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To select effective interventions for pro-environmental behaviour change, we need to consider determinants of behaviour

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Encouraging pro-environmental behaviour is necessary to reduce CO_2 emissions and limit global climate change. Many reviews and meta-analyses have been published examining the effectiveness of interventions to promote pro-environmental behaviour. Yet, it remains unclear which interventions are most effective, when and why. Because interventions are more likely to encourage pro-environmental behaviour when they target key determinants of the relevant behaviour, it is critical to understand which interventions target which determinants. We introduce a classification system that links six types of interventions to 13 determinants of environmental behaviour. Our classification enables a theory-based understanding of when and why interventions are effective (or not) in encouraging pro-environmental behaviour and provides guidelines to practitioners to select interventions that are most likely to change the key determinants of a specific target behaviour, and thus likely to be the most successful in changing behaviour in the given context.

Mitigating global climate change is one of the most urgent challenges of the twenty-first century. To limit global warming to 1.5 degrees or lower, unprecedented changes are needed from governments, industry and communities[1]. Individuals can contribute to mitigating climate change by changing their behaviour and lifestyles—for example, by using less fossil-fuel-based energy, travelling more sustainably, purchasing fewer products and switching to a plant-based diet[2,3]. The most recent report of the Intergovernmental Panel on Climate Change indicates that changes in demand, including individual behaviour changes, could reduce CO_2 emissions by 40% to 70% by 2050, compared with current policies[1]. Individual behaviour that reduces CO_2 emissions, and environmental harm more generally, is referred to as pro-environmental behaviour[4]. Even though many people across the globe believe in the reality and human causes of climate change and express concern about climate change, people can do more to reduce their climate impact and their environmental impact more generally[5,6]. Motivating people to adopt (more) pro-environmental behaviours is therefore a key challenge.

In response to this challenge, many studies have examined which interventions are effective in promoting pro-environmental behaviour. The insights gained from these studies have been consolidated in many systematic literature reviews. At the time of writing, over 50 reviews and meta-analyses have been published on the extent to which different interventions can promote pro-environmental behaviour (see the Supplementary Information for the full details). These reviews have consistently come to the same general conclusion: while most interventions have the potential to encourage pro-environmental behaviours, the results vary considerably across studies[7–13]. An important question that follows is: when are interventions (most) effective, and how can their effectiveness be ensured in practice? Reviews and meta-analyses have so far not been able to identify when an intervention works or does not work well and why this might be the case[14]. A more robust understanding of how interventions work in changing pro-environmental behaviour is thus urgently needed.

To better understand when and why interventions are effective, we propose that it is necessary to develop a robust and theory-based

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understanding of the mechanism by which interventions ultimately lead to behaviour change. Within the behaviour change literature, it is typically implied that behaviour change interventions do not directly change behaviour. Rather, interventions target one or more determinants of behaviour (that is, variables that inhibit or enable the behaviour[4,15]), which in turn results in behaviour change. This implies that an intervention will be most effective if it targets key determinants of the relevant behaviour[4,15–17]. For example, the effectiveness of a campaign to reduce meat consumption by making people aware of the environmental consequences of meat consumption will be more effective when lack of awareness of these environmental impacts indeed affects the decision to eat or not eat meat. Taking into consideration which determinants are targeted by which interventions is therefore important to answer the question when and why particular interventions are effective or not. Yet, so far, this mediating effect of determinants between interventions and behaviours has been mostly overlooked. There have been no systematic efforts to theorize about which interventions target which determinants, and researchers mostly do not measure changes in psychological variables when they evaluate the effectiveness of interventions.

A more systematic consideration of which interventions target which determinants can also address another issue in the literature—namely, the lack of consensus on how interventions should be grouped and analysed. Researchers who conduct meta-analyses and reviews typically inductively determine their own criteria by which they classify interventions[8,18], which has resulted in two problems. First, interventions that affect behaviour in different ways are often grouped together. For example, information about the causes of climate change affects behaviour in a different way than the provision of feedback on the environmental impact of one's behaviour, because they target different determinants of behaviour (as explained in more detail below). Even so, some meta-analyses group the provision of information and feedback together into a single category and then draw conclusions about the effectiveness of this overarching category[8]. This makes it difficult to determine when and why particular interventions were or were not effective. In addition, the use of inductive approaches has resulted in inconsistent classifications of the same studies. For example, a study on the effects of goal setting and commitment making[19] was classified as a commitment intervention in one meta-analysis[8] but was considered a choice architecture intervention in another[10]. This means that meta-analyses are not comparable—even when they include the same intervention studies—and can reach different conclusions.

In sum, to accelerate the behaviour changes needed to keep climate change limited to 1.5 degrees, a better understanding of when and why interventions are effective to promote behaviour change is urgently needed. We propose that to understand the effectiveness of interventions, it is necessary to understand which interventions target which determinants of environmental behaviour. A large body of literature on the determinants of environmental behaviour has developed over the years, indicating which factors inhibit or encourage pro-environmental actions[4,20–22]. Yet, it remains unclear which interventions target which determinants. In this Review, we integrate literature on the determinants of environmental behaviour and interventions, and we propose a classification system that links six types of interventions to 13 determinants of environmental behaviour. This classification provides a theory-based understanding of when and why interventions are effective or not effective, and it helps researchers to classify interventions more consistently within and across reviews and meta-analyses. This is necessary to build a consistent and reliable evidence base for the design and practical application of behaviour change interventions.

Determinants of behaviour and interventions

We define determinants of environmental behaviour as psychological variables (for example, perceptions, beliefs, attitudes, norms and emotions) that motivate people to engage in a particular environmental behaviour. Determinants are specified in theories to explain environmental behaviour and include individual cognitions (for example, attitudes and beliefs), emotions, and perceptions related to the social (for example, social norms) and physical context (for example, self-efficacy). We propose that determinants mediate the effects of many interventions on behaviour. In other words, interventions are assumed to target and lead to changes in determinants, which subsequently cause people to change their behaviour[15]. For example, the provision of information about the consequences of climate change is assumed to increase people's knowledge about the issue, which in turn is assumed to result in behavioural changes.

We selected determinants of environmental behaviour by considering relevant theoretical frameworks and by conducting a literature search (for an overview and definitions of all included determinants, see Table 1; for the full details of the literature search, see the Supplementary Information). Because our overview aims to map which interventions can change specific determinants of behaviour, we focus only on determinants that are to some extent malleable and can realistically be changed by interventions.

A commonly assumed reason why people do not act pro-environmentally is that they lack knowledge about the causes and impacts of environmental problems; this is also referred to as the knowledge deficit model[23]. We therefore included knowledge as the first determinant of environmental behaviour. A textbook on environmental psychology[24] discusses five other prominent theories to explain environmental behaviour: the theory of planned behaviour[25] (TPB), protection motivation theory[26] (PMT), the norm activation model[27] (NAM), value–belief–norm theory[28,29] (VBN) and the focus theory of normative conduct[30] (FTNC). From these theories, we extracted the following determinants: attitudes towards the behaviour (TPB), self-efficacy (TPB and PMT), injunctive norms towards the behaviour (TPB and FTNC), descriptive norms towards the behaviour (FTNC), problem awareness (NAM and VBN), ascription of responsibility (NAM and VBN), outcome efficacy (NAM, VBN and PMT), personal norms (NAM and VBN) and risk perception (PMT).

The VBN further includes values[31,32] and the New Ecological Paradigm[33] as determinants of environmental behaviour. Following our inclusion criteria, we do not incorporate these two variables in our classification, as they represent relatively stable constructs that are difficult to change via interventions[34].

The prominent theoretical frameworks listed above emphasize cognitive factors but overlook the important role of emotions in environmental behaviour[35,36]. We therefore included two additional determinants that reflect the emotional counterpart of the determinants included in the above-mentioned theories. First, while risk perception is defined as the perceptions of the severity and likelihood of a risk (reflecting cognitions), the emotional response to a risk, specifically negative affect in response to environmental risks, can also critically affect behaviour[37,38]. Indeed, researchers have argued for the inclusion of negative affect in the protection motivation model[39,40].

Second, we added self-focused emotion, which refers to emotions people feel in response to their own behaviour[35,41]. These emotions can be positive (for example, pride) or negative (for example, guilt)[42]. Self-focused emotions are closely associated with personal norms in the NAM and VBN, because violating or adhering to personal norms towards environmental actions is assumed to be an important reason why people feel negative or positive self-focused emotions, respectively[27,36,42].

Recently, the value–identity–personal norm model[43–46] has been proposed, which additionally includes the determinant of environmental self-identity, referring to the extent to which people perceive themselves as pro-environmental[47–49]. Environmental self-identity is a particularly relevant variable, as it has the potential to influence different kinds of environmental behaviours in different contexts[50].

Table 1 | Overview of determinants of pro-environmental behaviour, the theoretical frameworks in which these determinants are included and their definitions

	Determinant	Theoretical framework	Definition
1.	Knowledge	Knowledge deficit model	Understanding of the scientific facts on the causes and impacts of environmental problems
2.	Risk perception	Protection motivation theory	An individual's evaluation of the likelihood and severity of a particular environmental hazard
3.	Negative affect towards environmental problems	Protection motivation theory	Concern, worry or fear towards environmental problems
4.	Problem awareness	Norm activation model Value–belief–norm theory	Awareness that performing or not performing a certain behaviour increases environmental problems
5.	Ascription of responsibility	Norm activation model Value–belief–norm theory	The extent to which people personally feel responsible for the (negative) environmental consequences of their actions
6.	Personal norms	Norm activation model Value–belief–norm theory Value–identity–personal norm model	A person's perceived moral obligation to engage in or abstain from a particular behaviour
7.	Self-focused emotions	Norm activation model Value–belief–norm theory	Emotions people feel in response to their own environmental behaviour, including guilt, shame and pride
8.	Attitudes towards behaviour	Theory of planned behaviour	The degree to which a person positively or negatively evaluates a particular behaviour
9.	Descriptive norms	Focus theory of normative conduct	The extent to which people believe others engage in a behaviour
10.	Injunctive norms	Theory of planned behaviour Focus theory of normative conduct	The extent to which people believe a behaviour is commonly approved or disapproved of by people or groups
11.	Self-efficacy	Theory of planned behaviour Protection motivation theory	The extent to which people feel capable of implementing a specific action
12.	Outcome efficacy	Norm activation model Value–belief–norm theory Protection motivation theory	The extent to which people perceive their behaviour as effective in contributing to resolving environmental problems
13.	Environmental self-identity	Value–identity–personal norm model	The extent to which people think of themselves as pro-environmental

Moreover, people infer their identities on the basis of past behaviour, suggesting that environmental self-identity is susceptible to change, making it a relevant target for interventions[22,47].

Similarly, we selected interventions by considering relevant theoretical discussions of this topic[4,51–55]. From these sources, we identified six relevant overarching categories of interventions that are used to change environmental behaviour: information provision, feedback, goal setting, commitment, incentives and choice architecture (also known as nudging) (for an overview and definitions of all included interventions, see Table 2). Importantly, within some overarching categories, we propose a more fine-graded distinction of interventions, to clearly identify which interventions target a given determinant. For example, while information provision is often discussed as one single intervention, we distinguish among eight different types of information provision that each target different determinants.

A literature search of reviews and meta-analyses (see the Supplementary Information for the details) confirmed that these overarching categories are the most extensively applied interventions to change environmental behaviour. Many review papers also mentioned the use of social norms as a distinct intervention. Yet, social norms need to be conveyed via information or feedback. We therefore included social norms in our overview as a subcategory of these interventions, specifically the provision of social norm information and the provision of social comparison feedback, respectively. Another intervention yielded by the literature search is the use of prompts or reminders. We included this intervention as a type of choice architecture, because prompts and reminders specifically play into more automatic processes of decision-making by providing environmental cues. We did not include the use of labels or social modelling as a separate intervention, as they represent ways of providing specific types of information—that is, information about the consequences of behaviour and information on how to perform behaviours, respectively. We also did not include invoking emotions as an intervention. While an emotional response can be invoked via interventions such as feedback or information provision, it is not an intervention in and of itself. Lastly, we did not include the framing of information as a separate intervention, as framing is focused on matching information provision to relevant individual characteristics and is thus part of information provision. We return to this point in the discussion.

Linking behavioural determinants to interventions

Below, we theorize which determinants of environmental behaviour are being targeted by which interventions. Research shows that all determinants discussed below are related to environmental behaviour, implying that all interventions could also be effective in promoting pro-environmental behaviour to at least some degree, as is also suggested by literature reviews and meta-analyses of interventions[7–13]. However, our reasoning implies that the effectiveness of the interventions will depend on the extent to which the determinants that are targeted by the intervention are important determinants of the target behaviour, which will depend on the behaviour itself, the context and the target group. This can explain why the effectiveness of interventions is found to vary substantially across studies.

Table 2 | Overview of interventions, their subcategories and definitions

Intervention	Definition
1. **Information provision**	Providing people with information (for example, about environmental problems, consequences of behaviour, social norms or how to perform a behaviour)
a. Information about the causes of environmental problems	Information about the causes of environmental problems
b. Information about the consequences of environmental problems	Information about the consequences of environmental problems
c. Information about the environmental consequences of a specific behaviour	Information about the environmental consequences of a specific behaviour
d. Information about the (non-environmental) benefits and costs associated with a behaviour	Information about the (non-environmental) benefits and costs associated with a behaviour
e. Descriptive norm information	Information about how many people are already engaging in a particular pro-environmental behaviour (or abstaining from an environmentally harmful behaviour)
f. Dynamic norm information	Information about the extent to which more and more people are changing their behaviour
g. Injunctive norm information	Information about the extent to which other people approve or do not approve of a particular behaviour
h. Information about how to perform a specific behaviour	Information about how to perform a specific behaviour
2. Commitment	People pledging or promising that they will engage in a certain pro-environmental behaviour (or abstain from an environmentally harmful behaviour)
a. Private commitment	Commitment (or pledge) made privately, not observable to others
b. Public commitment	Commitment (or pledge) made publicly, observable to others
3. Feedback	Providing individuals with information about their past behaviour or performance
a. Historic feedback	Feedback that compares one's current behaviour or performance to one's past behaviour or performance (for example, energy use in the past month versus energy use in the same month last year)
b. Goal-based feedback	Feedback that compares one's current behaviour or performance to a personal goal or commitment
c. Social comparison feedback	Feedback that compares one's own behaviour or performance to the behaviour or performance of other people (for example, the neighbourhood average or that of similar households)
d. Group-based feedback	Feedback about environmental behaviour or performance at the group level
4. Incentives	Offering rewards for engaging in pro-environmental behaviours or penalties for engaging in environmentally harmful behaviours
a. Reward	Providing a positive consequence when people engage in pro-environmental behaviour
b. Penalty	Providing a negative consequence when people engage in environmentally harmful behaviour
5. Goal setting	People setting a (behavioural) target that they aim to achieve
6. Choice architecture	Making changes to the context in which people make decisions, without limiting people in the choices they can make and without affecting the actual costs and benefits of actions

Knowledge

The knowledge deficit model[23] assumes that people will act more pro-environmentally if they have sufficient knowledge about environmental problems[56–59], notably understanding of the scientific facts on the causes and impacts of environmental problems[60,61]. Hence, knowledge can be increased by giving people information about the causes of environmental problems (1a in Table 2; hereafter, the parenthetical numbers and letters all refer to Table 2) (for example, that climate change is caused by emissions of greenhouse gases through the combustion of fossil fuels) and the consequences of environmental problems (1b) (for example, that climate change results in sea level rise, loss of biodiversity and increases in extreme weather events).

Risk perception

Environmental risk perception refers to an individual's evaluation of the likelihood and severity of a particular environmental hazard[62]. The more risk people perceive, the more likely they are to engage in behaviour to decrease that risk, such as pro-environmental behaviour[63–65]. People's perception of environmental risks can be increased by providing information about the consequences of environmental problems (1b).

Negative affect towards environmental problems

Negative affect towards environmental problems includes negative emotions such as concern, worry or fear, which can motivate people to engage in action to relieve these negative feelings, including acting pro-environmentally[66,67]. Like risk perception, negative affect towards environmental problems can be increased by providing information about the consequences of environmental problems (1b).

Problem awareness

Problem awareness (or awareness of consequences) is defined as awareness that performing or not performing certain behaviours increases environmental problems[36,68]. Higher problem awareness is associated with more engagement in pro-environmental behaviour[20,21,69,70]. Problem awareness can be increased by providing information about the consequences of environmental problems (1b) and/or the environmental consequences of specific behaviours (1c).

Ascription of responsibility

The ascription of responsibility refers to the extent to which people personally feel responsible for the (negative) environmental consequences

of their actions[68]. The more responsible people feel for the environmental problems caused by their actions, the more likely they are to engage in pro-environmental behaviour[20,21,71]. People's ascription of responsibility can be increased by providing information about the environmental consequences of specific behaviours (1c).

Personal norms

Personal norms towards pro-environmental behaviour refer to a person's perceived moral obligation to engage in or abstain from a particular behaviour[29,72]. The more strongly people hold a personal norm to act pro-environmentally, the more likely they are to act in line with this norm[20,21,58,73]. Personal norms can be strengthened through making a commitment (2a and 2b), where individuals are asked to pledge or promise that they will engage in a certain pro-environmental behaviour (or abstain from an environmentally harmful behaviour), either indefinitely or for a specified period (for example, pledging to not eat meat for a month)[74,75]. Because people are motivated to be consistent in their thoughts and actions[76], they feel obliged to keep a promise; making a commitment can thus strengthen feelings of personal moral obligation to act accordingly[75].

According to the NAM[27] and the VBN[28], personal norms are stronger when people are more aware of the environmental problems caused by their behaviour, feel responsible for these problems and believe they can reduce these problems by acting pro-environmentally. People's personal norms could thus theoretically be influenced (indirectly) by the same interventions that target those three determinants (that is, problem awareness, ascription of responsibility and outcome efficacy), including providing information about the consequences of environmental problems (1b) and the environmental consequences of specific behaviours (1c).

Self-focused emotions

When people act pro-environmentally, they may feel good about themselves, experiencing self-focused positive emotions, such as pride[42] or a warm glow[77,78]. Because people like to feel good, anticipating the experience of these self-focused positive emotions can be an important motivator of pro-environmental behaviour[42,79,80]. Conversely, if people do not act pro-environmentally, they may feel negative self-focused emotions, such as guilt and regret, and anticipating such negative feelings can motivate them to act pro-environmentally to avoid feeling negatively again[20,42,79,80]. When provided with information about the environmental consequences of specific behaviours (1c), people are likely to feel better about acting pro-environmentally and worse about not acting pro-environmentally because they are more aware of its impacts[81]. Making people aware of their own behaviour via feedback (3a, 3b and 3c) may also trigger self-focused positive or negative emotions, if the feedback demonstrates that they are acting or are not acting pro-environmentally, respectively.

Attitudes towards behaviour

Attitudes towards behaviour refer to the degree to which a person positively or negatively evaluates a particular behaviour, which is based on the beliefs and evaluation of the costs and benefits of behaviour[25]. The more positive a person's attitude towards a pro-environmental behaviour, the more likely they are to engage in that behaviour[20,21,73,82]. This implies that people's attitudes towards a behaviour can be influenced through different information provision interventions. First, providing information about the environmental consequences of specific behaviours (1c) can change whether people evaluate a behaviour positively or negatively. For example, people may perceive eating meat less positively after they learn of the environmental impact of meat consumption[83]. Attitudes can also be changed by providing information about the (non-environmental) co-benefits and costs associated with behaviour (1d). For example, emphasizing the health benefits of cycling to work or the health and financial benefits of energy conservation can encourage pro-environmental actions[84,85], and emphasizing the health risks of red meat consumption can change people's attitudes towards this behaviour[86].

People's attitudes towards behaviour can also be changed by providing incentives (4) that actually alter the costs and benefits of engaging in behaviours. A reward (4a) (for example, a discount on coffee if you bring a reusable cup) for engaging in pro-environmental behaviour can increase people's positive attitude towards this behaviour, when people believe that this behaviour now has more positive consequences. Conversely, instating a penalty (4b) (for example, a tax premium on gasoline) for not acting pro-environmentally can lead people to have more negative attitudes towards this behaviour, as they are likely to think that this behaviour now has more negative consequences.

Descriptive norms

Perceptions of descriptive norms refer to the extent to which people believe others engage in a behaviour and whether the behaviour is therefore normative[30]. When people think that many others engage in a (pro-environmental) behaviour, they are more likely to follow that descriptive norm and are more likely to engage in pro-environmental behaviour as well[58,87–89]. This is because people may think the behaviour is the sensible thing to do, and they are motivated to avoid the social stigma associated with violating descriptive norms. People's perception of the descriptive social norm can be increased via different interventions. The most evident way is to provide descriptive norm information (1e)—that is, information that communicates that a majority of people are already engaging in the sustainable behaviour[90].

Perceptions of the descriptive norm can also be changed through social comparison feedback (3c), which compares one's own behaviour or performance to the behaviour or performance of other people, such as the neighbourhood average or that of similar households[7,74,91,92]. This comparison information may reveal that other people are acting more environmentally friendly than one previously assumed, thus altering people's perceptions of the descriptive norms surrounding a particular behaviour. Importantly, social comparison feedback is most likely to be effective when it demonstrates that others are acting more pro-environmentally than the individual receiving the feedback. If feedback demonstrates that others are acting less pro-environmentally, this may cause a boomerang effect where people start acting less pro-environmentally to match the descriptive norm[92]. In addition, group-based feedback (3d) (that is, feedback about pro-environmental behaviour at the group level) can implicitly convey information about whether most people in the group are acting pro-environmentally or not, which can change perceptions of the descriptive norm and motivate individuals who are not acting pro-environmentally to conform to this norm[93,94].

Importantly, as indicated above, targeting people's perceptions of descriptive norms is most likely to be effective if a large group of people is already engaging in the behaviour. If the behaviour is not normative yet, dynamic norm information (1f) may be more effective: information that indicates that an increasing number of people are changing their behaviour[83,95,96]. Such information may signal to people what behaviour may be normative in the near future, to which people may already want to conform.

Injunctive norms

Perceptions of injunctive norms (or subjective norms) refer to the extent to which people believe a behaviour is commonly approved or disapproved of by people or groups that are important to them. The more people perceive an injunctive norm to act pro-environmentally, the more likely they are to comply with this norm[87,89,97,98], to avoid the social sanctions associated with breaking a norm and to gain social approval when they act in line with injunctive norms[30]. Injunctive norm information (1g) indicating that many people approve or disapprove of a particular behaviour can alter perceptions of injunctive norms.

People's perceptions of injunctive norms could also be changed by providing descriptive norm information (1e). Receiving information that many people are already acting pro-environmentally may cause people to infer that other people find acting pro-environmentally important and expect others to act pro-environmentally too, thus indirectly signalling information about the injunctive norms surrounding a particular behaviour. Similarly, perceptions of the injunctive norm can be changed by providing dynamic norm information (1f). People may infer from information indicating that more and more people are changing their behaviour that there is also a shift in what people value and approve or disapprove of, which may affect people's perceptions of the injunctive norm.

Self-efficacy

Self-efficacy (or perceived behavioural control) refers to the extent to which people feel capable of implementing a specific action[25,26,63]. The more people feel capable of implementing a particular action, the more likely they are to do so[20,21,58,63,82]. The most straightforward way to increase people's sense of self-efficacy is to provide information about how to perform a specific behaviour (1h), such as information on how to save energy at home or on how to prepare a vegetarian meal[17]. In addition, self-efficacy can be increased by providing descriptive norm information (1e) or dynamic norm information (1f), because people may assume that if many people are already engaging in a behaviour, they are probably also able to do so[99]. Self-efficacy may also be enhanced via goal setting (5). Specifically, if goals are specific, realistic and well-defined, they can make an abstract desired outcome (for example, reducing one's carbon footprint) more concrete by outlining the distinct steps that people could take (for example, eating meat no more than once a month), which can raise people's sense of self-efficacy that they are able to reach more abstract outcomes as well[100].

Outcome efficacy

Outcome efficacy is defined as the extent to which people perceive their behaviour as effective in contributing to resolving environmental problems[26,63]. The more people perceive their behaviour as effective in reducing environmental problems, the more likely people are to engage in that behaviour[63,80,101]. Outcome efficacy can be increased by providing people with information on the environmental consequences of specific behaviours (1c). For example, if people receive information that in-home energy use makes up a large part of a person's carbon footprint, they may subsequently perceive the act of reducing their own energy use as having a bigger impact, increasing their outcome efficacy. Outcome efficacy can also be increased via historic feedback (3a), which is feedback that compares current behaviour to past behaviour (for example, energy use in the past month versus energy use in the same month last year)[7]. Such historic feedback can indicate to what extent particular behaviour changes people have implemented have been effective (for example, people can see whether turning down the thermostat lowered their energy use), thereby increasing the outcome efficacy of specific actions.

Environmental self-identity

Environmental self-identity refers to the extent to which people think of themselves as pro-environmental[50]. As indicated above, people strive for a sense of consistency between their thoughts and actions and are motivated to act in line with their self-image[76]. Environmental self-identity indeed appears to be an important determinant of pro-environmental behaviour[22,50,56,102]. Similar to personal norms, environmental self-identity can be strengthened by making a commitment (2a and 2b), as people may infer from the commitment that they are people who value the environment, bolstering their environmental self-identity. Additionally, if people are already acting pro-environmentally, increasing their awareness of their own behaviour via historic feedback (3a) or social comparison feedback (3c) can lead them to infer that they are more pro-environmental than previously assumed, increasing their environmental self-identity.

Intervening in automatic decision-making

The previously discussed interventions all target determinants directly and assume that people make a conscious decision about the behaviour they are undertaking, by considering the determinants we have previously discussed. Yet, when people have little time, mental resources or motivation to evaluate all possible options when making a decision, they are more likely to rely on more automatic and heuristic decision-making processes[103,104]. Choice architecture interventions (6) (or nudges) target such automatic and heuristic decision-making processes[104]. They aim to promote pro-environmental behaviour by making changes to the context in which people make decisions, without limiting people in the choices they can make and without affecting the (perceptions of) actual costs and benefits of actions[10]. Examples include making pro-environmental options the default or more visually salient, or placing strategic reminders or prompts to encourage pro-environmental behaviour in relevant locations (for example, remembering to turn off the lights)[2].

Conclusions and future directions

Interventions are more likely to encourage pro-environmental behaviour when they target key determinants of the relevant behaviour. We have proposed a classification that links six different interventions to 13 determinants that have been theorized and empirically found to be important enablers of or barriers to pro-environmental behaviour. This classification represents a start to developing a theory-based understanding of the mechanism by which interventions ultimately lead to behaviour change, which is urgently needed to better understand when and why interventions to promote pro-environmental behaviour are effective or not effective. Yet, research is still needed to test the merits of our classification and to empirically confirm the links between determinants and interventions that we have proposed. As such, our classification provides an agenda for future research; future studies examining the effectiveness of interventions should not only measure changes in the target behaviour but also include measures that assess (changes in) the relevant determinant(s) of the target behaviour.

Notably, by focusing on the determinants of environmental behaviour, we were able to develop a more fine-grained distinction between different interventions, which can contribute to developing more precise insights about the effectiveness of different interventions. This contributes to resolving the problem that reviews and meta-analyses have so far employed overly inclusive categories that overlook important nuances between different interventions, which complicates drawing conclusions about when and why particular interventions are effective. For example, previous reviews have often considered information provision as one single intervention. Our classification of interventions according to the determinants they target indicates that it is important to distinguish at least eight different types of information, each targeting different determinants of behaviour and thus affecting behaviour in different ways. Additionally, by offering clear definitions of both interventions and determinants, our classification can reduce the inconsistencies between different reviews and meta-analyses in how interventions and studies are classified.

Interestingly, our classification demonstrates that different types of interventions can, in theory, target the same determinants of behaviour. For example, both information provision and commitments can be used to strengthen people's personal norms to act pro-environmentally. An important question for future research is which of these interventions are most effective, and under which conditions, in targeting the relevant determinants of behaviour. Importantly, some interventions make use of the psychological principle of consistency, which is a powerful principle for behaviour change, as people are motivated to (appear to) be consistent in their thoughts

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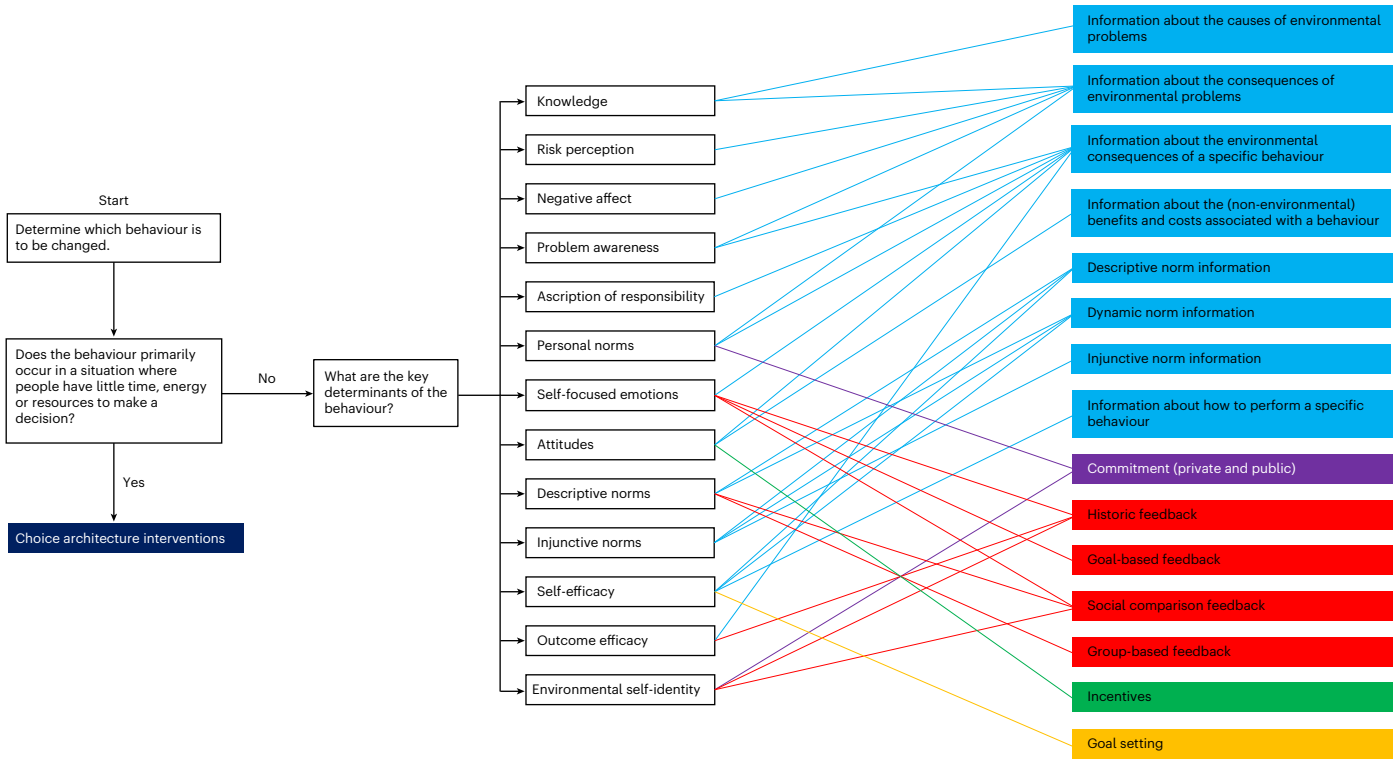

Fig. 1 | Procedure for selecting promising interventions to promote pro-environmental behaviour. First, determine which determinants form key barriers or enablers for people to engage (or stop engaging) in the relevant behaviour, and then select interventions targeting those determinants. Please refer to the manuscript text for details on the relationships between determinants and interventions depicted here. For the definitions of the determinants and interventions, see Tables 1 and 2, respectively.

and behaviour[30,75]. Specifically, commitments, goal setting and feedback can make people aware of a (possible) discrepancy between their commitments, goals or thoughts and their actual behaviour. Due to the desire to be consistent, people are likely to feel negative emotions if such a discrepancy is perceived[105,106], which can motivate people to change their behaviour. Future studies can examine whether interventions that capitalize on the consistency principle are more effective than interventions that do not invoke this principle.

Our classification focuses specifically on the determinants mediating the effect of interventions on environmental behaviour. We theorized that the effectiveness of interventions depends on whether they target key determinants of actions, which implies that the effects of interventions are likely to vary across behaviours, contexts and time. Various additional factors may affect the extent to which interventions work or do not work, moderating the impacts of interventions on behaviour, including individual characteristics such as people's personalities, values or political views. For example, providing feedback on the environmental impact of people's behaviour will probably be more effective if people more strongly care about acting pro-environmentally[107–109]. Similarly, framing information to match people's political orientation can result in more behaviour change, especially in countries where the topic of climate change is highly politicized[110,111]. People may also differ in their susceptibility to social norm information, which may be culturally determined[87,91,112]. More theory-based and empirical work is necessary to outline to what extent different factors can affect the impacts of different interventions on determinants of environmental behaviour and actual behaviour change.

Our classification offers practical guidelines for policymakers that aim to implement interventions (Fig. 1). We recommend that practitioners first determine which behaviours they aim to change. From a practical point of view, a focus on behaviours with a demonstrable large impact on the environment is preferred over a focus on less impactful behaviours[113,114]. Next, practitioners would need to identify (possibly on the basis of case-specific data or research) which determinants form the key barriers or enablers for people to engage (or stop engaging) in this behaviour[4,16,115,116]. On the basis of this analysis, an appropriate intervention can be determined that targets the key determinants, using the classification we have presented. Importantly, in many cases, a combination of different types of determinants may inhibit or enable pro-environmental behaviours simultaneously. In such cases, a single intervention that targets one specific determinant may be less or even not effective in changing the behaviour if other critical determinants of the behaviour remain unaddressed. A combination of interventions that addresses all relevant bottlenecks to behaviours may therefore be necessary to encourage and enable behaviour change[2].

When selecting which interventions to implement in practice, it is critical that researchers and practitioners consider not only the effectiveness of interventions in the short term and on targeted behaviours but also their broader and longer-term consequences in promoting pro-environmental behaviours or even lifestyles. For example, choice architecture interventions seem particularly suitable to encourage automatic behaviours that occur in the context in which they are employed (for example, placing a reminder to switch off the lights directly above the light switch). However, as choice architecture interventions rely on automatic processes and do not directly change the determinants of environmental behaviour, their effects may not generalize to other contexts or behaviours and may not persist when the intervention is removed[117,118]. In a similar vein, some determinants that we have identified are specific to certain behaviours (for example, attitudes towards car use or personal norms to adopt a plant-based diet), and targeting such determinants is likely to particularly affect the target behaviour. But other determinants are more

general (for example, environmental self-identity or personal norms to act pro-environmentally in general), and their influence on behaviour will probably transcend different situations and contexts and may thus encourage wider behaviour changes. Behaviour-specific determinants are probably easier to change and more likely to have a stronger effect on specific behaviours[119]. While achieving changes in general determinants may be less effective in changing a specific behaviour, they are likely to have a greater potential to lead to widespread and durable behaviour change across behaviours and contexts[120]. Interventions that target more general determinants of environmental behaviour, such as environmental self-identity, are arguably more likely to promote large-scale changes in behaviours and lifestyles needed to sufficiently reduce CO_2 emissions[2], compared with interventions focused on specific determinants or automatic processes.

In conclusion, our categorization links key determinants of environmental behaviour to interventions, including different types of information provision, commitment, feedback, incentives, goal setting and choice architecture. This classification enables a theory-based understanding of when and why interventions are effective or not. Future research is needed to systematically test the links between determinants and interventions that we have proposed. Our classification provides guidelines to practitioners to select those interventions that are most likely to change the key determinants of a specific target behaviour and thus likely to be the most successful in changing that behaviour. We hope that the classification presented here can accelerate research on and application of behavioural science insights to promote widespread pro-environmental behaviour that will be necessary to limit climate change to 1.5 degrees.

References

1. IPCC: Summary for Policymakers. in *Climate Change 2022: Impacts, Adaptation, and Vulnerability* (eds Pörtner, H.-O. et al.) (Cambridge Univ. Press, 2022).
2. Clarke, L. et al. in *Climate Change 2022: Mitigation of Climate Change* (eds Shukla, P. R. et al.) Ch. 6 (IPCC, Cambridge Univ. Press, 2022).
3. Wynes, S. & Nicholas, K. A. The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environ. Res. Lett.* **12**, 074024 (2017).
4. Steg, L. & Vlek, C. Encouraging pro-environmental behaviour: an integrative review and research agenda. *J. Environ. Psychol.* **29**, 309–317 (2009).
5. Hall, M. P., Lewis, N. A. & Ellsworth, P. C. Believing in climate change, but not behaving sustainably: evidence from a one-year longitudinal study. *J. Environ. Psychol.* **56**, 55–62 (2018).
6. Steg, L. Limiting climate change requires research on climate action. *Nat. Clim. Change* **8**, 759–761 (2018).
7. Karlin, B., Zinger, J. F. & Ford, R. The effects of feedback on energy conservation: a meta-analysis. *Psychol. Bull.* **141**, 1205–1227 (2015).
8. Nisa, C. F., Belanger, J. J., Schumpe, B. M. & Faller, D. G. Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. *Nat. Commun.* **10**, 4545 (2019).
9. Composto, J. W. & Weber, E. U. Effectiveness of behavioural interventions to reduce household energy demand: a scoping review. *Environ. Res. Lett.* **17**, 063005 (2022).
10. Mertens, S., Herberz, M., Hahnel, U. J. J. & Brosch, T. The effectiveness of nudging: a meta-analysis of choice architecture interventions across behavioral domains. *Proc. Natl Acad. Sci. USA* **119**, e2107346118 (2022).
11. Andor, M. A. & Fels, K. M. Behavioral economics and energy conservation—a systematic review of non-price interventions and their causal effects. *Ecol. Econ.* **148**, 178–210 (2018).
12. Delmas, M. A., Fischlein, M. & Asensio, O. I. Information strategies and energy conservation behavior: a meta-analysis of experimental studies from 1975 to 2012. *Energy Policy* **61**, 729–739 (2013).
13. Varotto, A. & Spagnolli, A. Psychological strategies to promote household recycling: a systematic review with meta-analysis of validated field interventions. *J. Environ. Psychol.* **51**, 168–188 (2017).
14. Schultz, P. W. Strategies for promoting proenvironmental behavior. *Eur. Psychol.* **19**, 107–117 (2014).
15. Michie, S. et al. From theory-inspired to theory-based interventions: a protocol for developing and testing a methodology for linking behaviour change techniques to theoretical mechanisms of action. *Ann. Behav. Med.* **52**, 501–512 (2018).
16. Geller, E. S. in *Handbook of Environmental Psychology* (eds Bechtel, R. B. & Churchman, A.) 525–540 (Wiley, 2002).
17. Abrahamse, W., Steg, L., Vlek, C. & Rothengatter, T. A review of intervention studies aimed at household energy conservation. *J. Environ. Psychol.* **25**, 273–291 (2005).
18. Osbaldiston, R. & Schott, J. P. Environmental sustainability and behavioral science. *Environ. Behav.* **44**, 257–299 (2011).
19. McCaul, K. D. & Kopp, J. T. Effects of goal setting and commitment on increasing metal recycling. *J. Appl. Psychol.* **67**, 377–379 (1982).
20. Bamberg, S. & Möser, G. Twenty years after Hines, Hungerford, and Tomera: a new meta-analysis of psycho-social determinants of pro-environmental behaviour. *J. Environ. Psychol.* **27**, 14–25 (2007).
21. Klöckner, C. A. A comprehensive model of the psychology of environmental behaviour—a meta-analysis. *Glob. Environ. Change* **23**, 1028–1038 (2013).
22. Vesely, S. et al. Climate change action as a project of identity: eight meta-analyses. *Glob. Environ. Change* **70**, 102322 (2021).
23. Schultz, P. W. in *New Tools for Environmental Protection: Education, Information and Voluntary Measures* (eds Dietz, T. & Stern, P. C.) 67–82 (National Academy Press, 2002).
24. Steg, L. & de Groot, J. I. M. (eds) *Environmental Psychology: An Introduction* 2nd edn (Wiley, 2018).
25. Ajzen, I. The theory of planned behaviour. *Organ. Behav. Hum. Decis. Process.* **50**, 179–211 (1991).
26. Rogers, R. W. in *Social Psychophysiology: A Sourcebook* (eds Cacioppo, B. L. & Petty, L. L.) 153–176 (Guildford, 1983).
27. Schwartz, S. H. in *Advances in Experimental Social Psychology* (ed. Berkowitz, L.) Vol. 10, 221–278 (Academic Press, 1977).
28. Stern, P. C., Dietz, T., Abel, T., Guagnano, G. A. & Kalof, L. A value–belief–norm theory of support for social movements: the case of environmentalism. *Res. Hum. Ecol.* **6**, 81–97 (1999).
29. Stern, P. C. Toward a coherent theory of environmentally significant behavior. *J. Soc. Issues* **56**, 407–424 (2000).
30. Cialdini, R. B., Reno, R. R. & Kallgren, C. A. A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places. *J. Pers. Soc. Psychol.* **58**, 1015–1026 (1990).
31. Steg, L. Values, norms, and intrinsic motivation to act proenvironmentally. *Annu. Rev. Environ. Resour.* **41**, 277–292 (2016).
32. Schwartz, S. H. An overview of the Schwartz theory of basic values. *Online Read. Psychol. Cult.* **2**, 11 (2012).
33. Dunlap, R. E. & Van Liere, K. D. The "New Environmental Paradigm". *J. Environ. Educ.* **9**, 10–19 (1978).
34. Stern, P. C., Dietz, T. & Guagnano, G. A. The New Ecological Paradigm in social–psychological context. *Environ. Behav.* **27**, 723–743 (1995).

35. Brosch, T. & Steg, L. Leveraging emotion for sustainable action. *One Earth* **4**, 1693–1703 (2021).
36. Onwezen, M. C., Antonides, G. & Bartels, J. The norm activation model: an exploration of the functions of anticipated pride and guilt in pro-environmental behaviour. *J. Econ. Psychol.* **39**, 141–153 (2013).
37. Sjöberg, L. Emotions and risk perception. *Risk Manage.* **9**, 223–237 (2007).
38. Loewenstein, G. F., Weber, E. U., Hsee, C. K. & Welch, N. Risk as feelings. *Psychol. Bull.* **127**, 267–286 (2001).
39. Dang, H., Li, E. & Bruwer, J. Understanding climate change adaptive behaviour of farmers: an integrated conceptual framework. *Int. J. Clim. Change Impacts Responses* **3**, 255–272 (2012).
40. Westcott, R., Ronan, K., Bambrick, H. & Taylor, M. Expanding protection motivation theory: investigating an application to animal owners and emergency responders in bushfire emergencies. *BMC Psychol.* **5**, 13 (2017).
41. Taufik, D. & Venhoeven, L. in *Environmental Psychology: An Introduction* (eds Steg, L. & de Groot, J. I. M.) 189–197 (Wiley, 2018).
42. Shipley, N. J. & van Riper, C. J. Pride and guilt predict pro-environmental behavior: a meta-analysis of correlational and experimental evidence. *J. Environ. Psychol.* **79**, 101753 (2022).
43. Ateş, H. Merging theory of planned behavior and value identity personal norm model to explain pro-environmental behaviors. *Sustain. Prod. Consum.* **24**, 169–180 (2020).
44. van der Werff, E. & Steg, L. The psychology of participation and interest in smart energy systems: comparing the value–belief–norm theory and the value–identity–personal norm model. *Energy Res. Soc. Sci.* **22**, 107–114 (2016).
45. Ajibade, I. & Boateng, G. O. Predicting why people engage in pro-sustainable behaviors in Portland Oregon: the role of environmental self-identity, personal norm, and socio-demographics. *J. Environ. Manage.* **289**, 112538 (2021).
46. Schuster, C., Goseberg, T., Arnold, J. & Sundermann, A. I share because of who I am: values, identities, norms, and attitudes explain sharing intentions. *J. Soc. Psychol.*, https://doi.org/10.1080/00224545.2022.2044282 (2022).
47. Gatersleben, B. & van der Werff, E. in *Environmental Psychology: An Introduction* (eds Steg, L. & de Groot, J. I. M.) 198–206 (Wiley, 2018).
48. Van der Werff, E., Steg, L. & Keizer, K. I am what I am, by looking past the present. *Environ. Behav.* **46**, 626–657 (2013).
49. Whitmarsh, L. & O'Neill, S. Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. *J. Environ. Psychol.* **30**, 305–314 (2010).
50. van der Werff, E., Steg, L. & Keizer, K. The value of environmental self-identity: the relationship between biospheric values, environmental self-identity and environmental preferences, intentions and behaviour. *J. Environ. Psychol.* **34**, 55–63 (2013).
51. Abrahamse, W. *Encouraging Pro-environmental Behaviour: What Works, What Doesn't, and Why* (Academic Press, 2019).
52. Abrahamse, W. & Matthies, E. in *Environmental Psychology: An Introduction* (eds Steg, L. & de Groot, J. I. M.) 261–272 (Wiley, 2018).
53. Bolderdijk, J. W., Lehman, P. K. & Geller, E. S. in *Environmental Psychology: An Introduction* (eds Steg, L. & de Groot, J. I. M.) 273–282 (Wiley, 2018).
54. Grilli, G. & Curtis, J. Encouraging pro-environmental behaviours: a review of methods and approaches. *Renew. Sustain. Energy Rev.* **135**, 110039 (2021).
55. Schultz, P. W. & Kaiser, F. in *The Oxford Handbook of Environmental and Conservation Psychology* (ed. Clayton, S. D.) 556–580 (Oxford Univ. Press, 2012).
56. Blankenberg, A. & Alhusen, H. *On the Determinants of Pro-environmental Behavior: A Literature Review and Guide for the Empirical Economist* (University of Göttingen, Center for European, Governance and Economic Development Research, 2019).
57. Bergquist, M., Nilsson, A., Harring, N. & Jagers, S. C. Meta-analyses of fifteen determinants of public opinion about climate change taxes and laws. *Nat. Clim. Change* **12**, 235–240 (2022).
58. Gifford, R. & Nilsson, A. Personal and social factors that influence pro-environmental concern and behaviour: a review. *Int J. Psychol.* **49**, 141–157 (2014).
59. Hines, J. M., Hungerford, H. R. & Tomera, A. N. Analysis and synthesis of research on responsible environmental behavior: a meta-analysis. *J. Environ. Educ.* **18**, 1–8 (1987).
60. Tobler, C., Visschers, V. H. M. & Siegrist, M. Consumers' knowledge about climate change. *Climatic Change* **114**, 189–209 (2012).
61. Kaiser, F. & Fuhrer, U. Ecological behavior's dependency on different forms of knowledge. *Appl. Psychol.* **2003**, 598–613 (2003).
62. Grothmann, T. & Patt, A. Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Glob. Environ. Change* **15**, 199–213 (2005).
63. Kothe, E. J. et al. Protection motivation theory and pro-environmental behaviour: a systematic mapping review. *Aust. J. Psychol.* **71**, 411–432 (2020).
64. Joshi, Y. & Rahman, Z. Factors affecting green purchase behaviour and future research directions. *Int. Strateg. Manage. Rev.* **3**, 128–143 (2015).
65. Stankuniene, G., Streimikiene, D. & Kyriakopoulos, G. L. Systematic literature review on behavioral barriers of climate change mitigation in households. *Sustainability* **12**, 7369 (2020).
66. Tilikidou, I. & Zotos, Y. Ecological consumer behaviour: review and suggestions for future research. *Prospettive e Proposte Mediterranee Rivista di Economia, Agricoltura e Ambiente* **1**, 14–21 (1999).
67. Kollmuss, A. & Agyeman, J. Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environ. Educ. Res.* **8**, 239–260 (2010).
68. de Groot, J. I. M. & Steg, L. Morality and prosocial behavior: the role of awareness, responsibility, and norms in the norm activation model. *J. Soc. Psychol.* **149**, 425–449 (2009).
69. Delaroche, M. Adoption of conservation practices: what have we learned from two decades of social–psychological approaches? *Curr. Opin. Environ. Sustain.* **45**, 25–35 (2020).
70. Hoffmann, C., Abraham, C., White, M. P., Ball, S. & Skippon, S. M. What cognitive mechanisms predict travel mode choice? A systematic review with meta-analysis. *Transp. Rev.* **37**, 631–652 (2017).
71. Okumah, M., Martin-Ortega, J., Novo, P. & Chapman, P. J. Revisiting the determinants of pro-environmental behaviour to inform land management policy: a meta-analytic structural equation model application. *Land* **9**, 135 (2020).
72. Schwartz, S. H. & Howard, J. A. in *Altruism and Helping Behaviour* (eds Rushton, J. P. & Sorrentino, R. M.) 189–211 (Lawrence Erlbaum, 1981).
73. Geiger, J. L., Steg, L., van der Werff, E. & Ünal, A. B. A meta-analysis of factors related to recycling. *J. Environ. Psychol.* **64**, 78–97 (2019).

74. Abrahamse, W. & Steg, L. Social influence approaches to encourage resource conservation: a meta-analysis. *Glob. Environ. Change* **23**, 1773–1785 (2013).
75. Lokhorst, A. M., Werner, C., Staats, H., van Dijk, E. & Gale, J. L. Commitment and behavior change. *Environ. Behav.* **45**, 3–34 (2011).
76. Cialdini, R. B. *Influence: Science and Practice* (HarperCollins, 2001).
77. Taufik, D., Bolderdijk, J. W. & Steg, L. Acting green elicits a literal warm glow. *Nat. Clim. Change* **5**, 37–40 (2015).
78. van der Linden Warm glow is associated with low- but not high-cost sustainable behaviour. *Nat. Sustain.* **1**, 28–30 (2018).
79. Turuga, R. M. R., Howart, R. B. & Borsuk, M. E. Pro-environmental behavior: rational choice meets moral motivation. *Ann. N. Y. Acad. Sci.* **1185**, 211–224 (2010).
80. Lin, M.-T., Zhu, D., Liu, C. & Kim, P. B. A meta-analysis of antecedents of pro-environmental behavioral intention of tourists and hospitality consumers. *Tour. Manage.* **93**,104566 (2022).
81. Venhoeven, L. A., Bolderdijk, J. W. & Steg, L. Why acting environmentally-friendly feels good: exploring the role of self-image. *Front. Psychol.* **7**, 1846 (2016).
82. Morren, M. & Grinstein, A. Explaining environmental behavior across borders: a meta-analysis. *J. Environ. Psychol.* **47**, 91–106 (2016).
83. Carfora, V., Zeiske, N., van der Werff, E., Steg, L. & Catellani, P. Adding dynamic norm to environmental information in messages promoting the reduction of meat consumption. *Environ. Commun.*, https://doi.org/10.1080/17524032.2022.2062019 (2022).
84. Asensio, O. I. & Delmas, M. A. Nonprice incentives and energy conservation. *Proc. Natl Acad. Sci. USA* **112**, E510–E515 (2015).
85. Bain Paul, G. et al. Co-benefits of addressing climate change can motivate action around the world. *Nat. Clim. Change* **6**, 154–157 (2015).
86. Grundy, E. A. C. et al. Interventions that influence animal-product consumption: a meta-review. *Future Food* **5**,100111 (2022).
87. Farrow, K., Grolleau, G. & Ibanez, L. Social norms and pro-environmental behavior: a review of the evidence. *Ecol. Econ.* **140**, 1–13 (2017).
88. Masson, T. & Fritsche, I. We need climate change mitigation and climate change mitigation needs the 'we': a state-of-the-art review of social identity effects motivating climate change action. *Curr. Opin. Behav. Sci.* **42**, 89–96 (2021).
89. Niemiec, R. M., Champine, V., Vaske, J. J. & Mertens, A. Does the impact of norms vary by type of norm and type of conservation behavior? A meta-analysis. *Soc. Nat. Resour.* **33**, 1024–1040 (2020).
90. Goldstein, N. J., Cialdini, R. B. & Griskevicius, V. A room with a viewpoint: using social norms to motivate environmental conservation in hotels. *J. Consum. Res.* **35**, 472–482 (2008).
91. Allcott, H. Social norms and energy conservation. *J. Public Econ.* **95**, 1082–1095 (2011).
92. Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldberg, N. J. & Griskevicius, V. The constructive, destructive, and reconstructive power of social norms. *Psychol. Sci.* **18**, 429–434 (2007).
93. Carrico, A. R. & Riemer, M. Motivating energy conservation in the workplace: an evaluation of the use of group-level feedback and peer education. *J. Environ. Psychol.* **31**, 1–13 (2011).
94. Siero, S., Boon, M., Kok, G. & Siero, F. Modification of driving behavior in a large transport organization: a field experiment. *J. Appl. Psychol.* **74**, 417–423 (1989).
95. Mortensen, C. R. et al. Trending norms: a lever for encouraging behaviors performed by the minority. *Soc. Psychol. Personal. Sci.* **10**, 201–210 (2017).
96. Sparkman, G. & Walton, G. M. Dynamic norms promote sustainable behavior, even if it is counternormative. *Psychol. Sci.* **28**, 1663–1674 (2017).
97. Pettifor, H., Wilson, C., Axsen, J., Abrahamse, W. & Anable, J. Social influence in the global diffusion of alternative fuel vehicles—a meta-analysis. *J. Transp. Geogr.* **62**, 247–261 (2017).
98. St John, F. A. V., Edwards-Jones, G. & Jones, J. P. G. Conservation and human behaviour: lessons from social psychology. *Wildl. Res.* **37**, 658–667 (2010).
99. Thøgersen, J. The mediated influences of perceived norms on pro-environmental behavior. *Rev. Econ. Polit.* **124**, 179–193 (2014).
100. Appelbaum, S. H. & Hare, A. Self-efficacy as a mediator of goal setting and performance: some human resource applications. *J. Manage. Psychol.* **11**, 33–47 (1996).
101. Zhuang, W., Luo, X. & Riaz, M. U. On the factors influencing green purchase intention: a meta-analysis approach. *Front. Psychol.* **12**, 644020 (2021).
102. Udall, A. M., Groot, J. I. M., Jong, S. B. & Shankar, A. How do I see myself? A systematic review of identities in pro-environmental behaviour research. *J. Consum. Behav.* **19**, 108–141 (2020).
103. Kahneman, D. *Thinking Fast and Slow* (Macmillan, 2011).
104. Thaler, R. H. & Sunstein, C. R. *Nudge* (Yale Univ. Press, 2008).
105. Inzlicht, M., Legault, L. & Teper, R. Exploring the mechanisms of self-control improvement. *Curr. Dir. Psychol. Sci.* **23**, 302–307 (2014).
106. Latham, G. P. & Locke, E. A. New developments in and directions for goal-setting research. *Eur. Psychol.* **12**, 290–300 (2007).
107. Bolderdijk, J. W., Gorsira, M., Keizer, K. & Steg, L. Values determine the (in)effectiveness of informational interventions in promoting pro-environmental behavior. *PLoS ONE* **8**, e83911 (2013).
108. Boomsma, C. & Steg, L. The effect of information and values on acceptability of reduced street lighting. *J. Environ. Psychol.* **39**, 22–31 (2014).
109. van den Broek, K., Bolderdijk, J. W. & Steg, L. Individual differences in values determine the relative persuasiveness of biospheric, economic and combined appeals. *J. Environ. Psychol.* **53**, 145–156 (2017).
110. Gromet, D. M., Kunreuther, H. & Larrick, R. P. Political ideology affects energy-efficiency attitudes and choices. *Proc. Natl Acad. Sci. USA* **110**, 9314–9319 (2013).
111. Wolsko, C., Ariceaga, H. & Seiden, J. Red, white, and blue enough to be green: effects of moral framing on climate change attitudes and conservation behaviors. *J. Exp. Soc. Psychol.* **65**, 7–19 (2016).
112. Laursen, B. & Faur, S. What does it mean to be susceptible to influence? A brief primer on peer conformity and developmental changes that affect it. *Int. J. Behav. Dev.* **46**, 222–237 (2022).
113. Whitmarsh, L., Poortinga, W. & Capstick, S. Behaviour change to address climate change. *Curr. Opin. Psychol.* **42**, 76–81 (2021).
114. Dietz, T., Gardner, G. T., Gilligan, J., Stern, P. C. & Vandenbergh, M. P. Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. *Proc. Natl Acad. Sci. USA* **106**, 18452–18456 (2009).
115. Steg, L., Keizer, K., Buunk, A. P. & Rothengatter, T. *Applied Social Psychology* (Cambridge Univ. Press, 2017).
116. Buunk, A. P., Dijkstra, P. & van Vught, M. *Applying Social Psychology: From Problems to Solutions* (Sage, 2021).
117. Stern, P. C., DIetz, T., Gardner, G. T., Gilligan, J. M. & Vandenbergh, M. P. Energy efficiency merits more than a nudge. *Science* **328**, 308–309 (2010).
118. Mols, F., Haslam, S. A., Jetten, J. & Steffens, N. K. Why a nudge is not enough: a social identity critique of governance by stealth. *Eur. J. Polit. Res.* **54**, 81–98 (2015).

119. Siegel, J. T., Navarro, M. A., Tan, C. N. & Hyde, M. K. Attitude–behavior consistency, the principle of compatibility, and organ donation: a classic innovation. *Health Psychol.* **33**, 1084–1091 (2014).
120. van der Werff, E. & Steg, L. One model to predict them all: predicting energy behaviours with the norm activation model. *Energy Res. Soc. Sci.* **6**, 8–14 (2015).

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