Journal of Environmental Psychology 92 (2023) 102153

Contents lists available at ScienceDirect

Journal of Environmental Psychology

journal homepage: www.elsevier.com/locate/jep

Probing pro-environmental behaviour: A systematic review on its relationship with executive functions and self-regulation processes

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ARTICLE INFO

Handling Editor: W. Schultz

Keywords:
Pro-environmental behaviour
Self-regulation
Executive functions
Environmental attitude-behaviour gap

ABSTRACT

Given the role of self-regulation and executive functions in enabling goal pursuit and top-down regulation of behaviour, it is plausible to assume that these factors would affect individuals' ability to act upon their environmental concerns, hence contributing to explain individual differences in the performance of pro-environmental behaviour. This article examines the heterogeneous literature investigating the relationship of self-regulation processes (i.e., goal setting, monitoring and goal striving) and of executive functions (i.e., working memory, inhibitory control, and cognitive flexibility) with pro-environmental behaviour, with the aim of providing an extensive and unifying overview of this topic of research. We conducted a systematic literature review using the PRISMA protocol, searching three databases (Scopus, PubMed and PsycInfo). We included as records empirical studies on healthy adult participants, with no restrictions for the methodology, published in English in peer-reviewed journals. We excluded discussion, opinion, and review articles, as well as studies referring to human behaviours unrelated to environmental conservation, or referring to subjects other than individuals (e.g., households or organisations). After applying these criteria, 31 records with 41 individual studies with low estimated probability of bias were identified and included in the review. The reviewed literature suggests that greater top-down regulation is associated with increased engagement in pro-environmental behaviour. Yet, evidence is uneven for each self-regulation component and less robust for executive functions. Accordingly, we call for more research to be carried out to clarify the link between executive functions and self-regulation with respect to pro-environmental engagement, and to assess their intermingled contribution in reducing the environmental attitude-behaviour gap.

1. Introduction

Human responsibility for the environmental crisis has been documented by increasing scientific evidence (IPCC, 2021; WMO, 2021). Still, despite rising global concern about the catastrophic consequences of anthropogenic climate change on the ecosystem (Kantar, 2019; UNDP, 2021), humans are struggling to take the necessary action to effectively curb greenhouse gases emissions (Ritchie & Roser, 2020; UNEP, 2022). Several studies in psychology, neuroscience and social sciences have been devoted to understanding both intra- and inter-individual factors explaining people's engagement in pro-environmental behaviours, i.e., behaviours aimed at reducing one's impact on the environment (Kollmuss & Agyeman, 2002).

As a result, considerable research efforts have been focused on the identification of predictors of pro-environmental behaviour (Bamberg & Möser, 2007; Blankenberg, October 2019; Nielsen, 2019) and, specifically, to studying the effects of aspects like environmental knowledge, individual motivation, and contextual opportunity, on people's propensity to act for the environment (Bamberg & Möser, 2007; Steg et al., 2015). Less attention has been dedicated to understanding the role of cognitive factors, like self-regulation processes (Gómez-Olmedo, Carrero Bosch, & Martínez, 2020; Nielsen, 2017) or executive functions

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https://doi.org/10.1016/j.jenvp.2023.102153
Received 23 February 2023; Received in revised form 29 September 2023; Accepted 3 October 2023
Available online 18 October 2023

(Langenbach, Berger, Baumgartner, & Knoch, 2019), in explaining pro-environmental behaviour. Yet evidence of their role in explaining performance of desirable and beneficial behaviours across different domains (e.g., academic performance, professional achievement, healthy eating, psychosocial adjustment, and satisfactory relationships) has been widely documented (De Ridder et al., 2012; Houben et al., 2011; Houben & Jansen, 2011; Mischel & Ayduk, 2004; Moffitt et al., 2011). Furthermore, the most commonly applied predictive models of pro-environmental behaviour, i.e., Ajzen's theory of planned behaviour (1991) and Stern's Value-Belief-Norm theory (2000), have been largely criticised for failing to explain the environmental attitude-behaviour gap (Bamberg, 2013; Bamberg & Möser, 2007; Gifford & Chen, 2017; Siegel et al., 2018), i.e., why pro-environmental intentions do not always reflect into concrete actions (Kollmuss & Agyeman, 2002).

Thus, given the fundamental role of self-regulation and executive functions in enabling goal pursuit and top-down regulation of behaviour (Baumeister & Heatherton, 1996; Carver & Scheier, 1982, 2012; Jurado & Rosselli, 2007; Roebers, 2017), it is plausible to assume that these cognitive factors would contribute to explain individual differences in the performance of pro-environmental behaviour. By increasing individuals' ability to act upon their environmental concerns, self-regulation and executive functions would, indeed, support the actual implementation of their pro-environmental intentions (Bamberg, 2013; Gómez-Olmedo et al., 2020; Nielsen, 2017).

1.1. Self-regulation

The concept of self-regulation has been widely investigated in psychology and a wide array of models have been used to describe this aspect of human functioning (Baumeister et al., 2007; Hofmann et al., 2009; Inzlicht et al., 2021). Self-regulation can be defined as the ability to alter one's own automatic responses and inner states, to pursue long-term goals and adapt to one's environment (Baumeister & Heatherton, 1996; Blair, 2016; Carver & Scheier, 1982; Karoly, 1993; Lerner et al., 2011; McClelland, Geloof, Cameron, & Wanless, 2015; Nielsen, 2019). Conceptualisations of self-regulation vary with respect to the focus of their scrutiny (i.e., how self-regulation operates versus how it is developed) and the level of their analysis (i.e., interindividual differences versus intrapsychic processes involved; Inzlicht et al., 2021; McClelland et al., 2015). Yet, all the approaches seem aligned in considering self-regulation as the process or ability to "determine a desired end state and to take action to move toward it, while monitoring progress along the way" (Inzlicht et al., 2021, p. 320).

From the perspective of personality psychology, self-regulation is considered as a stable individual trait defining individuals' propensity to resist or give in to impulsion (Carver, 2005; Tangney et al., 2004; Whiteside & Lynam, 2001). Similarly, developmental scientists tend to consider self-regulation as a relatively plastic general ability, predicting a wide variety of positive life outcomes (Blair & Razza, 2007; Moffitt, 1993), which individuals develop throughout their lifespan, and which is affected by both biological (e.g. genetically coded sensitivity to stimulation or executive functioning) and contextual factors (e.g., parenting, culture, or social conditions) (Blair & Raver, 2015; McClelland et al., 2015).

In contrast with the interindividual focus of the above-mentioned perspectives, the outlook of cognitive psychology rather pinpoints the individual processes occurring when individuals modulate and control cognition, emotion, and behaviour, to reach a desired end-state. Dual models of self-regulation (Blair & Ursache, 2011; Heatherton & Wagner, 2011; Hofmann et al., 2009; Kahneman, 2011) describe self-regulation in terms of a balance between two distinct mental operating modes: one, faster and more impulsive, sub-serving habitual behaviour and short-term personal gratification, and the other, slower but more deliberate, enabling goal pursuit. The strength model of self-regulation (Baumeister et al., 1998, 2018), on the other hand, proposes that individuals' top-down capacity to override automatic responses for the purpose of goal pursuit (i.e., the ability to exert self-control, Tangney et al., 2004) would depend on the availability of a temporarily limited cognitive resource that can be strengthened through training (Baumeister, & HeathertonTice, 1994; Baumeister & Heatherton, 1996). Whilst both dual system models and the strength model of self-regulation tend to focus on the inhibitory dimension of the self-regulatory process, other conceptualisations move beyond the operationalisation of self-regulation as effortful control over unwanted responses, to include a preventive or initiatory dimension, deemed necessary to start and maintain behaviour aimed at reaching a goal (Hofmann & Kotabe, 2012; Gillebaart, 2018; Gillebaart & de Ridder, 2015). Among them we find choice models (Berkman et al., 2017; Buckholtz, 2015; Neal et al., 2017) and strategy models of self-control (Duckworth et al., 2016; Hennecke et al., 2019; Hofmann & Kotabe, 2012), as well the cybernetic model of self-regulation (Carver & Scheier, 1998).

The cybernetic model is one of the broadest and most influential models of self-regulation (Inzlicht et al., 2021; Gillebaart, 2018), therefore we refer to it in this paper for the operationalisation of the concept. The model compares self-regulation to a cybernetic control process consisting of three components, i.e., goal setting, monitoring, and goal striving. Such components relate to each other via feedback loops, through which individuals ensure behavioural adjustment towards the desired end-state (Carver & Scheier, 2012; Gillebaart, 2018; Inzlicht et al., 2014; Nielsen, 2019). The first component of the self-regulatory process is goal setting. To self-regulate successfully, individuals need to identify a desired end-state (or standard), providing the direction towards which behaviours need to be steered. Standards can either be "ideals" (i.e., defining the way one would like to be) or "oughts" (i.e., defining what one wishes to avoid) (Higgins et al., 1994) and form both within the self (i.e., when a person embraces a particular goal or value system) or from other people (i.e., when a person tries to comply with other people's expectations) (Baumeister et al., 2007). The second component is referred to as monitoring, i.e., the ability to monitor progress and to identify discrepancies between desired goals and current behaviours. Monitoring implies evaluating consistency between behavioural outcomes and goals. To effectively monitor one's behaviour, individuals need to consciously direct attention to their present state and be enabled to compare it with their desired end state. The last component, i.e., goal striving (or operating), refers to the planning and implementation of the behavioural strategy aimed at reaching a set goal. As such, goal striving entails identifying which behaviours should be performed for goal achievement, initiating the identified behaviours, and performing them till the goal is achieved. During this process, individuals are confronted with multiple challenges: they need to coordinate efforts to balance multiple goals, to prioritize some goals over others and, eventually, to disengage from incompatible/unproductive ones. Additionally, individuals are required to avoid/resist performing goal-conflicting behaviours, that is, to exert self-control (Fujita, 2011; Kotabe & Hofmann, 2015; Nielsen, 2019).

In this perspective, self-control can be seen as a fundamental subdimension of self-regulation underlying goal striving. Whilst the definition of self-control has been restricted, in the past, to its effortful and inhibitory component (Hoffman et al., 2009; Ainslie, 1975; Mischel et al., 1989), more recently researchers have suggested that self-control would include strategies that do not require effort (Galla & Duckworth, 2015; Gillebaart & de Ridder, 2015; Hennecke et al., 2019) nor inhibition of undesired behaviour (de Ridder et al., 2011; Gillebaart, 2018). The notion of self-control would, therefore, include the ability to initiate and automatise a desired behaviour (de Ridder et al., 2011; Gillebaart, 2018; Wood, 2017) as well as that of avoiding self-control dilemmas via preventive strategies (e.g., diverting attention from a temptation or redefining one's representation of restraining and/or giving in; Duckworth, 2016). This would explain why people with high self-control trait have been found to be more prone to automatise behaviours that are congruent with long term goals, and less vulnerable to self-control

dilemmas resulting into self-control fatigue/depletion (Hofmann et al., 2012). Also, this provides some insight onto why strategies aimed at automatising self-control, like for instance the adoption of implementation intentions (Gollwitzer, 1999; Gollwitzer & Brandstätter, 1997), appear effective for goal striving without affecting self-regulatory resources (Baumeister, 2007).

Given the critical role that self-regulation processes play in enabling people to plan and carry out behaviours aimed at achieving desired end states, investigating how self-regulation relates with pro-environmental behaviour should help to clarify why people's motivation and opportunities to act in a pro-environmental manner do not always result in actual engagement in pro-environmental behaviour (Bamberg, 2013; Nielsen, 2017). Poor self-regulation may, indeed, limit people's capacity to respond to the environmental crisis in a way that is congruent with their view of the environmental problem, despite being motivated to do so (Gómez-Olmedo et al., 2020).

1.2. Executive functions

Executive functions, also called cognitive control or executive control (Diamond, 2013), are a set of heterogeneous higher-order cognitive processes which govern individuals' ability to hold information in mind (i.e., working memory or updating), resist automatic urges (i.e., inhibitory control or inhibiting), and flexibly shift attention (i.e., cognitive flexibility or shifting; Miyake et al., 2000). Executive functions have been found to underlie adaptive behaviour and the top-down regulation of thoughts, emotions, and actions, and to be especially triggered in front of novel, challenging, and complex situations (Barkley, 2001; Diamond, 2013; Hofmann et al., 2012; Jurado & Rosselli, 2007; Miyake et al., 2000; Roebers, 2017).

Scientific evidence has shown that executive functions tend to overlap with self-regulation processes when it comes to their underpinning neural substrates (e.g., prefrontal cortex; Cohen & Lieberman, 2010), their developmental stages (Montroy et al., 2016) and the associated life outcome (Howard & Williams, 2018; Kahle et al., 2018; Ogilvie et al., 2011; Sulik et al., 2015). As such, executive functions have been referred to as the underlying cognitive dimensions of self-regulated action (Best & Miller, 2010; Doebel, 2020), enabling allocation of attention and top-down control in the service of goal directed behaviour (Cohen, 2017; Ursache et al., 2012).

Executive functioning is thought to support every step of the cybernetic feedback loop (Carver & Scheier 1998; Hofmann et al., 2012). Working memory, for instance, has been found to support the mental representation of individuals' self-regulatory goals and of the means required to attain them (Hofmann et al., 2012; Miller & Cohen, 2001), as well as the ability to focus attention on the goal in front of distracting stimuli (Hofmann et al., 2008; Kane et al., 2001). On the other hand, inhibitory control is required to resist impulses and override habits standing in the way of goal pursuit (Hoffman et al., 2009; Houben & Wiers, 2009; Payne, 2005). Lastly, cognitive flexibility has shown to facilitate goal attainment by enabling individuals to switch ineffective strategies with more effective ones and to disengage from goals that are no longer relevant (Fishbach et al., 2009; Marien, Aarts, & Custers, 2012).

By supporting the self-regulatory processes, executive functions should, by their very nature, also play a significant role in explaining individuals' propensity to act pro-environmentally. Hence, they should support individual's ability to adapt to the new global climate change challenge, just like the self-regulatory processes they appear to underlie (e.g., Barkley, 2001; Hofmann et al., 2012; Roebers, 2017).

1.3. Objectives of the review

Although executive functions and self-regulation have shown to be intertwined in supporting goal-directed behaviour (Baumeister et al., 2007; Carver & Scheier, 1998; Hofmann et al., 2012), research on the role of executive functions in explaining pro-environmental behaviour appear rather disconnected from that on the role of self-regulation. As such, this systematic review aims to integrate findings coming from the different theoretical backgrounds of cognitive psychology and neuroscience (executive functions) with those coming from social, personality, and applied psychology (self-regulation) and provide an answer to the following question: how do self-regulation processes and executive functioning contribute to explain individual engagement in pro-environmental behaviour?

Considering that acting pro-environmentally would imply the ability to resist immediately rewarding alternatives in favour of long-term collective gains, and to initiate new behaviours that are less onerous for the environment, and more coherent with one's attitudes regarding climate change, we expect effective self-regulation processes and executive functioning to be positively related to pro-environmental behaviour performance. Yet, beyond evaluating this hypothesis, with this review we wish to provide a more extensive and unifying overview on the dynamics of the relationship between self-regulation, executive functioning, and pro-environmental behaviour.

2. Methods

We carried out this systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). PRISMA considers three stages for the identification, screening, and inclusion of the identified records (see Fig. 1).

2.1. Exclusion and inclusion criteria

In our search, we considered all the studies in which the relationship between executive functions, self-regulation and pro-environmental behaviour was investigated empirically. Thus, discussion, opinion, and reviews articles, as well as grey literature, have been excluded from the review. Moreover, studies referring to human behaviours unrelated to environmental conservation were excluded, as well as studies in which executive functions, self-regulation, and pro-environmental behaviour (or underlying dimensions of them) are neither measured nor are the object of an experimental manipulation. Finally, studies referring to subjects other than individuals (e.g., households or organisations), or to minors or clinical populations were also excluded. As a result, all the articles included in our final sample were empirical studies on the relationship between executive functions, self-regulation, and pro-environmental behaviour, with no restrictions for the methodology, that involved healthy adult participants, and that have been published in English and in peer-reviewed journals.

2.2. Information sources and search strategy

The scientific literature was assessed using interdisciplinary (Scopus, Elsevier), life-science-focused (PubMed, MEDLINE) and psychology-focused (PsycInfo, Ovid) databases. The search was performed first on June 6th, 2022, and then updated on October 7th, 2022, to check for potential new publications available. The keywords used for the search were words referring to the notion of pro-environmental behaviour associated, through the Boolean operator AND, with terms referring to self-regulation or executive functions. We made sure that different spellings of the assessed concepts were taken into consideration. We restricted our search to articles presenting these terms in their title, abstract and keywords. Also, we limited results to journal articles published in English. No time restriction was set. The complete strings used for the searches carried out in the different databases and the limits set for each database search are detailed in Table 1. Finally, a manual search of the reference list of the included articles was carried out to identify potential additional eligible records.

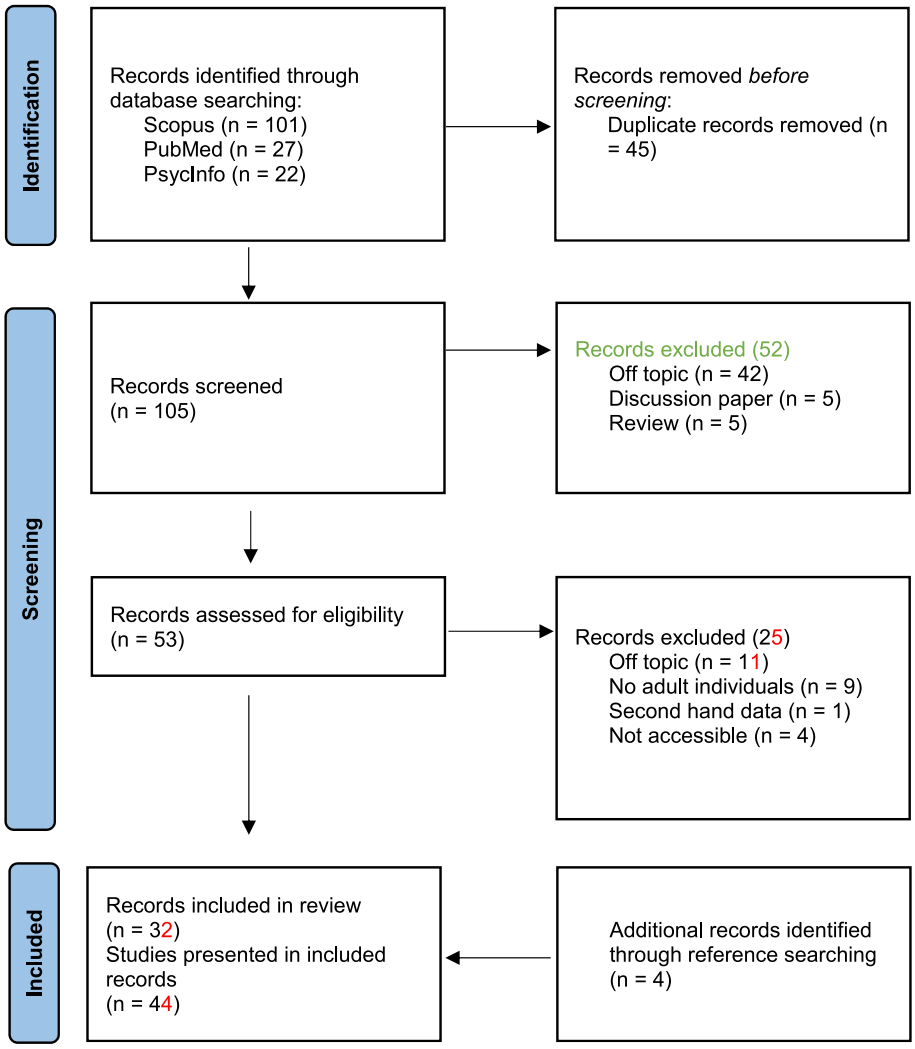

Fig. 1. Prisma flowchart.

2.3. Screening and selection process

The selection process was made in accordance with the PRISMA guidelines (Moher et al., 2009). First, all 150 search results were downloaded. Then, 45 duplicates were removed. The resulting list of 105 records was screened via the assessment of title and abstract, and further 52 records were excluded based on the eligibility criteria. The full text of the resulting 53 records was then assessed to identify the studies to be included in the narrative synthesis. 29 records were retained from database searching and 4 extra records were added to the final selection through manual reference checks. The final sample of records assessed for the systematic review consisted of 32 articles which presented the results of 44 studies, relevant for our research. The outlined process is represented in the PRISMA flowchart provided in Fig. 1. Information was extracted from each scrutinised study and collected in an Excel sheet detailing the aim of the study, the design, the number of participants, the measures and manipulations used to assess executive functions, self-regulation, and pro-environmental behaviour, the overall results, and the risk of bias. Multiple studies within the same article were included in the database as separate records. The detailed results are reported in separate tables throughout the Results' subsections.

2.4. Assessing quality of evidence and risk of bias

To assess the quality of the studies included in our systematic review, and the reliability of their findings, we used the Appraisal Tool for Cross-Sectional Studies (AXIS; Downes et al., 2016), a tool designed to address issues that are often apparent in cross-sectional studies. Our choice of the AXIS checklist was grounded on the fact that a large amount of the studies included in our systematic review are cross-sectional, and no specific tool has yet been developed to assess the quality of a sample of studies which use different research designs. The AXIS was developed to facilitate quality assessment through a detailed checklist and was conceived to be used across disciplines and in non-medical studies. As reported in Fig. 3, the AXIS consists of 20 items that address issues commonly observed in scientific studies, within the following sections: Introduction (item 1), Methods (item from 2 to 11), Results (from 12 to 16), Discussion (items 17 and 18), and Other (Items 19 and 20). Also, as it was intended by its authors as an organic tool that can be modified whenever necessary, we decided to exclude two items of the AXIS checklist, i.e., the item number 5 (regarding the sample frame) and the item number 14 (regarding non-responders), as mainly redundant. The final items are listed in Fig. 3.

The AXIS has areas to record a "yes", "no" or "don't know" answer for each question. Each study of our sample was evaluated on the different dimensions of the AXIS checklist. Then, we converted the "yes" answers in a score 2, the "no" answers in a score 0, and the "don't know" answers in a score 1. This allowed us to compute a percentage score from 0 to 100%, referring to the probability for the study to be biased (i.e., between 0 and 33% = low bias; between 33 and 66% = medium bias;

Table 1
Details of database searches in Scopus, Pubmed and PsycInfo.

Database	Search string	Filters applied	Results
Scopus	TITLE-ABS-KEY ("pro-environmental behavio*" OR "environmentally responsible behavio*" OR "environmentally friendly behavio*" OR "mitigat* behavio*" OR "conservati* behavio*" OR "green behavio*" OR "ecological behavio*" OR "sustainable behavio*" OR "climate action" OR "pro-environmental action" OR "mitigat* action" OR "conservat* action" OR "sustainable consum*" OR "green consum*" AND "executive function*" OR "supervisory attentional system" OR "executive control" OR "cognitive control" OR "cognitive flexibility" OR "set shifting" OR "task switching" OR "inhibitory control" OR "response inhibition" OR "self control" OR "self regulation" OR "cognitive inhibition" OR "interference control" OR "working memory" OR "goal setting" OR "goal striving") AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (EXCLUDE (PUBSTAGE, "aip"))	Limit to: Title, abstract, keywords Limit to: English Limit to: Articles Exclude: Article in press	101
Pubmed	(("pro-environmental behavio*"[Title/Abstract]) OR ("environmentally responsible behavio*"[Title/Abstract]) OR ("environmentally friendly behavio*"[Title/Abstract]) OR ("mitigat* behavio*"[Title/Abstract]) OR ("conservati* behavio*"[Title/Abstract]) OR ("green behavio*" [Title/Abstract]) OR ("ecological behavio*"[Title/Abstract]) OR ("sustainable behavio*"[Title/Abstract]) OR ("climate action"[Title/Abstract]) OR ("pro-environmental action"[Title/Abstract]) OR ("mitigat* action"[Title/Abstract]) OR ("conservati* action"[Title/Abstract]) OR ("sustainable consum*"[Title/Abstract]) OR ("green consum*"[Title/Abstract])) AND (("executive function*"[Title/Abstract]) OR ("cognitive control"[Title/Abstract]) OR ("supervisory attentional system"[Title/Abstract]) OR ("executive control"[Title/Abstract]) OR ("cognitive flexibility"[Title/Abstract]) OR ("set shifting"[Title/Abstract]) OR ("task switching"[Title/Abstract]) OR ("inhibitory control"[Title/Abstract]) OR ("response inhibition"[Title/Abstract]) OR ("self control"[Title/Abstract]) OR ("self regulation"[Title/Abstract]) OR ("cognitive inhibition"[Title/Abstract]) OR ("interference control"[Title/Abstract]) OR ("working memory"[Title/Abstract]) OR ("goal setting"[Title/Abstract]) OR ("goal striving"[Title/Abstract]))	Limit to: Title and abstract	27
Psycinfo	AB ("pro-environmental behavio*" OR "environmentally responsible behavio*" OR "environmentally friendly behavio*" OR "mitigat* behavio*" OR "conservati* behavio*" OR "green behavio*" OR "ecological behavio*" OR "sustainable behavio*" OR "climate action" OR "pro-environmental action" OR "mitigat* action" OR "conservat* action" OR "sustainable consum*" OR "green consum*") AND ("executive function*" OR "cognitive control" OR "supervisory attentional system" OR "executive control" OR "cognitive flexibility" OR "set shifting" OR "task switching" OR "inhibitory control" OR "response inhibition" OR "self control" OR "self regulation" OR "cognitive inhibition" OR "interference control" OR "working memory" OR "goal setting" OR "goal striving")	Limit to: Abstract Limit to: English Limit to: Journal articles Limit to: Peer-reviewed journal	22

Table 2
Final number of studies for each category.

Category	Subcategory	N of studies
Executive functions	Cognitive flexibility	2
	Working memory	1
	Cognitive control	2
Self-regulation	Goal setting	13
	Monitoring	4
	Goal striving	19

between 66 and 100% = high bias). Results are reported in Fig. 2, and in Tables 3–6.

Following this process, three studies from one paper were excluded from the systematic review (McCalley, 2006, as they were found to present a medium-to-high risk of bias due to missing information in the reporting of methods and results. Then, we calculated, for each item of the AXIS checklist, the proportion of studies presenting a risk of bias among the final 41 studies included in the review (results are reported in Fig. 3).

3. Results

Following the further exclusion of 3 studies due to high risk of bias, we included in the final sample of our systematic review 41 separated studies, found in 31 peer-reviewed papers. Most of the studies were carried out using a cross-sectional (n = 18) or an experimental design (n = 21), one used a longitudinal survey design, and one used a qualitative method. Beyond self-report and behavioural measures, two studies used neuroscientific measures to assess the variables investigated. All the studies were completed in the past twenty years. Specifically, the papers addressing the relationship between executive functions and pro-environmental behaviour were published after 2019, and over 70% of

Table 3
Studies on executive functions (EFs) and pro-environmental behaviours (PEB).

STUDY	EF	AIM OF THE STUDY	DESIGN	PARTICIPANTS	MEASURES OF PEB	MEASURES OF EFs	FINDINGS	RISK OF BIAS
Brevers et al (2021)	Inhibitory control	To explore the core network of brain regions involved in the prospective thinking about (un)sustainable behaviours.	Within group experimental design with (neuroimaging cue exposure)	N = 86	Self-reported feasibility of increasing/ decreasing (un) sustainable behaviour pictured in stimuli	Task-dependent MRI	rdlPFC (supporting inhibitory control) is activated when simulating the reduction of unsustainable behaviours. HC, vmPFC and parahyppocampal gyrus (supporting prospective thinking) are activated when imagining increasing sustainable behaviours. rdlPFC activity is negatively associated with activity within the left HC (supporting retrieval and episode-construction processes).	14%
Langenbach et al., 2019	Working memory	To investigate the role of cognitive resources in explaining the environmental attitude-behaviour gap.	Cross-sectional design (Self-report measures & behavioural task)	N = 71	Ecological momentary assessment (self-reported PEB)	Visual n-back task (Sweet, 2011).	Individual differences in central aspects of cognitive control (assessed by working memory capacity) moderate the relationship between environmental attitudes and behaviour	14%
Baumgartner et al (2019)	Inhibitory control	To identify interindividual markers that explain variance in the frequency of every-day pro-environmental behaviour.	Cross-sectional design (EEG and self-report measures)	N = 87	Experience sampling (multiple questionnaires per day on PEB to immediately fill out)	Task-independent resting electroencephalography (EEG)	Positive correlation between higher baseline activation in the right lateral PFC (supporting inhibitory control, SR and EFs) and daily PEB. Baseline activation in the right lateral PFC explains unique variance, beyond attitude (NEP)	26%
Lange & Dewitte, 2019 **(study 1)**	Cognitive Flexibility	To explore the role of cognitive flexibility as a correlate of PEB.	Cross-sectional design (self-report and behavioural measures)	N = 143	Pro-environmental behaviour task (PEBT, Lange et al., 2018) Self-reported PEB (Schultz et al., 2005)	Task switching (Friedman & Miyake, 2017) eWCST (Barceló, 2003) Voluntary switching (Arrington & Rhodes, 2010), CFI (Dennis & Vander Wal, 2010) CFS (Martin & Rubin, 1995) COHS (Ersche et al., 2017) BRIEF-A (Roth et al., 2005)	Moderate correlation between self-report measures of CF (most notably the CFI) and self-reporfted PEB. Weak negative correlation between perseverative behaviour on the cWCST and pro-environmental behaviour on the PEBT.	21%
Lange & Dewitte, 2019 **(study 2)**	Cognitive Flexibility	To replicate the previous study and confirm the role of cognitive flexibility as a correlate of PEB.	Cross-sectional design (self-report and behavioural measures)	N = 264	Pro-environmental behaviour task (PEBT, Lange et al., 2018) Self-reported PEB (Schultz et al., 2005	CFI (Dennis & Vander Wal, 2010) eWCST (Barceló, 2003)	Significant positive medium-sized correlation between self-reported CF and self-reported PEB. Negative correlation between perseverative behaviour on the eWCST and pro-environmental behaviour on the PEBT not statistically significant	18%

Table 4
Studies on self-regulation (SR) and pro-environmental behaviours (PEB) referring to the goal-setting component of the self-regulatory process.

STUDY	AIM OF THE STUDY	DESIGN	PARTICIPANTS	MEASURES OF PEB	MEASURES OF SR	FINDINGS	RISK OF BIAS
Kanay et al., 2021 **(Study 1)**	To evaluate the effect of goal setting on consumer behaviour and compare the effectiveness of basket goal setting to product information strategies.	Between group randomised experiment (5 conditions)	N = 176	Behavioural task (reduced carbon basket)	Manipulation (information architecture directed at eliciting goal setting)	Basket goal setting has significant effect on consumer's carbon footprint, regardless of the form of presentation (graphic or numerical). No effect of product information and feedback alone.	11%
Kanay et al., 2021 **(Study 2)**	To replicate the finding of study 1 and extend them by evaluating the potential role of colour coded label as product/basket information.	Between group randomised experiment (5 conditions)	N = 196	Behavioural task (reduced carbon basket)	Manipulation (information architecture directed at eliciting goal setting)	Effect of basket goal setting on consumer behaviour is significant only in colour-coded condition.	11%
Kanay et al., 2021 **(Study 3)**	To replicate previous findings and evaluate the role of repeated visits in determining more accurate representations of product carbon footprint.	Between group randomised experiment (2 x 2)	N = 31	Behavioural task (reduced carbon basket)	Manipulation (information architecture directed at eliciting goal setting)	Positive effect of goal setting on basket carbon footprint. Number of visits increase accuracy of carbon footprint representation and mediates the effect of goal setting in reducing the carbon footprint	11%
Zhang et al., 2020 **(Study 1)**	To examine the effect of self-quantification and goal requirements on consumers' participation in promotional green consumption activities.	Between group randomised experiment (2x2)	N = 100	Task measuring participation in promotional green consumption activities	Manipulation (goal/no goal condition x self-quantification/no self-quantification)	Self-quantification and goal requirement contribute to determine engagement in promotional green consumption activities: - SQ + goals = lower participation + less higher intensity activities + better experience (perceived certainty as a mediator) - SQ + no goals = higher participation performance + more higher intensity activity + worse experience (outcome salience as mediator).	18%
Zhang et al., 2020 **(Study 2)**	To examine the effect of self-quantification and goal requirements on consumers' participation in promotional green consumption activities.	Between group randomised experiment (2x2)	N = 60	Task measuring participation in promotional green consumption activities	Manipulation (goal/no goal condition x self-quantification/no self-quantification)	Self-quantification and goal requirement contribute to determine engagement in promotional green consumption activities: - SQ + goals = lower green energy value + better experience - SQ + no goals = higher green energy value + worse experience (outcome salience as mediator).	21%
Zhang et al., 2020 **(Study 3)**	To examine the effect of self-quantification and goal limitations on consumers' participation in defensive green consumption activities.	Between group randomised experiment (2x2)	N = 100	Task measuring participation in promotional green consumption activities	Manipulation (goal/no goal condition x self-quantification/no self-quantification)	Self-quantification and goal limitation contribute to determine engagement in defensive green consumption activities: - self-quantification + goal = higher carbon emission (within goal limitation) - self-quantification + no goals = lower carbon emission (mediated by outcome salience).	21%
Zhang et al., 2020 **(Study 4)**	To examine the effect of self-quantification and goal limitations on consumers' participation in defensive green consumption activities.	Between group randomised experiment (2x2)	N = 60	Task measuring participation in promotional green consumption activities	Manipulation (goal/no goal condition x self-quantification/no self-quantification)	Self-quantification and goal limitation contribute to determine engagement in defensive green consumption activities:	21%

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Table 4 (*continued*)

STUDY	AIM OF THE STUDY	DESIGN	PARTICIPANTS	MEASURES OF PEB	MEASURES OF SR	FINDINGS	RISK OF BIAS
						- self-quantification + goal = higher carbon emission (within goal limitation) - self-quantification + no goals = lower carbon emission (mediated by outcome salience).	
Brandsma and Blasch (2019)	To investigate how different types of energy feedback, combined with goal setting, impact on consumers' motivation to conserve electricity.	Between group randomised experiment with 3 conditions + Within group experiment with 3 conditions	N = 651	Self-reported intention to conserve energy	Manipulation (high goal, low goal, no goal)	Non-significant effect of goal setting (high or low) on intention to conserve energy except for the high goal + monetary feedback condition, and for individuals driven by egoistic values. No impact of goals in the relationship between values and motivation to conserve energy but different impact of different feedback framing.	25%
Davis et al. (2019)	To evaluate the effect of green human resources interventions (goal and feedback conditions) and autonomous environmental motivation in increasing employees' engagement in green behaviour.	Cross-sectional design (self-report and behavioural measures)	n = 1112	Behaviour (participation in EGB scheme)	Self-reported commitment to different levels of goals of the programme. Perceived level of feedback on programme.	Significant effect of feedback on EGB but no direct effect of goal commitment and autonomous environmental motivation. Interaction between goal commitment, feedback, and autonomous environmental motivation in affecting EGB participation: - no effect of goal commitment or autonomous environmental motivation expressed when low feedback - significant positive effect of autonomous environmental motivation when high feedback and low goal commitment - significant negative effect of autonomous environmental motivation when high feedback and high goal commitment.	14%
Bashir et al., 2014 **(Study 1)**	To examine whether individuals can be induced to subjectively experience remote future goals as temporally close and whether this affects their present-day motivation to pursue them.	Between groups randomised experiment (2 x 2 + control) conditions)	N = 61	Pro-environmental intentions (Bashir et al., 2011)	Manipulation (close vs distant temporal perception)	Induced subjective temporal proximity affects intention to engage in PEB. Increasing the subjective temporal proximity of remote future goals may boost motivation regardless of whether these goals are described in mildly or highly pessimistic terms.	17%
Bashir et al., 2014 **(Study 2)**	To examine the mechanism through which increasing the perceived closeness of a remote outcome affects goal pursuit.	Between groups randomised experiment (2 x 2)	N = 182	Pro-environmental intentions Bashir et al., 2011) Self-reported PEB	Manipulation (close vs distant temporal perception)	Increasing the subjective temporal proximity of remote future goals increases individuals' motivation and actual goal-pursuit of PEB. Goal construals mediate this relationship, with participants in the close versus distant and control conditions behaving more pro-environmentally because they construed climate change goals more concretely.	19%

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Table 4 (*continued*)

STUDY	AIM OF THE STUDY	DESIGN	PARTICIPANTS	MEASURES OF PEB	MEASURES OF SR	FINDINGS	RISK OF BIAS
McCalley et al. (2011)	To compare the effects of a foot- in-the-door intervention, designed to activate a general conservation goal, and a specific task-related goal setting procedure based on feedback intervention theory (FIT).	Between group randomised experiment (2x2)	N = 121	Behavioural task measuring conservation intention (energy-conserving goal selected) and energy consumption (amount of energy saved per wash).	Manipulation (goal X foot-in-the-door)	Significant effect of goal setting on energy savings. Reduced effect of goal setting on energy savings when combined with foot-in-the door technique activating higher order conservation goal as expected based on FIT.	14%
McCalley and Midden (2002)	To test whether product specific feedback can be effective in generating and supporting conservation behaviour using the psychological principles of the goal– feedback relationship.	Between group randomised experiment (3 conditions)	N = 100	Behavioural task measuring energy consumption (amount of energy consumed in washing trials).	Goal/no goal as experimental condition	Significant effect of goal setting on energy savings. No significant difference between self-set goal and experimenter-set goals' effects. Social orientation (pro-self/ pro-social) moderates the effect of goal setting type on energy savings, with pro-self individuals saving more energy when allowed to self-set a goal and pro-social individuals saving more energy when assigned a goal.	28%

those regarding the role of self-regulation were published in the past five years.

Based on content analysis, eligible studies were organised into two categories: executive functions and pro-environmental behaviour (n = 5) and self-regulation and pro-environmental behaviour (n = 36). Within the two categories, records were grouped according to the main executive function or self-regulation component investigated: cognitive flexibility (n = 2), working memory (n = 1), inhibitory control (n = 2), goal setting (n = 13), monitoring (n = 4), goal striving (n = 19). To assign each study to a specific category, we first examined the authors' vocabulary. Specifically, whenever a study explicitly referred to a self-regulation or executive functioning dimension covered by Miyake's (2000) and Carver & Scheier (1988)'s definitions, we chose the category named after the corresponding dimension. Whenever the authors' terminology did not align with the aforementioned definitions, we looked at the measurement tools and experimental manipulations used in the study to identify the executive function or self-regulation process they aimed to assess. Thanks to this procedure, we were able to assign each study to a single category, as reported in Table 2.

3.1. *Executive functions and pro-environmental behaviour*

Executive functions have shown to support goal-directed behaviour and predict positive outcomes across a variety of life domains (e.g., academic performance, health and wellbeing, income, relationships; Diamond & Ling, 2016; Moffitt, 2012; Moffitt, 1993; Munakata & Michaelson, 2021). Additionally, they are considered critical for humans to flexibly adapt to the challenges posed by their environment (Barkley, 2001; Diamond, 2013), such as those imposed by the glooming perspective of irreversible climate change. However, few of the retrieved articles specifically refer to the role played by executive functions in explaining individuals' likelihood to enact pro-environmental behaviour (see Table 3).

Among those, two studies by F. Lange and Dewitte (2019) indicate a moderate to medium-sized correlation between self-reported measures of cognitive flexibility (i.e., the ability to shift cognitive sets, perspectives, thoughts, thinking styles, or strategies, e.g., Diamond, 2013; Miyake et al., 2000) and self-reported pro-environmental behaviour performance. The two studies indicate that cognitive flexibility would predict pro-environmental engagement above and beyond their common correlation with openness trait, which has also been repeatedly associated with pro-environmental behaviour (Soutter et al., 2020). However, when cognitive flexibility was measured through behavioural tasks (i.e., a computerised version of the Wisconsin Card Sorting Task for cognitive flexibility – cWCST; Barceló, 2003; F. Lange et al., 2015; - and the Pro-Environmental Behaviour Task - PEBT, F. Lange et al., 2018), a significant correlation between the two variables was found only in the first of the two studies. The authors suggest that such inconsistency might be related to the lack of convergent validity of cognitive flexibility measures and to the fact that self-report measures, but not performance measures, would be able to capture a facet of cognitive flexibility that is relevant to pro-environmental behaviour (F. Lange & Dewitte, 2019). Despite this limitation, F. Lange & Dewitte's findings (2019) represent a first indication about the role of cognitive flexibility in explaining behaviour aimed at environmental conservation. Furthermore, a study by Langenbach et al. (2019) highlights a moderating effect of working memory capacity (measured through the visual n-back task; Sweet, 2011) in the relationship between pro-environmental attitudes and behaviours, suggesting a role of executive functions in enabling individuals to translate their attitudes into concrete actions (Langenbach et al., 2019). Working memory would indeed be crucial to enable individuals to hold their environmental goals in mind and translate environmental attitudes and knowledge into a concrete action plan (Diamond, 2013; Hofmann et al., 2012).

Two other studies included in this section indicate the involvement of brain regions associated with executive functions, when individuals are required to enact – or simulate the enactment – of pro-environmental behaviour. For example, through a study combining EEG and experience sampling techniques, Baumgartner et al. (2019) identified a positive correlation between the baseline activation of the right dorso-lateral prefrontal cortex (rdlPFC), a region supporting executive functions in general and, specifically, inhibitory control (i.e., the ability to interrupt or inhibit automated or prepotent responses or behaviour; Roebers, 2017) and daily performance of pro-environmental behaviour. Similarly, a study by Brevers et al. (2021), highlights how the same region of the brain (rdlPFC) is activated when individuals are required to think about reducing specific environmentally unfriendly behaviours. This is also combined with an inhibition of left hippocampal activity

Table 5
Studies on self-regulation (SR) and pro-environmental behaviours (PEB) referring to the monitoring component of the self-regulatory process.

STUDY	AIM OF THE STUDY	DESIGN	PARTICIPANTS	MEASURES OF PEB	MEASURES OF SR	FINDINGS	RISK OF BIAS
Abrams et al. (2021)	To test the relative impact of three theory-based persuasive messages focusing on psychological constructs that have proven to be effective in driving behavioural change (e.g., outcome efficacy, self-regulation, social norm).	Field experiment (3 conditions)	N = 6533	Behaviour (turn off the engine) Outcome (volume of pollutant emitted)	Manipulation (message aimed at eliciting self-regulation)	The social norm and outcome efficacy messages reduced engine idling rates by up to 42% compared to baseline. The self-regulation message only led to small variations. Meaningful increase in impact as a function of the volume of traffic (the number of stationary vehicles)	0%
Meleady et al., 2017 **(study 1)**	To test whether surveillance cues (watching eyes) at railway crossing would increase drivers' tendency to switch off their engine while waiting compared to informational sign.	Field experiment (2 conditions)	N = 216 drivers	Behaviour (turn off the engine)	Manipulation (surveillance cue aimed at eliciting self-focused attention and self-regulation)	No significant difference in the proportion of drivers who turned off their ignition surveillance cue condition (20.2%) and the base-line condition (26.8%)	13%
Meleady et al., 2017 **(study 2)**	To compare the effectiveness of an instructive self-surveillance cue manipulation designed to evoke public self-focus (watching eyes), with a manipulation designed to evoke private self-focus in increasing drivers' tendency to switch off engines when waiting at railway crossing.	Field experiment (3 conditions)	N = 325 drivers	Behaviour (turn off the engine)	Manipulation (surveillance cue aimed at eliciting public self-focus vs private self-focus)	Non-significant increase of the number of drivers who switched off their engine in the public self-focus condition versus baseline conditions. Significant impact of the private self-focus cue on drivers' behaviour compared to baseline and public self-focus condition.	20%
Joyner Armstrong et al. (2016)	To explore how students in a fashion-oriented discipline respond to the degrowth imperative.	Qualitative longitudinal study	N = 112 students	Manipulation (participation to fashion detox programme)	Questions about barriers to comply with the programme. Questions about experienced benefits.	Internal yearning for new and different things (compulsion) and external prompts (temptation) reported as the main barriers to programme compliance. Main benefits of participation: sense of Creativity (92%), Self-Regulation (90%), Reflection/clarity (69%), Product Life Extension (60%).	29%

(responsible for retrieval and episode-construction processes) suggesting that executive functions would be involved in inhibiting access to episodic memory of behaviours in contrast with conservation goals. Whilst the aim of these two studies was to provide insight on the brain networks supporting pro-environmental engagement, neural measures have been frequently used to assess executive functions (Houdé & Borst, 2014; Kang et al., 2022), and performance of behavioural tasks measuring inhibitory control has been often linked to an activation of the dorso-lateral prefrontal cortex region of the brain (Casey et al., 1997; Constantinidis & Luna, 2019; Nguyen et al., 2021). As such, we interpret the findings of the two above-mentioned neuroscientific studies as indicating an implication of inhibitory control in individual performance of pro-environmental behaviour.

The analysis of the risk of bias for all five studies revealed a low overall mean risk of bias (18%). However, there was a medium-to-high risk of bias specifically in the methods and results sections (AXIS items 2 to 16), accounting for 46.15% of the risk. This higher risk was primarily driven by insufficient information related to sample size, such as the lack of justification, unclear population definition, and the use of convenience or self-selected samples. No biases were reported in the procedure or statistical analysis, which enhances the reliability of the findings.

To sum up, considering the limited number of studies and their modest effects, the reported studies provide only initial evidence of the possible role of executive functions in explaining individual differences in the performance of pro-environmental behaviour. Yet, the limited quantity of studies in this field could be justified by the fact that this topic has only recently attracted the interest of researchers (e.g., the first study of our sample on the link between executive function and pro-environmental behaviour was published in 2019). Nonetheless, findings of the studies reviewed indicate that executive functions would potentially play a role in enabling individuals to align their behaviours with their views of the environmental challenge. Moreover, the evidence that was reviewed suggests that multiple dimensions of executive functions would contribute to explain daily performance of pro-environmental behaviour, with working memory potentially enabling the translation of environmental knowledge and attitudes into concrete goals and action plans, inhibitory control enabling the inhibition of prepotent unsustainable behaviour, and cognitive flexibility facilitating the switch to more environmentally friendly behaviours. Further investigations are required to confirm the relationship between executive function and pro-environmental behaviour, but this area of research appears to be promising.

3.2. *Self-regulation and pro-environmental behaviour*

Through our search, we found 36 studies addressing the relationship between self-regulation and pro-environmental behaviour, which we have included in our review and organised in the following sections:

Table 6
Studies on self-regulation (SR) and pro-environmental behaviours (PEB) referring to the goal-striving component of the self-regulatory process.

STUDY	AIM OF THE STUDY	DESIGN	PARTICIPANTS	MEASURES OF PEB	MEASURES OF SR	FINDINGS	RISK OF BIAS
Wang et al. (2022)	To explore the potential determinants of online impulsive buying behaviour from the perspective of consumer characteristics grounded on the literature on sustainability, psychology, and consumer behaviour.	Cross-sectional design (self-report measures)	N = 425	Items from Impulsive buying behaviour scale (Mattila & Wirtz, 2008)	Self-control scale items (Haws et al., 2012)	Significant negative effect of self-control on impulsive buying behaviour (direct and mediated by negative emotions)	19%
Wei & Yu, 2022 **(study 2)**	To investigate the relationship between dispositional envy and environmental behaviour and examine the role of self-control as mediator.	Cross-sectional design (self-report measures)	N = 170	Self-reported engagement in PEB and in environmentally harmful behaviour	BCSC (Tagney et al., 2004)	Mediating effect of self-control in the relationship between dispositional malicious envy and environmental behaviour (PEB and environmentally harmful behaviour). No mediating effect of self-control in the relationship between benign dispositional envy and environmental behaviour	19%
Wyss et al. (2022)	To investigate the role of pro-environmental attitude and self-control trait in environmental decision-making under varying personal costs & environmental consequences (dilemma).	Cross-sectional design (behavioural task and self-report measures)	N = 1536 over 4 sessions	Carbon-emission task (Environmental decision-making task)	BCSC (Tagney et al., 2004)	Opportunity cost and environmental harm (cost vs benefits) moderate the effect of environmental attitudes on PEB. Self-control increases by 33% the likelihood to align behaviour and attitude, especially in high conflict decisions.	33%
Datu and Buenconsejo (2021)	To explore the correlation between grit (i.e., perseverance of effort and consistency of interests) - associated with self-regulation) with environmental passion, environmentally friendly behaviours, and environmental awareness	Cross-sectional design (self-report measures)	N = 700	Workplace Environmental-Friendly Behaviour scale (Robertson & Barling, 2012) Environmental Passion Scale (Robertson & Barling, 2012) Environmental Attitude and Behaviour Scale (Gatersleben et al., 2002)	Short Grit Scale (Duckworth & Quinn, 2009)	Both dimensions of grit are positively correlated with environmental passion, environmentally friendly behaviour, and environmental awareness Perseverance has stronger intensity of associations with environmentally friendly behaviours and environmental awareness while consistency was strongly related to environmental passion	14%
Dorina et al. (2021)	To explore determinants of soft plastic recycling and assess the applicability of temporal self-regulation theory to soft plastic recycling.	Cross-sectional design (self-report measures)	N = 318	Self-reported recycling intentions Self-reported recycling behaviour	BCSC (Tagney et al., 2004)	Connectedness beliefs and temporal valuations account for significant variance in intention. Intention and habit account for significant variance in behaviour. Habit at low levels moderated the relationship between intention and behaviour. Self-control is not a significant moderator between intention and behaviour.	17%
M. Li, Tan, et al., 2021 **(study 1)**	To examine the impact of self-control exertion (cognitive depletion) onto green consumption behaviour.	Between group randomised experiment (2 conditions)	N = 80	Green product choice task.	Stroop task (Stroop, 1935)	Cognitive depletion induced by exerting of self-control has a negative effect on green consumption behaviour.	9%
M. Li, Tan, et al., 2021 **(study 2)**	To assess the role of moral elevation in moderating the effect of exerting self-control on green consumption behaviour.	Between group randomised experiment (2X2)	N = 142	Green product choice task.	Stroop task (Stroop, 1935)	Exertion of self-control has a negative effect on green consumption behaviour, but moral elevation moderates the negative effect of cognitive depletion on PEB, with self-control exertion predicting PEB in moral elevation condition but not in the neutral one.	9%
Nielsen & Hofmann, 2021	To investigate the influence of moral and environmental considerations on the self-control process and purchasing decisions and how these co-vary within people across time and settings.	Longitudinal survey design	N = 594	Self-reported purchase behaviour	Self-control trait (Tagney et al., 2004) Reported experience of conflict & resistance	Inhibitory influence of moral considerations (moral & environmental) on clothing purchasing decisions are mediated by self-control processes of awareness of conflict and resistance. Resistance has a strong negative predictive effect of purchase decision.	17%

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Table 6 (*continued*)

STUDY	AIM OF THE STUDY	DESIGN	PARTICIPANTS	MEASURES OF PEB	MEASURES OF SR	FINDINGS	RISK OF BIAS
Gillebaart & Kroese, 2020 (Study 1)	To investigate the role of behavioural resistance in the relation between self-control and goal-directed sustainable behaviours.	Cross-sectional design (self-report measures)	N = 250	PBS (Whitmarsh & O'Neill, 2010)	BCSC (Tagney et al., 2004)	Self-control is associated to long-term directed behaviours in the domain of sustainability. The effect of self-control on sustainable behaviours is mediated by lower behavioural resistance (thus aversion) to the behaviour.	17%
Gómez-Olmedo et al., 2021	To examine the direct influence of self-control (SC) on the adoption of pro-environmental behaviour (PEB).	Cross-sectional design (self-report measures)	N = 412	PBS (Whitmarsh & O'Neill, 2010)	BCSC (Tagney et al., 2004)	Self-control is found to be a direct predictor of PEB. Self-control is a stronger predictor of PEB than PBC in the TPB model. Direct effect of self-control on PEB is higher for actions with limited external barriers.	22%
Y. Li, Tan, et al., 2021	To examine the psychological mechanisms underlying the effects of mindfulness on ethical consumption (refinement and reduction).	Cross-sectional design (self-report measures)	N = 546	SRPD scale (Webb et al., 2008) Voluntary simplicity scale (Huneke, 2005) Frugal purchasing scale (Pepper et al., 2009)	BCSC (Tagney et al., 2004)	Significant correlation of mindfulness and ethical consumption (reduction and refinement). Full mediation of connectedness-to-nature and self-control in the mindfulness – ethical consumption relation when it comes to consumption reduction association.	19%
Nguyen et al. (2019)	To examine the relationship between self-control and sustainability behaviours in both the United States and India.	Cross-sectional design (self-report measures)	N = 719	Items assessing purchasing of environmentally friendly products, spending control and waste control (Haws et al., 2012)	Items assessing emotional control (Gross & John, 2003) Items assessing cognitive and Behavioural control (Reid & Ware, 1974)	Higher cognitive, emotional, and behavioural control do not predict higher purchase of environmentally friendly products. Higher cognitive and behavioural control predict higher spending control, eating control and but not higher emotional control. Higher behavioural control predicts higher waste control but not higher cognitive and emotional control.	32%
Song & Kim, 2016	To explore the impact of good traits (i.e., virtuous and personality traits) on socially responsible consumption.	Cross-sectional design (self-report measures)	N = 400	Items from SRPD scale (Webb et al., 2008)	Items from two self-control scales (Peterson & Seligman, 2004; Goldberg et al., 2006)	The higher levels of consumers' virtuous traits, such as self-efficacy), self-control and courage, and the higher level of personality traits such as openness and conscientiousness predict high SRPD. Self-efficacy and openness are greatest predictors of high SRPD. Low level of self-efficacy and conscientiousness significantly predict low SRPD.	25%
Redondo & Puelles, 2016	To identify the combination of variables that best predict the existence of the environmental attitude–behaviour gap and measure their individual effect on it.	Cross-sectional design (self-report measures)	N = 10001	Discrepancy between self-reported pro-environmental attitudes and behaviours	Degree of impulsiveness Presence of attitude-behaviour gap in other domains	Environmental attitude behaviour gap correlates with lower level of environmental scepticism, higher degree of impulsiveness, thriftlessness, orientation towards ethics and religion as well as lower knowledge of environmental problem (but higher viewing of nature-related TV channels). Environmental attitude-behaviour gap is directly associated to attitude-behaviour gaps in other domains.	17%
Martin et al., 2017	To analyse the relationship between pro-environmental motives and illegal anti-environmental behaviour.	Cross-sectional design (self-report measures)	N = 311	Self-reported illegal anti-environmental behaviour (past) Self-reported PEB	Items from MTES (Pelletier et al., 1998) influencing behavioural regulation	Predictive role of intrinsic pro-environmental motivation on PEB, reusing and recycling. Predictive role of integrated pro-environmental regulation on recycling, saving and responsible purchasing. Predictive role of identified regulation on recycling and saving. Predictive role of external regulation on reusing. No predictive effect of introjected and amotivation. Stronger predictors of future illegal anti-	44%

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Table 6 (*continued*)

STUDY	AIM OF THE STUDY	DESIGN	PARTICIPANTS	MEASURES OF PEB	MEASURES OF SR	FINDINGS	RISK OF BIAS
						environmental behaviour are identified and introjected PRO-ELP regulation and to a lesser extent external pro-ELP regulation.	
Chuang et al., 2016 **(Study 2)**	To examine whether self-control mediates the relationship between self-construal (independence vs interdependence) and pro-environmental vs self-interested consumption choices.	Between group randomised experiment (2 conditions)	N = 118	Scenario task asking to simulate consumption choice	Stroop task (Stroop, 1935)	Significant effect of self-construal's (independence & interdependence) on pro-environmental choices facing pro-environment vs pro-self dilemma: participants with interdependent orientations are more likely to choose the pro-environmental option when faced with conflicting self-interested and pro-environmental options. Mediating role of self-control on the effect of self-construal on the outcome of pro-environment-self-interest conflict.	14%
Chuang et al., 2016 **(Study 3)**	To provide further evidence on the role of self-control in mediating the relationship between self-construal and pro-environmental vs self-interested consumption choices.	Between group randomised experiment (2x2)	N = 81	Scenario task asking to simulate consumption choice	Stroop task (Stroop, 1935)	Significant effect of self-efficacy and self-control on pro-environmental choice but no effect of self-construal. Effects of self-construal on environmental choice was significant in the control condition but not in the depletion condition.	22%
Loy et al. (2016)	To test the effectiveness of MCII intervention (Mental Contrasting Implementation Intention - a self-regulation strategy) in reducing discrepancy between individuals' intentions to consume less meat and actual behaviour.	Longitudinal randomised experiment with 2 conditions	N = 60	Self-reported PEB (meat consumption)	Manipulation (information + MCII intervention)	Participants' intentions of reducing their meat consumption in the MCII condition were more predictive of their actual reduction than those in the information only control condition	8%
Osbaldiston & Sheldon, 2003	To understand the nature of "high-quality'' motivation at theoretical level and to understand how to promote ERB (Environmentally responsible behaviour) at a practical level.	Cross-sectional design (Self-report measures & experience sampling)	N = 162	Self-reported performance on autonomously selected environmental goals.	Type of goal (induced by internal or external motivation).	Greater internalized motivation regarding a set of self-selected environmental goals predicts higher environmental goal performance during the following week, and higher intentions to keep on striving after completing the study.	25%

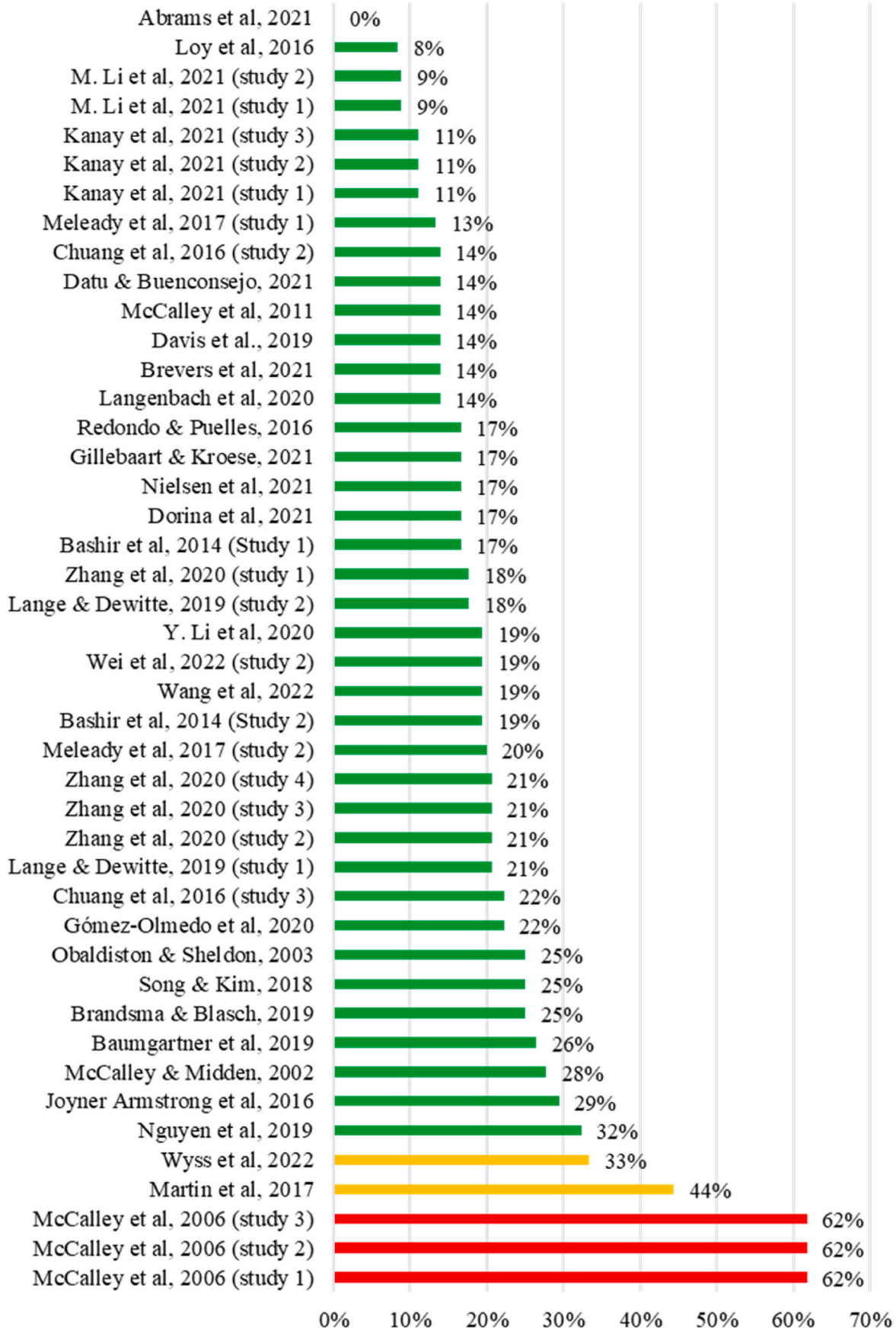

Fig. 2. Risk of bias (in percentage %) per each single study.

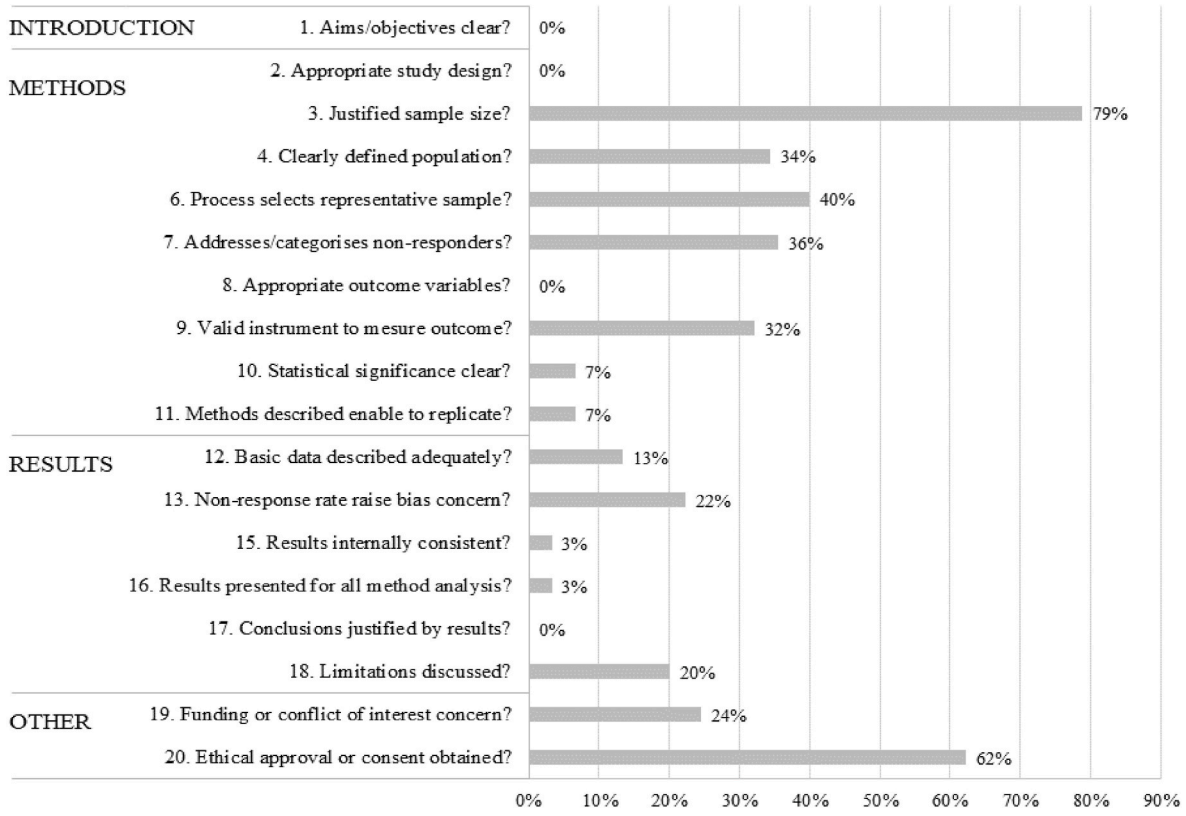

Fig. 3. The percentage of risk of bias on each AXIS item computed over all the studies.

Goal setting (n = 13), *Monitoring* (n = 4), *Goal striving* (n = 19).

3.2.1. Goal setting

Seven articles discuss the relationship between goals and pro-environmental behaviour, investigated through 12 experiments and 1 cross sectional study (see Table 4). An overall positive effect of goal setting on pro-environmental behaviour was found in five studies. The first three studies investigated the effect of goal setting interventions on reducing consumer carbon footprint in a simulated online supermarket (Kanay et al., 2021, study 1, 2, 3), the other two, its impact on decreasing electricity consumption during a simulated machine wash (McCalley et al., 2011; McCalley & Midden, 2002). These findings indicate that when people have a pro-environmental goal to pursue, their behavioural engagement in favour of environmental conservation increases. Yet, evidence seems to suggest that the effect of goal setting on individuals' propensity to act pro-environmentally would work in conjunction with other factors. For example, in the abovementioned studies by Kanay et al. (2021) and by McCalley and colleagues (McCalley et al., 2011; McCalley & Midden, 2002), goal setting was paired with information regarding the environmental footprint of the different available choices, suggesting that awareness of one's performance in relation to a specific goal (i.e., monitoring) might cooperate with goal setting in determining individuals' environmentally friendly behaviour. This appears supported also by the results of one of these studies (Kanay et al., 2021, study 3), indicating that increased experience in interpreting feedback, resulting from repeated exposure to it, would mediate the effect of goal setting on consumers' behaviour. Additionally, five extra studies (Davis et al., 2019; Zhang et al., 2020) point out that feedback on - or self-quantification of - the progress made in embracing pro-environmental behaviour would modulate the effect of goal setting on individual performance of pro-environmental behaviour.

The influence of goal setting on the implementation of pro-environmental behaviour appears to vary also according to the characteristics of the people performing it and of the types of goals that are set and the ways in which they are set. For example, a study by McCalley and Midden (2002), evaluating the effect of goal setting on individuals' propensity to save energy during machine washing, indicates that self-set versus assigned goals have different effects on people's engagement in pro-environmental behaviour, depending on their social orientation. Pro-self individuals tend to respond better to self-set environmental goals compared to pro-social individuals, who seem more reactive to assigned environmental goals. This appears in line with Legault & Inzlicht's findings (2013), indicating improved self-regulatory outcomes when the characteristics of the goal and the individual's motivational orientation are aligned. Two other studies investigating, respectively, employees' engagement in green corporate activities (Davis et al., 2019) and energy consumers' motivation to conserve energy (Brandsma & Blasch, 2019), also indicate that different types of goals (i.e., high versus low) interact with different levels of autonomous motivation, as well as different forms of feedback, to explain engagement in pro-environmental behaviour. The results show that setting ambitious goals is particularly predictive of pro-environmental engagement when individuals lack autonomous motivation to engage in conservation behaviour and in consonance with relevant feedback. Whilst apparently in contrast with the findings mentioned above, and with Legault and Inzlicht's perspective (2013) on the positive effect of autonomous motivation in increasing self-regulatory processes, these findings suggest that adherence and commitment to a goal proposed by others can activate self-regulatory processes even in absence of motivation. This result is in line with the goal-setting theory (Locke et al., 1981) and indicates that goal setting could counterbalance a lack of motivation in encouraging individuals to engage in pro-environmental behaviour.

Finally, two other characteristics of goals have been found to modulate the effect of goal setting on pro-environmental behaviour performance. Result from one study (McCalley et al., 2011) points out that basic goals (i.e., to reduce energy consumption during machine wash) result into higher energy savings compared to higher order goals

(i.e., to lead a pro-environmental life), suggesting that goals that convert attention to goal-related tasks would be more likely to activate self-regulated action and translate into relevant behaviour compared with lifestyle goals. These findings appear in accordance with the Feedback Intervention Theory (FIT; Kluger & DeNisi, 1996). In parallel, findings from another study (Bashir et al., 2014) highlight how another characteristic of the goal, i.e., the goal's temporal distance as perceived by the individuals, also affect the effects of goal setting on individuals' propensity to pursue pro-environmental goals, and thus to engage in pro-environmental behaviour. Perceived temporally closer goals are more likely to start goal-directed behaviour because they are more concretely represented in the mind of individuals.

The risk of bias assessment for all 13 studies indicates a low overall risk of bias (18%). However, the methods and results sections show a low-to-medium risk of bias (30.83%) due to two main factors: the lack of justified sample sizes and the utilization of new generated tasks (e.g., Brandsma & Blasch, 2019; Zhang et al., 2020). As a positive note, the majority of the experiments employed randomized controlled designs, with 12 studies being either between-group or mixed randomized studies, and only one being a correlational study. This highlights the good reliability of such findings as compared to cross-sectional findings. In summary, all the 13 studies provide substantial converging evidence of an effect of goal setting on pro-environmental behaviour. Yet, the effect of goal setting on individual performance of pro-environmental behaviour appears mostly conditioned by other factors, such as the characteristics of the goal and/or of the individuals, and the concurrent availability of information regarding the progress made. The latter suggests that goal setting, as a component of the self-regulatory process, would explain engagement in pro-environmental behaviour in conjuncture with the other components, and, specifically, according to the studies reviewed, with the monitoring component.

3.2.2. *Monitoring*

As discussed above, monitoring implies the ability to identify discrepancies between a desired end-state and a current behaviour. To do so, individuals are required to direct attention to their behaviour and its outcome, so to assess whether it is compatible with their present goal. Whilst articles addressing the effect of monitoring (through feedback) on pro-environmental behaviour in conjunction with goal setting were included in the above section, we included in this section articles providing insights onto how becoming aware of one's own behaviour affects engagement in pro-environmental behaviour (see Table 5). It has been suggested, indeed, that higher awareness of the present moment could contribute to higher attitude-behaviour consistency by enabling individuals to detect and reduce potentially unsustainable behaviours otherwise carried out on autopilot (Bahl et al., 2016; Rosenberg, 2004).

Only three studies of our sample specifically investigated the effect of this aspect of monitoring on pro-environmental behaviour (Abrams et al., 2021; Meleady et al., 2017., study 1 and 2). Such studies used a field design to test the effectiveness of messages and cues aimed at eliciting awareness of one's behaviour, in encouraging drivers to switch off their engine when waiting at a railway crossing. Only one of the three studies reports a significant effect of self-regulation - and specifically of monitoring prompts - on drivers' likelihood to turn off their engine to reduce emissions (Meleady et al., 2017, study 2), whilst no effect has been obtained in the other two studies (Abrams et al., 2021; Meleady et al., 2017, study 1). Yet, it is worth noticing that these contradicting findings might be related to the characteristics of the prompts used in the study rather than the dynamic which they were meant to elicit. Also, whilst Abrams et al. (2021) reported no significant effect of cues aimed at eliciting self-regulation in determining engine switch off, they reported a significant effect of normative and outcome efficacy messages. Though activating different goals, i.e., (1) comply with the norm, (2) contribute to reducing emissions, (3) be consistent with one's attitudes, all three conditions focussed on the assessment of congruency or discrepancy between goals and behaviours, that is, to monitoring.

The last study of this section is a qualitative study that evaluated the effect of a 10-weeks fashion detox programme on students' experience of degrowth (Joyner Armstrong et al., 2016). Throughout the programme, students had to report the main challenges encountered when practicing degrowth (i.e., abstaining to acquire new clothing or fashion items) as well as the main subjective benefits of such experience. Temptation and compulsion were reported by participants as the most challenging barriers they had to overcome to comply with the goals set by the programme, whilst self-regulation and clarity were among the most reported benefits. Students reported, indeed, an improved sense of empowerment and self-control resulting from an increased ability to identify behaviours driven by automatisms or by addictive cravings for shopping. In parallel, they reported being enabled to discern more clearly what truly mattered to them and what was, instead, conditioned. This could suggest that monitoring would enhance individuals' awareness of their automatic behaviours, potentially affecting their ability to exert control over consumption impulses.

Despite the limited number of studies reported in this section, both the qualitative and quantitative assessments of these studies demonstrate a reliable methodological rigor. The overall mean risk of bias is found to be 16.33%, with a mean risk of bias for the method and results sections (AXIS items from 2 to 16) at 20.51%. It is important to note that the quality of the research was further supported by the utilization of very large sample sizes in the field studies (in particular, Abrams et al.'s study involved 6533 participants) and the qualitative study (N = 112). The findings of the reviewed studies combined with an overall good methodological evaluation collectively suggest that monitoring would play a significant role in explaining individuals' pro-environmental behaviour. This adds to the evidence, already provided by the studies discussed in the previous section, on the intermingled effects of feedback (which we could assimilate to monitoring the outcome of one's action) on individuals' compliance with pro-environmental goal setting. Monitoring skills appear, indeed, related with individuals' ability to ensure their actions are consistent with their attitudes towards the environment, potentially contributing to the pursuit of pro-environmental goal.

3.2.3. *Goal striving*

This section discusses the results of 19 studies providing insights onto the last component of the self-regulatory process (i.e., goal striving), which underlies the planning and implementation of the behaviours deemed necessary to reach a set goal. We included in this section 15 studies investigating the relationship between self-control and pro-environmental behaviour performance, and four studies highlighting a role of factors, such as grit (Datu & Buenconsejo, 2021), motivational orientation (Martin et al., 2017; Osbaldiston & Sheldon, 2003), and the use of automatization techniques (Loy et al., 2016).

Self-control has been traditionally referred to as the ability to inhibit undesired behavioural tendencies and refrain from acting on them (Hoffman et al., 2009), or as the ability to delay immediate gratification of a smaller reward for a larger reward later in time (Ainslie, 1975; Mischel et al., 1989). Such ability is thought to be affected by both dispositional (Tangney et al., 2004) and situational factors (Baumeister & Heatherton, 1996) and as such it can be measured both as a stable trait or as a time-contingent state (Inzlicht et al., 2021). Within the 15 studies on self-control included in our review (see Table 6), 11 of them assessed how individual tendency to exert self-control (i.e., self-control trait) contribute to explain differences in individuals' propensity to engage in pro-environmental behaviour (Dorina et al., 2021; Gillebaart & Kroese, 2020; Gómez-Olmedo et al., 2020; Y. Li et al., 2021; Nguyen et al., 2019; Nielsen & Hofmann, 2021; Redondo & Puelles, 2016; Song & Kim, 2016; Wang et al., 2022; Wey et al., 2022; Wyss et al., 2022). To do this they used trait measures of self-control, such as, for example, the Brief Self Control Scale (Tangney et al., 2004) or other measures indicating poor self-control abilities such as impulsiveness or reported attitude-behaviour inconsistencies in other life domains (Redondo & Puelles, 2016). Four studies, on the other hand, explored how a

momentary depletion of self-control affects individuals' decisions impacting the environment (Chuang et al., 2016; M. Li et al., 2021) using a behavioural task (i.e., the Stroop Task, a task aimed at measuring the ability to inhibit cognitive interference; Stroop; 1935) with the purpose of generating self-control fatigue.

Thirteen studies report a significant positive link between self-control and individual performance of (pro)environmental behaviour. For example, six correlational studies (Gillebaart & Kroese, 2020; Gomez-Olmedo et al., 2021; Y. Li, Tan, et al., 2021; Nielsen & Hofmann, 2021; Song & Kim, 2016; Wei & Yu, 2022) and one experimental study (Chuang et al., 2016, study 2) indicate that trait self-control would be a positive predictor of various forms of pro-environmental behaviour. Additionally, three supplementary studies (Nielsen & Hofmann, 2021; Wang et al., 2022; Wei & Yu, 2022; study 2) picture self-control trait as a negative predictor of environmentally unfriendly behaviour (e.g., environmentally harmful behaviour, impulsive buying, and unnecessary clothing purchasing). Also, reduced ability to exert self-control (measured in term of ego depletion, impulsiveness, or attitude-behaviour inconsistencies in other domains) is negatively associated to pro-environmental behaviour in four studies (Chuang et al., 2016, study 3; M. Li, Tan, et al., 2021, study 1 and 2; Redondo & Puelles, 2016). Lastly, one study points out self-control as a moderator of the relationship between pro-environmental attitudes and behaviours (Wyss et al., 2022), and another one reports that the inclusion of self-control as a variable of the TPB model (Theory of Planned Behaviour, Ajzen, 1991), a widely used framework used to explain pro-environmental behaviour, would increase its predictive power (Gomez-Olmedo et al., 2021).

Only one study (Dorina et al., 2021) does not report any effect of self-control on pro-environmental behaviour, possibly due to the very specific type of pro-environmental behaviour measured (soft-plastic recycling) and its important level of automaticity. Another study, on the other hand, provides contradicting evidence for a relationship between self-control and pro-environmental behaviours, with results indicating a predictive effect of self-control on behaviours like waste control, but not on other types of behaviours, like choosing environmentally friendly products at moment of purchase (Nguyen et al., 2019).

Among the studies indicating a relationship between self-control and pro-environmental behaviour, some provide insight into its dynamics. More specifically, in two of those, the mediators of the relationship between self-control and pro-environmental behaviour are investigated. The first one suggests that the effect of self-control on pro-environmental behaviour performance would be mediated by lower behavioural resistance to such behaviours (Gillebaart & Kroese, 2020), whilst the second one indicates that the effect of self-control on reducing impulsive buying would be mediated by the experience of negative emotions (Wang et al., 2022). Five other studies, on the other hand, investigate the role of self-control as a mediator of the effects that other factors exert on pro-environmental behaviour performance, among them dispositional traits and moral considerations. Findings of two different studies by Chuang et al. (2016), for instance, indicate that self-control mediates the relationship between self-construal (i.e., whether individuals view themselves as primarily separate from, or integrally connected to, others; Markus & Kitayama, 1991) and pro-environmental behaviour, and contribute to determine individuals' propensity to choose a pro-environmental option when facing a dilemma confronting environmental benefits with self-interests. In another study, self-control was found to mediate the effects of dispositional malicious envy (i.e., the tendency to experience negative emotions to another person's superior quality resulting into the desire to level the other person down; J. Lange & Crusius, 2015) on environmentally harmful behaviour (Wei & Yu, 2022). According to the authors, the negative emotions repeatedly experienced by individuals with high dispositional malicious envy would, indeed, affect their self-control skills and reduce their capacity to restrain from performing environmentally harmful behaviours (Wei & Yu, 2022). Similarly, self-control was found to mediate the positive effect of mindfulness on ethical consumption (Y. Li, Tan, et al., 2021) potentially signifying that the higher propensity to engage in pro-environmental behaviour, experienced by individuals higher in mindfulness trait, could be linked to their higher capacity to control their impulses over consumption temptations. Lastly, findings of a study on the effects of moral considerations on pro-environmental behaviour performance (Nielsen & Hofmann, 2021) identify self-control as a mediator of the relationship between these two variables, with moral considerations exerting an inhibitory effect on consumption decisions via stronger experience of conflict (between values and behaviours) and stronger resistance to consumption desire (i.e., stronger exertion of self-control).

Besides self-control, four articles included in the review address the relationship between pro-environmental behaviour and other factors supporting the goal striving step of the self-regulatory process, which appear to influence individuals' tendency to implement pro-environmental goals and intentions. Among them, a cross-sectional study by Datu and Buenconsejo (2021) reports a correlation between grit (i.e., trait-level perseverance and passion for long-term goals; Duckworth et al., 2007) and, more specifically, its perseverance aspect (i.e., the capacity to endure and effectively manage setbacks and failures in pursuit of long-term goals) and environmentally friendly behaviours. Also results of a study by Loy et al. (2016) on the environmental attitude-behaviour gap in the domain of meat consumption, show a positive effect of a Mental Contrasting Implementation Intentions (MCII) intervention in increasing behaviour-attitude consistency. This would indicate that the ability to anticipate obstacles and to define concrete strategies to address them would reduce discrepancy between intentions and behaviours. Findings of the two studies suggest that goal striving skills would exert an effect on pro-environmental behaviour beyond the ability to inhibit goal-conflicting behaviours.

Lastly, two studies call attention to the role of motivational orientation (i.e., whether engagement in behaviour is driven by satisfaction inherent to the behaviour or by external contingencies such as rewards, avoidance of punishment or instrumental value of acting; Deci & Ryan, 1985) in predicting individual propensity to comply with pro-environmental goals. In the first one (Osbaldiston & Sheldon, 2003), greater internalized motivation was found to increase individual propensity to comply with self-selected pro-environmental goals, and to continue pursuing those goals in the future. In the second one (Martin et al., 2017), authors report how different types of internalized motivation predict autonomous engagement in pro-environmental behaviour (identified and introjected motivation) or respect of environmental regulation (integrated motivation), highlighting that the two behaviours would be influenced by different self-regulatory mechanisms despite being highly related.

In total, 18 studies reported a significant positive relationship between goal-striving processes and pro-environmental behavior, with only Dorina et al. (2021) reporting no significant effects. The risk of bias analysis conducted on these studies demonstrated a low overall mean risk of bias (20.27%) and a very low risk of bias specifically for the methods and results sections (8.46%). These results support the rigorous and reliable methodologies of the experiments reported here. Among the studies, only Martin et al. (2017) exhibited a medium risk of bias (>33%), primarily due to the use of non-validated scales and a lack of discussion regarding limitations. The quality of these studies was further reinforced by examining the substantial number of participants involved in both the cross-sectional studies and the randomized experiments.

In conclusion, there appears to be evidence supporting a positive association between goal striving processes and individual's propensity to engage in pro-environmental behaviour, with a specific focus on self-control. It is suggested that self-regulation might be significant, not only in resisting hedonistic and consumeristic temptations when pursuing pro-environmental goals, but also in initiating and sustaining behaviours that prioritize long-term collective benefits over immediately rewarding alternatives.

4. General discussion

This systematic review reports the results of 41 studies from 31 peer-reviewed journal articles, which empirically investigate the relationship between executive functions and related self-regulation processes with pro-environmental behaviours. Among the analysed studies, eighteen studies employed a cross-sectional design, twenty-one an experimental design, one a longitudinal survey design, and one used qualitative method.

Studies in the sample come from different scientific disciplines (e.g., environmental, social and consumer psychology, neurocognitive and behavioural sciences, business and economic sciences, political sciences), and mostly focused on different dimensions of executive functioning (e.g., working memory, inhibitory control, cognitive flexibility), self-regulation processes (e.g., goal setting, monitoring andgoal striving) and pro-environmental behaviour (e.g., general pro-environmental behaviour, specific aspects of the behaviour, environmental goal performance, environmental impact), while investigating different dynamics of the relationship between the three (e.g., role of executive functions and self-regulation in explaining pro-environmental behaviour, brain networks involved with pro-environmental behaviour, effects of pro-environmental intervention strategies eliciting self-regulation processes, effectiveness of predictive models of pro-environmental behaviour).

Overall, a broad range of approaches for measuring and manipulating executive functions, self-regulation and pro-environmental behaviour were used, guided by various theoretical frameworks on human behaviour and behavioural change (e.g., Theory of planned behaviour; Ajzen, 1991; Value-belief-norm theory; Stern, 2000; Self-determination theory, Deci & Ryan, 1985; Temporal regulation theory; Hall & Fong, 2007; Ego depletion theory; Baumeister & Heatherton, 1996; Feedback intervention theory; Kluger & DeNisi, 1996, Self-construal theory; Markus & Kitayama, 1991). Most of the studies included in the review were published in the last five years and none of them were carried out over twenty years ago, suggesting that the relationship between executive functions, self-regulation and pro-environmental behaviour is a relatively recent, yet expanding, topic of research.

Though limited in number, all the studies investigating the relationship between executive functions and pro-environmental behaviour (Baumgartner et al., 2019; Brevers et al., 2021; F. Lange & Dewitte, 2019; Langenbach et al., 2019) back the hypothesis of a positive association between executive functions in supporting pro-environmental behaviour. Similarly, a positive relationship between different dimensions of the self-regulation process (i.e., goal setting, monitoring, and goal striving) and pro-environmental behaviour performance was found in most of the studies included in the review. Findings suggest that establishing a goal would influence an individual's likelihood to engage in pro-environmental behaviour (Bashir et al., 2014; Brandsma & Blasch, 2019; Davis et al., 2019; Kanay et al., 2021; Lalot, Falomir-Pichastor, & Quiamzade, 2021; McCalley et al., 2011; McCalley & Midden, 2002; Zhang et al., 2020), particularly when feedback on progress toward the goal is available concurrently. Additionally, the effects appear modulated by both the characteristics of the goal and the individual involved. Furthermore, evidence from the sample of studies reviewed suggests that monitoring would enable individuals to be aware of their automatic (and potentially unsustainable) behaviours, and of their progress in pursuing pro-environmental goals, a necessary condition to steer action towards them (Abrams et al., 2021; Joyner Armstrong et al., 2016; McCalley & Midden, 2002; Meleady et al., 2017; Zhang et al., 2020). Lastly, goal striving, and specifically, self-control, was consistently found to relate with various forms of pro-environmental behaviours. The findings indicate that self-control skills and related factors, such as grit, reduced impulsiveness, or implementation intentions, would play a predictive or moderating role in determining an individual's inclination to engage in pro-environmental behaviour (Chuang et al., 2016; Gillebaart & Kroese, 2020; Gomez-Olmedo et al., 2021; M. Li, Tan, et al., 2021; Nguyen et al., 2019; Nielsen & Hofmann, 2021; Redondo & Puelles, 2016; Song & Kim, 2016; Wang et al., 2022; Wei & Yu, 2022; Wyss et al., 2022).

Considering the above, the findings from the reviewed studies offer some initial insights into the involvement of top-down regulation processes in individual engagement in pro-environmental behaviour. In this perspective, the results of our review, provide credit to the assumption that executive functions and self-regulatory processes are important factors to be taken into account to understand individual engagement in pro-environmental behaviour, as they support the implementation of pro-environmental intentions (Bamberg, 2013; Nielsen, 2017). Yet, it is important to consider the wide variety of approaches and theoretical frameworks employed in the studies and the limited number of studies carried out until now on this topic. For instance, the association between self-regulation and pro-environmental behaviour is more extensively documented, with a greater number of findings and experimental designs (including more randomized experiments and fewer correlational studies), resulting in more reliable evidence. Furthermore, this evidence is derived from research in various disciplines investigating human behaviour in the context of the environmental crisis, including psychology literature. In contrast, the evidence concerning the effects of executive functions on pro-environmental behaviour is more limited, and thus the results must be interpreted with caution. However, considering the highly intertwined nature of executive functions and self-regulation, where each of the three main executive functions (i.e., working memory, inhibitory control, and cognitive flexibility) underlies a different phase of the self-regulatory process (Carver & Scheier, 1998; Hofmann et al., 2012), it could be speculated that evidence of the role of self-regulation would also imply an involvement of executive functions in pro-environmental behaviour. Furthermore, if we accept the notion that self-regulation is a process made up of three interconnected components (i.e., goal setting, monitoring, and goal striving) as opposed to a simple collection of independent skills (Carver & Scheier, 1998; Inzlicht et al., 2014; Nielsen, 2017), we could posit that evidence indicating involvement of one particular component of the self-regulation process would also imply the involvement of the other two, as well as the underlying mechanisms (i.e., executive functions).

However, it would be beneficial for future research to investigate how the different components of the self-regulatory process interact together in explaining pro-environmental behaviour. Also, research should be carried out to further investigate the relationship between executive functions and pro-environmental behaviour, and to increase our understanding of the cognitive processes supporting people's ability to regulate their behaviour when addressing the environmental crisis. We therefore advocate for more research to be carried out on the specific role of working memory, inhibitory control, and cognitive flexibility in determining human ability to embrace adaptive behaviour facing the climate emergency. Moreover, we propose that a way forward would be to integrate executive functioning models and measures in the study of self-regulatory dynamics involved with pro-environmental behaviour performance. Doing so would not only increase our understanding of how executive functions would support self-regulated action in face of the climate crisis, but also of the potential effect of executive functions training on individual likelihood to engage in pro-environmental behaviour. This would provide important insight for developing environmental policies and interventions aimed at reducing the environmental attitude behaviour gap which have, until now, mostly focussed on increasing knowledge of the environmental crisis and motivation to address it, without considering individual's ability to self-regulate their behaviour. Finally, we call for further attention to be dedicated to investigating the role of executive functions and self-regulation in explaining the environmental attitude-behaviour gap, to clarify the role that self-regulation would have, beyond motivation, in enabling individuals to translate pro-environmental attitudes into concrete actions (Bamberg, 2013; Gomez-Olmedo, 2021; Jankowski & Job, 2023). This

could also provide relevant insight on the potential benefit of coupling intervention techniques targeting environmental intentions determinants, like information and sensibilisation interventions, with techniques targeting self-regulation skills, like, for example, mindfulness-based interventions.

The present systematic review is not without limitations. First, to form a comprehensive outlook on the role of executive functions and self-regulation in explaining individual propensity to perform pro-environmental behaviour, we looked at studies coming from a rather diverse set of scientific disciplines, which are known to look at human behaviour from different perspectives. This resulted into a rather heterogeneous sample of studies, for our review, which discussed concepts that, although akin, were labelled and assessed differently from a study to another. The lack of a common framework of reference implied the necessity to make (sometimes difficult) choices with respect to what studies should be included in the final sample of our systematic review. This possibly led us to exclude from the review potentially relevant studies which used a terminology inconsistent with the definitions we chose to refer to. As a result, a selection bias towards studies using a vocabulary consistent with Carver and Scheier's definition of self-regulation (1988) and Miyake et al.'s definition of executive functions (2000) was potentially generated. However, to minimise this bias, we did our best to include, in our database search, keywords referring to synonyms of the concepts assessed and of their multiple dimensions.

Also, scarce homogeneity in the way the analysed concepts are operationalised and measured in literature implied the necessity for us to make choices regarding how to regroup results into unifying categories. For instance, we chose to include studies discussing the joint role of goal-setting and feedback in the goal-setting category, though data regarding the role of feedback in pro-environmental goal-pursuit also provides insight on how monitoring contributes to explain pro-environmental behaviour performance. On the other hand, we included in the monitoring section studies analysing the effects of priming techniques, eliciting awareness of present moment behaviour, on mitigative action and a study pinpointing self-regulation because of more controlled consumption. Also, we chose to include in the goal-striving category, studies referring to the role of self-control (state or trait) in enabling the pursuit of pro-environmental goals, as well as those dealing with other potential aspects facilitating the enactment of pro-environmental behaviour, such as motivational orientation or techniques like implementation intentions and mental contrasting. Whilst it was necessary to select a framework to refer to, in operationalising both self-regulation and executive functions, as it was necessary to fit studies not using the same framework into our structure, the process entailed subjective decisions regarding how results were analysed and interpreted. This might have created a bias in our conclusions regarding the role of different components of executive functions and self-regulation in explaining pro-environmental behaviour performance.

Second, all studies included in our review presented some risk of bias as evaluated through the AXIS checklist. Most of the bias we found was related to the sampling procedure and the measurement tools used in the study, as well as the lack of a mention of the obtention of consent and ethical approval. For instance, less than a fifth of the studies included in our review provided justification for the sample size and less than half of them used a randomised procedure for selecting or distributing participants into experimental groups. Also, about a third of the studies employed, for some of the variables assessed, measurement tools that despite seeming appropriate had not been previously validated, making their reliability questionable. This is particularly true for ad hoc surveys aimed at measuring pro-environmental behaviour and ad hoc manipulations aimed at eliciting specific components of the self-regulation process, for which there was no before/after measurement of the skills targeted. This bias might be due to a lack of validated protocols and shared guidelines for the study of the relationship between executive functions, self-regulation, and pro-environmental behaviour, which could reflect the relatively young age of the topic of this systematic research and its multidisciplinary interest, resulting into few validated protocols for research. To address this limitation, we call for researchers interested in pro-environmental behaviour across disciplines to cooperate in defining measurement tools and protocols that could be replicated across studies.

Third, we decided to include in our systematic review only articles published in peer reviewed journals and available in English. Whilst this choice was made to maximise the chance of including studies following rigorous methodological procedures, and to minimise the risk of including spurious or incomplete results, such decision might have introduced a selection bias towards studies reporting positive and significant results (Drucker et al., 2016; Egger et al., 1997). However, considering the fact that grey literature tends to present lower quality of reporting compared to peer-reviewed journal articles (Carneiro et al., 2020), that overestimation resulting from exclusion of non-published data seem to affect only a minority of reviews (Schmucker et al., 2017), and that including results from unpublished studies can generate new bias (e.g. lack of reproducibility, change of results presented in the pre-print and final article; Brietzke et al., 2023) we decided to prioritize higher reporting quality over the risk of potentially excluding relevant (but low quality) studies.

Finally, beyond offering a perspective on the role of executive functions and self-regulation on pro-environmental behaviour, some of the studies also discuss the role of specific intrapersonal factors which are thought to modulate individuals' SR abilities facing the environmental crisis. Examples include motivational orientation (Brandsma & Blasch, 2019; Davis et al., 2019; Martin et al., 2017; Osbaldiston & Sheldon, 2003), self construals (Chuang et al., 2016), social orientation (McCalley & Midden, 2002), regulatory focus (Lalot et al., 2021), grit (Datu & Buenconsejo, 2021), dispositional envy (Wei & Yu, 2022), moral considerations (Nielsen & Hofmann, 2021), norms (Abrams et al., 2021), subjective temporal perception (Bashir et al., 2014) and perspective thinking (Brevers et al., 2021). Whilst we briefly discuss the abovementioned factors in our review to enrich our understanding of how self-regulation relates to pro-environmental behaviour, our outlook on their specific effect on pro-environmental behaviour should not be considered exhaustive, as their investigation falls beyond the scope of this systematic review.

5. Conclusion

The study of the relationship between executive functions and self-regulation with pro-environmental behaviour performance is a relatively recent area of research which appears to be gaining interest in recent years, driven by a growing sense of urgency with respect to understanding why people are struggling to act against the climate crisis. Our review brings together studies highlighting a relationship between self-regulation and pro-environmental behaviour, suggesting that self-regulatory processes, subserved by executive functions, would play a role in explaining interindividual variability in pro-environmental behaviour performance. Considering the high heterogeneity of the studies analysed and the lack of a unifying framework of reference for the study of the self-regulatory dynamics involved in pro-environmental behaviour, we call for more research to be carried out on the link between executive functions and self-regulatory processes, with respect to pro-environmental behaviour. Understanding how executive functions contribute to different steps of the self-regulation process might not only help to clarify how they affect behavioural change facing the climate crisis, but also to design more effective interventions to tackle the environmental attitude-behaviour gap, and therefore increase actual individual engagement in pro-environmental action.

Declarations of interest

We have no known conflict of interests to disclose.

Funding

Luca Simione has been supported by the grant 309/2020 on "Assessing static and dynamic effects of mindfulness meditation on peripersonal space" by BIAL Foundation (Portugal). Antonino Raffone has been supported by the grant 272/70 on "Advancements on the Aware Mind-Brain: New Insights about the neural correlates of meditation states and traits" by BIAL Foundation (Portugal).

CRediT authorship contribution statement

Serena Colombo: Conceptualization; Data curation; Methodology; Writing – original draft; Writing – review & editing. Salvatore G. Chiarella: Conceptualization; Data curation; Methodology; Supervision; Writing – review & editing. Camille Lefrançois: Writing – review & editing.

Jacques Fradin: Writing – review & editing. Luca Simione: Conceptualization; Methodology; Supervision; Writing – review & editing. Antonino Raffone: Conceptualization; Supervision; Writing – review & editing. Serena Colombo and Salvatore G. Chiarella are co-first authors.

Acknowledgement

The authors would like to thank the two reviewers for their valuable comments, observations, and suggestions, which have led to a significant improvement of the article.

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