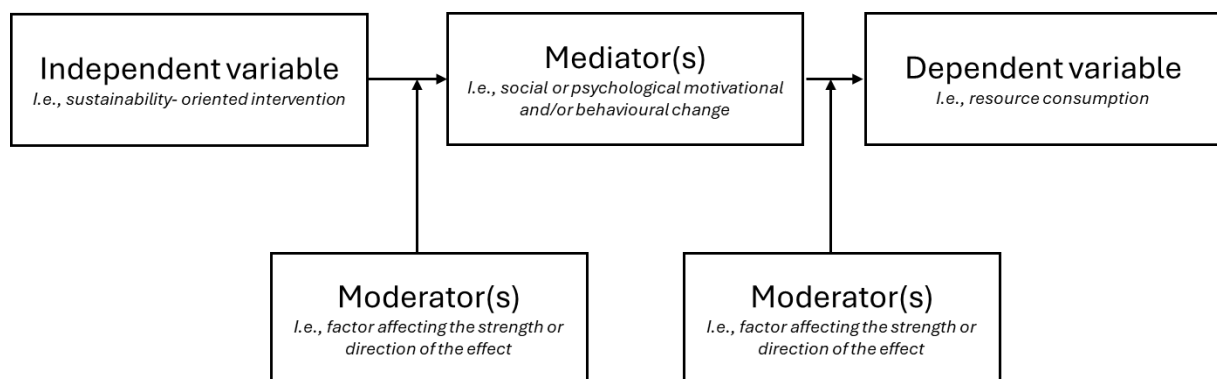


**Figure 1. Illustration of a RE and SB**

A behavioural SB mechanism occurs when a sustainability-oriented intervention (i.e., independent or predictor variable) triggers at least one change in social or psychological motivation (i.e., mediator) and corresponding behavioural change (i.e., mediator), eventually resulting in a higher order decrease in resource consumption (i.e., dependent or outcome variable) (Figure 2). Whereas the mediators (e.g., strengthened environmental identity) in a mechanism account for the relation between the independent and dependent variable, the moderators (e.g., environmental norms) affect the direction and/or strength of a relation between an independent and dependent variable (Baron & Kenny, 1986).

Although existing RE research generally fails to address SB (Vivanco et al., 2022), relevant insights can be found in spillover literature. A spillover effect occurs when engaging in one pro-environmental behaviour (PEB) prevents (i.e., negative spillover) or promotes (i.e., positive spillover) engagement in subsequent PEB (Truelove et al., 2014). For instance, a positive spillover effect arises when an initial PEB (e.g., recycling) strengthens the environmental identity of an actor resulting in subsequent behaviours in line with this identity (e.g., avoiding single use plastics) (Nilsson et al., 2017). Nevertheless, spillover mechanisms are insufficient to explain RE and SB due to structural differences (e.g., Nash et al., 2017).

Improved understanding of the occurrence of SB and the underlying mechanisms is needed to recognize under which circumstances sustainability-oriented interventions could lead to even more environmental gains than initially achieved. Consequently, this understanding might provide insights into how SB mechanisms can counteract RE mechanisms, ultimately contributing to a design process where the potential environmental gains from interventions are fully realized. Therefore, this study aims to define the potential behavioural mechanisms underlying the SB of sustainability-oriented interventions through a systematic literature review.



**Figure 2. Illustration of a behavioural SB/RE mechanism.**

## Methodology

A systematic literature review, following the guidelines of Biolchini et al. (2005), is employed to obtain a comprehensive overview of the behavioural mechanisms leading to SB. The search string includes “secondary benefits” and related synonyms in the “title”, and “behaviour” and “sustainability” and related synonyms in the “title, abstract, or keywords”. Through Scopus, a scientific database known for its extensive journal coverage related to the topic (Falagas et al., 2008), 417 unique articles have been identified. Articles are excluded when not meeting one or more inclusion criteria: elaborating on a (i) behavioural mechanism; (ii) SB; and (iii) the environmental sustainability context. After filtering, 59 articles are selected for the final analysis.

Next, the behavioural SB mechanisms are extracted from the articles. For clarification purposes, the mechanisms are clustered into 5 inductively defined categories. Information on the mediators and moderators of the mechanisms along with the polarity of the relationships (i.e., + if reinforcing, - if offsetting) and an explanatory quote, is used for the development of a comprehensive mechanism overview. Information on the independent variable (e.g., type of intervention) and

dependent variable (e.g., measured outcome) is used to develop a reflection of related research trends. Lastly, the results are interpreted, discussed, and translated into three recommendations for researchers to increase understanding of the implications of sustainability-oriented interventions.

## Results

This section presents an overview of the identified behavioural mechanisms underlying SB followed by an evaluation of related research trends.

### Behavioural mechanisms leading to SB

The 17 identified behavioural mechanisms explain distinct reasons for changes in PEB. The mechanisms are clustered into five not mutually exclusive categories: identity, consistency, efficacy, goals, and motivation (Figure 3). All mechanisms have been examined in an environmental sustainability context, of which most elaborate on conservation (i.e., 26%), carbon footprint (i.e., 29%) and/or circularity (i.e., 15%). It is important to notice, that no significant effect size was found for a few mechanisms (i.e., environmental social identity, goal contagion, and collective efficacy).

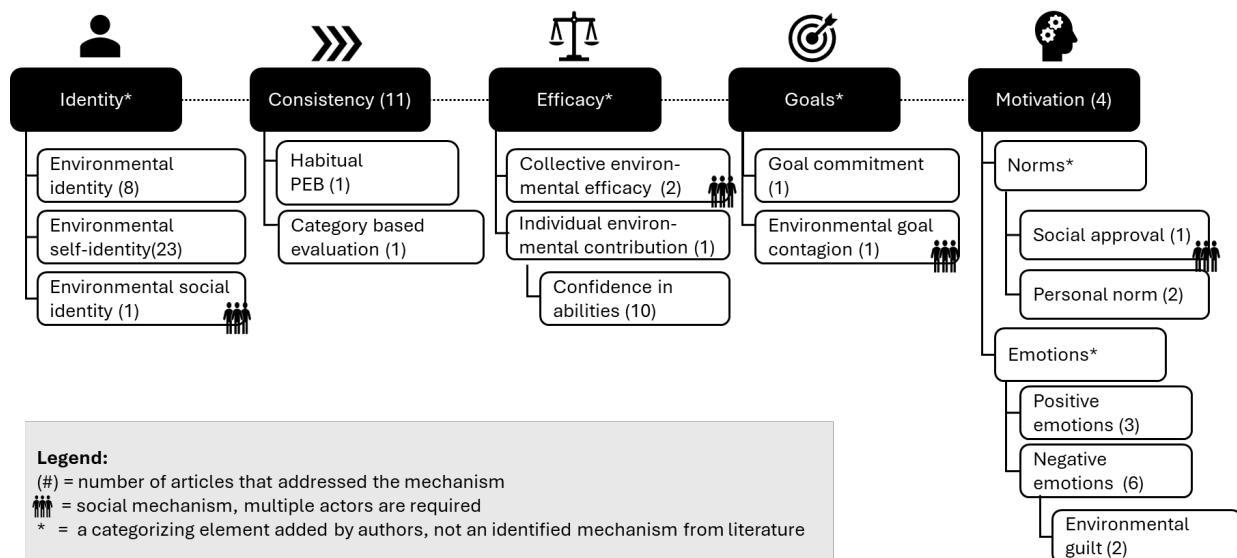
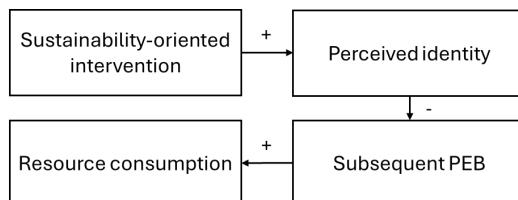


Figure 3. Categorised behavioural mechanisms leading to SB.

### Identity

Identity mechanisms (Figure 4) influence how individuals perceive themselves in relation to the environment (i.e., environmental identity), their self-concept (i.e., environmental self-identity), or social group (i.e., environmental social identity):



**Figure 4. Identity mechanisms.**

(1) Environmental self-identity: Identity perception in terms of caring for the environment.

Explanatory quote: “Driving a car with remanufactured components makes me identify myself as an environmentally friendly person and increase other PEB”

Moderators: Initial PEB is more difficult than subsequent PEB and initial and subsequent PEB are similar. Actor has high moral/environmental identity, educational attainment, family income levels, and environmental awareness, strong consistent personality, personal ecological norms, and salient environmental goals.

Sources (23): Capstick et al., 2019; Fanghella et al., 2019; Geiger et al., 2021; Geng et al., 2019; Hagggar et al., 2023; Henn et al., 2020; Lacasse, 2016; Lauren et al., 2019; Lope & Weave, 2021; Maki et al., 2019; Nash et al., 2019; Nilsson et al., 2017; Puntiroli et al., 2022; Steinhorst & Matthies, 2016; Thøgersen & Crompton, 2009; Truelove et al., 2014; Truelove & Nugent, 2020; Van Der Werff & Steg, 2018; Wolstenholme et al., 2020; Yang, Cheng, et al., 2021; Yang, Wei, et al., 2021; Zhang et al., 2024; Zhou et al., 2017

(2) Environmental identity: Identity perception in terms of closeness to the natural environment.

Explanatory quote: “Walking instead of driving makes me feel closer to the environment and increase other PEB”.

Moderators: Initial PEB is more difficult than subsequent PEB, actor has a high level of professional knowledge.

Sources (8): Frezza et al., 2019; Mateer et al., 2023; Poortinga et al., 2013; Sparkman et al.,

2021; Verfuert et al., 2019; Xu et al., 2018a, 2018b; Zhao & Huangfu, 2023

(3) Environmental social-identity: Identification with environmental groups.

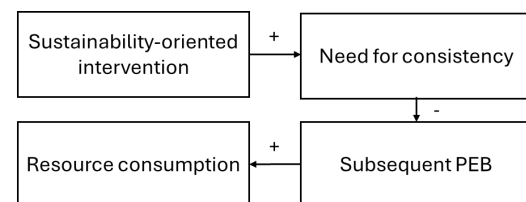
Explanatory quote: “I joined the remanufacturing program offered by my car maintenance supplier, now I feel part of the group of environmentalists and increase other PEB”

Moderators:-

Sources (1): Geiger et al., 2021

### Consistency

Consistency mechanisms (Figure 5) explain alignment of behaviours over time. Three consistency mechanisms have been identified, including habitual PEB and category-based evaluation as sub-mechanisms of need for consistency:



**Figure 5. Need for consistency mechanisms.**

(4) Need for consistency: Preference for stable patterns of behaviour.

Explanatory quote: “I drive a car with a remanufactured engine, now I also feel the need to get a remanufactured rather than brand new laptop”

Moderators: Initial PEB is more difficult than subsequent PEB and initial and subsequent PEB are similar. Actor has high educational attainment, family income, and environmental awareness, strong consistent personality, environmental self-identity, personal ecological norms, an analytical mindset, and recognises behaviour as normative.

Sources (11): Capstick et al., 2019; Geiger et al., 2021; Nilsson et al., 2017; Penz et al., 2019; Puntiroli et al., 2022; Sintov et al., 2019; Spaccatini et al., 2023; Steinhorst & Matthies, 2016; Suárez-Varela & Dinar, 2020; Thøgersen & Crompton, 2009; Zhou et al., 2017

(5) Habitual PEB: The establishment of automatic behaviours.

Explanatory quote: “Whenever a car part breaks, I try to repair it myself, which makes it

likely that I will apply this habit to other products too”

**Moderators:-**

**Sources (1):** Peng et al., 2024

(6) Category-based evaluation: The need to align behaviours of the same category.

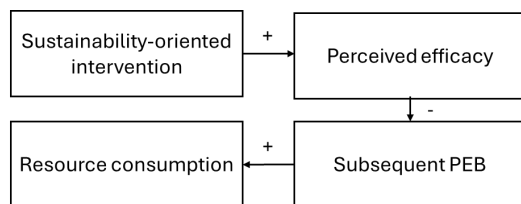
Explanatory quote: “I drive a car with remanufactured parts, now I also feel the need to drive more energy-efficient to further reduce the negative environmental impacts of my mobility behaviours”

**Moderators:-**

**Sources (1):** Thøgersen, 1999

### **Efficacy**

Efficacy mechanisms (Figure 6) deal with the perceived ability to effectively contribute to the outcome. Three efficacy mechanisms have been identified on the individual level (i.e., confidence in abilities, individual environmental contribution) and social level (i.e. collective environmental efficacy):



**Figure 6. Efficacy mechanisms.**

(7) Confidence in own abilities: Perceived confidence in one’s own knowledge and skills.

Explanatory quote: “I got a car with remanufactured parts, which gives me knowledge and skills that make it easier to adopt other remanufactured products”

**Moderators**: Initial and subsequent PEB are similar. Actor has a strong consistent personality and environmental self-identity.

**Sources (10)**: Elf et al., 2019; Hagggar et al., 2023; Kaida & Kaida, 2015; Lauren et al., 2016, 2019; Lope & Weave, 2021; Nilsson et al., 2017; Steinhorst et al., 2015; Wang et al., 2024; Ye et al., 2022

(8) Individual environmental contribution: Perception of added value to the environment.

Explanatory quote: “I drive a car with remanufactured instead of brand-new parts, this convinces me that I can make a difference and makes me increase other PEB”

**Moderators:-**

**Sources (1):** Arias & Trujillo, 2020

(9) Collective environmental efficacy: Perception of collective willingness and competency to make positive environmental impact.

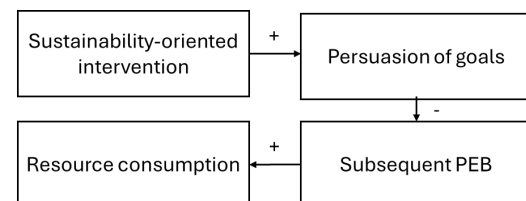
Explanatory quote: “Learning about the remanufacturing initiatives in my neighborhood convinces me that we can make a difference together and stimulates me to increase PEB”

**Moderators:-**

**Sources (2)**: Hagggar et al., 2023; Lauren et al., 2019

### **Goals**

The mechanisms in the goals cluster (Figure 7) relate to the pursuit of specific objectives. Environmental goal contagion and goal commitment are the two identified goal mechanisms:



**Figure 7. Goal mechanisms.**

(10) Environmental goal contagion: Adopting goals from other actors.

Explanatory quote: “Seeing my colleagues using remanufactured products inspires me to choose remanufactured rather than brand-new parts to my car”

**Moderators**: Messenger is significant to actor and the actor and messenger belong to the same social group.

**Sources (1)**: Jaich et al., 2023a

(11) Environmental goal commitment: Likelihood to pursue objectives.

Explanatory quote: “Driving a car with remanufactured parts motivates me to set a goal to lower my general environmental footprint and increase other PEB”

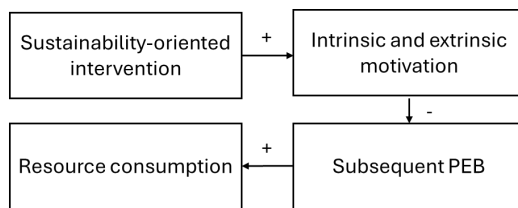
**Moderators**: User has low levels of relative deprivation and low levels of segmentation preference.

**Sources (1)**: Zhao et al., 2024



### Motivation

Motivation mechanisms (Figure 8) are related to changes in the driving forces of behaviours. Five motivation mechanisms have been identified, of which environmental motivation can be interpreted as the overarching mechanism. Negative emotion and environmental guilt can be interpreted as the emotional mechanisms and personal norms and social approval can be identified as the norm mechanisms:



**Figure 8. Motivation mechanisms.**

**(12) Environmental motivation:** Includes intrinsic (e.g., autonomy, relatedness, competence) and extrinsic (e.g., rewards) motivators.

**Explanatory quote:** “I enjoy driving a car with remanufactured parts, which makes me motivated to go for the most sustainable option more often”

**Moderators:-**

**Sources (3):** Akers & Yasué, 2019; Toussard & Meyer, 2024; Wang et al., 2021

**(13) Negative emotions:** Includes anger, worry, guilt.

**Explanatory quote:** “Learning about the negative environmental impact of short product lifetimes in the mobility industry makes me angry and motivates me to increase PEB in multiple domains”

**Moderators:** Initial and subsequent PEB are similar, actor has low product involvement.

**Sources (6):** Carrico et al., 2018; Ha & Kwon, 2016; Sparkman et al., 2021; Truelove & Nugent, 2020; Wang et al., 2021; Xu et al., 2018a

**(14) Environmental guilt:** Feeling of remorse and regret related to the environment.

**Explanatory quote:** “Learning about the negative impact of short product lifetimes in the mobility industry makes me feel guilty and motivates me to increase PEB in multiple domains”

**Moderators:** Initial and subsequent PEB are similar.

**Sources (2):** Truelove & Nugent, 2020; Yang, Cheng, et al., 2021

**(15) Positive emotions:** Includes pleasure, pride, approval.

**Explanatory quote:** “Driving a car with remanufactured instead of brand new parts makes me feel happy about reducing negative environmental impact, and motivates me to involve in other PEB”

**Moderators:** Actor has a high level of professional knowledge.

**Sources (3):** Wang et al., 2024; Ye et al., 2022; Zhao & Huangfu, 2023

**(16) Personal norm:** The moral obligation to do the ‘right thing’.

**Explanatory quote:** “After learning about the negative environmental impact of short product life times in the mobility sector, I realized I am not living up to my moral standards and decided to increase PEB in multiple domains”

**Moderators:-**

**Sources (2):** Lacasse, 2019; Steinhorst et al., 2015

**(17) Social approval:** Injunctive norms.

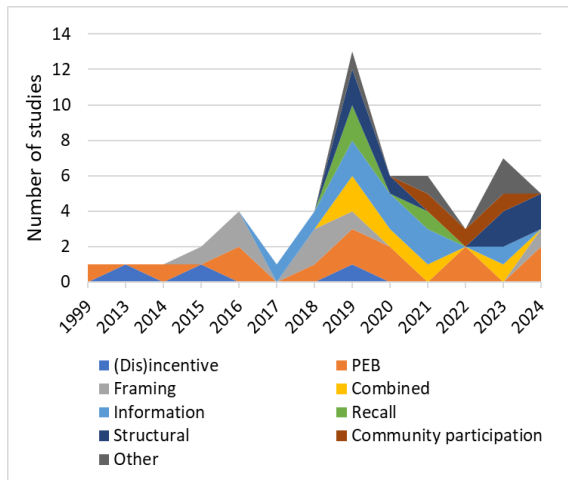
**Explanatory quote:** “Seeing many cars with remanufactured parts makes me realize this is the norm and adopt a remanufactured instead of a brand-new parts too”

**Moderators:** Recognising behaviour as normative.

**Sources (1):** Jaich et al., 2023b

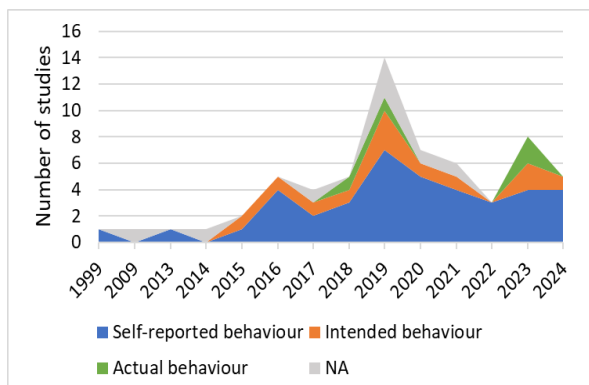
### Research trends

Sustainability-oriented intervention trends are investigated based on nine intervention categories (adopted from Geiger et al. (2021)). While the number of studies uncovering behavioural SB mechanisms and the diversity in interventions is increasing (Figure 9), most interventions are behavioural rather than economic, political, or technological, which could limit our understanding of the occurrence of behavioural SB mechanisms in different contexts.



**Figure 9. Examined interventions over time.**

Additionally, most studies are empirical studies measuring behavioural change as a change in self-reported or intended behaviour rather than actual behaviour (Figure 10), potentially reflecting an intention-behaviour gap (Sheeran & Webb, 2016) and response bias (Van de Mortel, 2008).



**Figure 10. Measured behavioural outcomes over time.**

## Discussion

To improve the understanding of the relatively unexplored SB, this study identified 17 behavioural SB mechanisms through a systematic literature review, clustered in 5 areas. Even though each mechanism is unique demonstrating that SB can happen because of different reasons, some of the mechanisms have similar mediators. For instance, goal contagion can be seen as a motivational change and the need for consistency is reflected in the goal commitment mechanism. This suggests that the mechanisms do not always occur in isolation and can interact.

Additionally, the results demonstrate that different mechanisms can be strengthened by similar moderators. For instance, similarity of the initial and subsequent behaviour is said to strengthen the preference for consistency, confidence in own abilities, negative emotions, environmental guilt, and environmental self-identity mechanism. Taken together, this indicates that in specific cases one intervention can be used to alter multiple SB mechanisms.

A comparison of the behavioural mechanisms leading to RE and SB reveals potential relationships. Moral licensing (RE), for instance, seems to counteract the need for consistency (SB), while negative stereotypes (RE) neutralise social approval (SB), and motivational crowding (RE) seems to counterbalance environmental motivation (SB). The connections between SB and RE mechanisms highlight the importance of in-depth mechanism analysis to develop accurate predictions and interventions capable of maximising environmental gains. Nevertheless, it is important to note that directions cannot be made for all RE and SB mechanisms. For instance, both information overload (RE) and environmental identity (SB) do not have a clear counteracting mechanism. Whereas this could suggest that certain mechanisms solely explain RE or SB, the gaps could also indicate that the counterparts of these mechanisms are still to be explored.

Nevertheless, one should keep in mind that RE and SB are heavily context dependent, and that the related negative and positive environmental sustainability impact can change accordingly.

The results can be translated into three research recommendations:

- i. RE studies should further explore SB mechanisms as there exists a variety of SB mechanisms that might counteract or occur in parallel to the RE mechanisms. A better understanding of SB mechanisms, their effect sizes, and stimulation strategies can ultimately increase environmental gains and potentially prevent the occurrence of RE.
- ii. SB researchers should tackle the existing limitations in literature (e.g., limited intervention diversity, intention-behaviour gap, response bias) to

improve understanding in different contexts. Additionally, since most results in this study stem from behavioural spillover literature, the assumptions made regarding changes in resource consumption should be addressed in follow-up studies to ensure the validity of the findings.

- iii. Lastly, due to the novelty of the field, not all included mechanisms have been examined in a product lifetime context. SB research is encouraged to verify the assumptions made related to this context, and is additionally encouraged to examine different perspectives (e.g., economic, social), types of mechanisms (e.g., direct, indirect), sustainability domains (e.g., biodiversity), and research methods (e.g., qualitative) to build towards a more comprehensive understanding of SB.

## Conclusion

The 17 identified behavioural SB mechanisms suggest that sustainability-oriented design can trigger behavioural or systemic changes resulting in strengthened environmental gains. Nevertheless, due to the novelty of the research area, future research is needed to examine the interaction with RE mechanisms, tackle the research gaps, and address different contexts. Ultimately, a comprehensive understanding of SB mechanisms can support designers in developing interventions that reach their full environmental potential.

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