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Green Nudges: How to Induce Pro-Environmental Behavior Using Technology

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Abstract

To avoid the detrimental consequences of global warming, digital nudges were recognized as effective means to steer individual behavior toward sustainability. We investigated the applications, contexts, and outcomes of green digital nudges by conducting a systematic literature review of 64 nudge interventions. We found six distinct types of nudges—priming, goal-setting, default, feedback, social reference, and framing—and 18 sustainable target behaviors (e.g., energy conservation). To explain how behavior changes through green nudges, we clustered the identified target behaviors into three behavior change outcomes: (i) altering an existing behavior, (ii) reinforcing an existing behavior, and (iii) forming a new behavior. Based on our findings, we propose guidance for researchers, practitioners, and policymakers who seek to design choice architectures that facilitate pro-environmental behavior.

Keywords: Digital Nudging, Pro-Environmental Behavior, Systematic Review.

Introduction

Since 1988, the United Nations' Intergovernmental Panel on Climate Change (IPCC) has reported regularly on climate change's scientific causes, developments, and consequences. The most recent report paints a dramatic picture: If the current status remains, the climate could warm as much as 1.5 degrees Celsius above pre-industrial levels by 2030 (IPCC, 2022); the report four years earlier estimated that this threshold would not be crossed before 2040 (IPCC, 2018). To avoid the rapidly approaching consequences of climate change, sustainable behaviors must be widely encouraged by governments and organizations, as their steering of collective environmental action will have arguably the most considerable effects on climate outcomes (Chinowsky et al., 2011; Cimato & Mullan, 2010; IPCC, 2014). However, with society's growing concern and the staggering aggregate effects of ignoring the problem (Kachaner et al., 2020), individual pro-environmental behavior has increasingly taken center stage (White et al., 2019). Research shows that a mere 1 percent of electrical energy savings by 10 million households would save 1.2 billion kWh, which translates to around 120 million USD and, more important, 800,000 metric tons of CO_2 (Loock et al., 2013), which is equivalent to the yearly emissions of 150,000 passenger vehicles (EPA, 2005). In private households,

reducing individuals' water consumption (Tiefenbeck et al., 2018, 2019) or heating energy consumption (Beermann et al., 2022) also has significant potential.

The information systems (IS) field has a long history of supporting individuals and organizations in achieving desired outcomes. With the emergence of Green IS as a field of research, the focus has increasingly shifted toward pro-environmental behavior and outcomes, with the goal of using IS to reduce the ecological footprint of individuals and organizations (Corbett, 2013; Watson et al., 2010). Green IS may be able to steer individual behavior in a pro-environmental direction (Shevchuk & Oinas-Kukkonen, 2016) by, for example, using digital nudges, which have proven effective in inducing behavioral change (e.g., Schultz et al., 2016). Digital nudges are, by definition, information technology (IT) artifacts (Mirsch et al., 2018) that make use of user-interface design elements aimed at altering users' behavior (Weinmann et al., 2016). Nudges use psychological mechanisms like loss aversion and social norms to influence human behavior through heuristic decision routes rather than purely rational (Thaler & Sunstein, 2008).

Digital nudges have been successful in various application areas, including health (e.g., Capasso & Umbrello, 2022), electronic commerce (e.g., Dennis et al., 2020; Schneider et al., 2021), and technical debt management (e.g., Haki et al., 2022). However, green nudges are welfarist, as they primarily serve a superordinate societal interest, not necessarily the individual user (Barton & Grüne-Yanoff, 2015). While empirical research on nudges supports the effectiveness of digital nudges in this sphere (e.g., Seidler et al., 2020), individual studies are situated in narrow contexts. Therefore, comparing these interventions, identifying their theoretical underpinnings, and deriving practical design implications at the aggregate level is challenging since target behaviors and decision routes differ. A categorical overview of the types of nudges, decision routes, and target behaviors and outcomes are needed to create targeted research programs and develop interventions and policy instruments. We sought to identify the relationships between green nudges, their application contexts, and their impact on target behavior, as described in the literature, to provide prescriptive guidelines for the successful creation of green nudges. We address the research question: *Which types of nudges have effective outcomes for which categories of target behaviors?*

We used a theoretical framework grounded in the behavior change literature to conduct a systematic review on green digital nudges to classify and cluster types of nudges, target behaviors, and associated outcomes. We analyzed 55 studies that investigated a total of 64 nudges. Most of these digital nudges were applied in energy and water conservation contexts, while others facilitated sustainable consumption. We identified six categories of nudges—priming, goal-setting, default, feedback, social reference, and framing—among which the feedback nudge was applied most often (26 of 64), and the default nudge is the most reliable in demonstrating effectiveness in every application (13/13). Regarding the desired behavior changes (i.e., altering, reinforcing, or forming a behavior), we found that most nudges alter existing unsustainable behavior to a sustainable behavior (26/64). Our findings contribute to research on digital nudging and welfarist decision-making and offer guidance for researchers, policymakers, and organizations in designing effective green nudges.

The remainder of the paper is structured as follows: First, we discuss the theoretical underpinnings of green nudging and the related literature on green nudging and outcomes regarding behavior changes ("behavior change outcomes" hereafter). Then we explain our methodological approach. Next, we delineate the results of the systematic review. Finally, we discuss our findings and contributions, provide practical guidelines for designing green nudges, and highlight the limitations of our study.

Background

Digital nudges are user-interface design elements that aim to alter users' behavior in a predefined way without precluding other options (Weinmann et al., 2016). To this end, nudging draws on psychological effects like loss aversion, framing, or anchoring (Mirsch et al., 2017). Psychological effects are used to trigger users' heuristic and intuitive decision-making (Thaler & Sunstein, 2008) by exploiting or counteracting psychological effects (Enste & Potthoff, 2021). For example, the status quo bias, the tendency to stick with the current state, has been used in default settings to exploit users' reluctance to change (Ebeling & Lotz, 2015). In other settings, nudges counteract the status quo bias by providing relevant decision information regarding the target behavior (Tiefenbeck et al., 2018).

Nudges have a long history of application in online environments to direct user behavior, such as in online commerce (Dennis et al., 2020), rating websites (Schneider et al., 2021), and software development (Haki et al., 2022). As digital nudges can target many behaviors, research on IS for behavioral change has relied on a theoretically grounded categorization (e.g., Lehrer et al., 2021; Rieder et al., 2021; Vlaev et al., 2016) of behavior change outcomes proposed by Oinas-Kukkonen (2013): (i) altering an existing behavior, (ii) reinforcing a familiar behavior, and (iii) forming a new behavior.

Nudges have gained particular traction in the context of pro-environmental behaviors. Scholars have applied them in areas like sustainable consumption (e.g., Amatulli et al., 2019), sustainable transportation (e.g., Kim & Hyun, 2021), waste and resource efficiency (e.g., Degirmenci & Recker, 2018), and energy and water conservation (e.g., Schultz, 2016). For example, in the context of sustainable consumption, Bull (2012) investigated the effect of framing nudges that trigger loss aversion on the willingness to buy sustainable washing machines. Studies have also investigated sustainable food consumption (e.g., Shreedhar & Galizzi, 2021) and grocery purchases (e.g., Berger et al., 2020). Research on sustainable transportation has dealt primarily with reducing fuel consumption (see Sanguinetti et al., 2020) and choosing more sustainable travel options (e.g., Hilton et al., 2014). Regarding waste and resource efficiency, investigations have focused on nudging people to use double-sided printing (e.g., Degirmenci & Recker, 2018) or purchase sustainable packaging (Wensing et al., 2020). In the context of energy conservation, research has focused on the use of electricity (e.g., Bonan et al., 2021), water conservation (e.g., Tiefenbeck et al., 2018), and the charging of electric vehicles (Huber et al., 2019).

What sets green nudges apart from other nudges is their welfarist underpinning (Ölander & Thøgersen, 2014), as they are intended primarily to benefit societal interests (Barton & Grüne-Yanoff, 2015; Hagman et al., 2015). Empirical research on pro-environmental behaviors has shed light on the dramatic misalignment between individuals' intention to engage in climate action and their behaviors (Klöckner, 2013). Therefore, identifying the specific target behaviors and decision routes that green nudges can harness can inform policy-making and intervention design. However, while research on green nudges provides empirical evidence for the effectiveness of individual applications (Zimmermann et al., 2021), most studies lack common ground in describing the target behaviors they use, and the decision routes people take (Shevchuk & Oinas-Kukkonen, 2016). As a result, comparability and accessibility are limited, restricting their power to inform nudge design, future research programs, and policy-making.

Method

To answer our research question, we conducted a structured literature review following Webster and Watson (2002) and Leidner's (2018) review principles. We used the PRISMA statement and adhered to the four phases: identification, screening, eligibility, and inclusion (Moher et al., 2009).

Selection Procedure

In the first phase, we identified studies that are likely relevant to our study. Since digital nudging for pro-environmental behavior is an interdisciplinary research topic involving the IS, psychology, management, and environmental and energy sciences fields, we began with the associated databases. We used the AIS eLibrary (e.g., Basket of Eight and IS conferences) for entries in the IS domain and the databases Ebsco Host Business Source Premier and APA PsyNet to cover the other fields. We combined three search areas with our keywords "digital", "nudging", and "pro-environmental behavior". The items *nudg* OR intervent* OR (behavio* AND change)* were coupled with *digit* OR information system OR technolog** and combined with *environm* OR sustainab* OR green* OR ecology**. The search strings targeted the title, abstract, and keywords of articles in peer-reviewed conference proceedings and journal articles from 2008 and later—due to the emergence of the nudge concept in Thaler and Sunstein's (2008) seminal book *Nudge: Improving Decisions about Health, Wealth, and Happiness*.

In the second phase, we screened the 2,511 search entries (255 from AIS eLibrary, 1,021 from Business Sources Premier, 1,235 from PsychNet). The screening process revealed several reviews that synthesized the literature on green nudging and neighboring themes (Byerly et al., 2018; Caraban et al., 2019; Henkel et al., 2019; Lehner et al., 2016; Mirsch et al., 2017; Soomro et al., 2021; Zimmermann et al., 2021). We added 507 articles from the reviews to our funnel. After removing 87 duplicates, we screened the titles, keywords, and abstracts of the remaining 2,931 papers for a fit for our review (i.e., empirical studies on green digital nudges). We selected 174 entries for the final assessment of eligibility.

In the third phase, we checked the papers further for eligibility by screening their full texts for compliance with our inclusion criterion of original research articles testing one or more *digital* nudges empirically in an experimental setting (i.e., between or within-subject design). For example, we excluded empirical studies that did not test a digital artifact, such as Ferraro and Price (2013), who sent physical letters. To ensure sufficient statistical power, we also excluded studies that had fewer than 30 participants per condition (e.g., Nilsson et al., 2014), studies that were not following the definition of nudges as "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler & Sunstein, 2008, p. 8), and one study that offered financial incentives (Tsirimpa et al., 2019). We also focused on individual behavior rather than team or organizational observations.

In the fourth phase, we selected 51 papers that complied with our inclusion criteria. Forward and backward searches (Webster & Watson, 2002) yielded four additional studies, resulting in 55 papers.

Analysis and Framework

We analyzed the studies according to their contexts, target behaviors, and types of nudges. We categorized the studies' contexts in terms of their experimental setting (i.e., online, laboratory, field) and area of application (i.e., energy and water conservation, (food) consumption, transportation, or waste and resource efficiency). The literature describes nudges by the psychological mechanism they employ (Mirsch et al., 2017) and/or the type of nudge (Sunstein, 2014). Since the IS discipline focuses on IT artifacts, we structured our analysis according to the types of digital nudges mentioned in each study. If the psychological mechanism was mentioned solely, we inferred the type of digital nudge from the mechanism. When distinct nudges were tested in one study (e.g., two experimental conditions, one testing a default and the other a priming nudge), we categorized and evaluated the effect of each nudge separately. We summarized the findings under one nudge in studies that tested different characteristics using the same mechanism (e.g., ecological, financial, and health-related framing nudges). A coding example is provided in Table 1.

Analysis Element	Category	Example: Loock et al. (2013)
Context	Title	Motivating energy-efficient behavior with green IS: an investigation of goal setting and the role of defaults
	Outlet	*MIS Quarterly*
	Setting	Field experiment with private households on a web portal
	Domain	Energy conservation
Target behaviors	Target outcome[1]	Electrical energy consumption
	Target behavior	For example, switching off appliances (no stand-by)
	Change outcome	Altering
Types of digital Nudges	Goal-setting	Results: Default goals led to significant savings. Default goals that were too low (0%) or too high (30%) had detrimental effects. Feedback on goal attainment moderated the default goal's effect on goal choice.
	Default	
	Feedback	

Table 1. Sample Analysis of Context, Target Behavior, and Type of Digital Nudge.

We build on psychological theories about the constructs that influence decision-making (e.g., Cialdini & Goldstein, 2004) and prior nudge taxonomies (Jesse & Janach, 2021; Münscher et al., 2016; Sunstein, 2014) to derive the types of nudges and clusters thereof. For example, Sunstein (2014) summarizes ten important nudges such as default rules, social norms, or precommitment strategies. Münscher et al. (2016) proposed a nudge taxonomy with decision (i) information (e.g., feedback), (ii) structure (e.g., choice

[1] The target outcome is the dependent variable and is closely associated with the target behavior.

defaults), and (iii) assistance (e.g., commitments). Based on the literature, we constructed the clusters with the goal of cohesion within and distinctiveness between the types of nudges.

Moreover, nudge effectiveness was assessed in three categories: First, a nudge was effective when the intervention produced a significant result (e.g., Loock et al., 2013). Second, a nudge was ineffective when the nudge intervention yielded a null result (e.g., Lieberoth et al., 2018). Third, a nudge produced "mixed" outcomes when contrary results in two or more assessments were found (e.g., Doran et al., 2017) or when significant results were obtained for a subpopulation only (e.g., Bonan et al., 2021).

As part of our analysis, we assessed the target behaviors and mapped them to the behavior change outcomes (Fogg & Euchner, 2019; Oinas-Kukkonen, 2013), which describe, for example, whether an existing behavior is altered or reinforced or whether a behavior is newly formed. The studies did not assess longitudinal data of the target behaviors. We, therefore, coded estimates about the population (e.g., whether most participants were using energy unsustainably or unsustainably) according to the definitions of each behavior change outcome (Table 2). Four target behaviors from 24 studies were classified as *altering* existing behaviors, such as electrical energy conservation (e.g., Loock et al., 2013) or eco-driving (Dahlinger, Wortmann, et al., 2018). Another four target behaviors from 15 studies focused on *reinforcing* familiar sustainable behaviors like purchasing sustainable products such as rechargeable and eco-friendly batteries (e.g., Amatulli et al., 2019) or groceries (e.g., Berger et al., 2020). Finally, ten target behaviors from 16 studies investigated green nudges aimed at *forming* a novel behavior, for example, choosing a green energy program (e.g., Hedlin & Sunstein, 2016) or switching to e-banking (e.g., Theotokis & Manganari, 2015).

Behavior Change	Definition	Coding Examples	PU	PS
Altering	An existing unsustainable behavior is changed to a pro-environmental form.	• Inefficient energy use is a common behavior (→ *Energy conservation*) • Inefficient driving is a common behavior (→ *Lowering fuel consumption*)	√	
Reinforcing	A familiar PEB is strengthened.	• *Choosing a vegetarian dish* is a common behavior • *Printing double-sided* is common behavior		√
Forming	A novel PEB is established.	• *Choosing a green energy program* is an uncommon behavior • *Purchasing a sustainable premium product* is an uncommon behavior		

Note: *Pro-Environmental Target Behaviors* are highlighted in italics, PU = Prior Unsustainable Behavior, PS = Prior Sustainable Behavior, √ = Coding of whether PU or PS is common.

Table 2. Coding of Pro-Environmental Behavior (PEB) to Behavior Change Outcomes.

Results

The first part is a general overview of the contexts, target behaviors, and types of digital nudges, while the second part provides insights into each behavior change outcome (i.e., altering, reinforcing, and forming).

Application Domains, Target Behaviors, and Types of Nudges

Application Domains and Target Behaviors

34 of the 55 studies were published in 2018 or later, with ten studies in each 2019 and 2021. 17 studies were published in IS outlets, with 16 published in the proceedings of IS conferences and one in *MIS Quarterly* (Loock et al., 2013). 14 of the 55 studies were published in management and economic journals (including those with specializations in tourism, marketing, and environment). One study was published in *Management Science* (Tiefenbeck et al., 2018), while ten papers were published in energy journals (e.g., *Nature Energy*), eight in journals that focus on environmental sciences (e.g., *Nature Climate Change*), and seven in psychological journals. 26 of the studies were placed in a field experiment, while 24 used a controlled online environment, and five were conducted in a laboratory setting.

Regarding the target behaviors, of the 55 studies, 28 investigated green nudges in the domain of energy and water conservation to facilitate (i) electrical energy conservation, (ii) heating energy conservation, (iii) water conservation, (iv) choosing a green energy program, (v) joining a smart grid, (vi) downloading an energy report, and (vii) increasing charging flexibility. 12 papers investigated food and general consumption for (i) purchasing sustainable products, (ii) purchasing sustainable premium products, and (iii) choosing sustainable dishes. Eight studies focused on transportation and sustainable mobility to (i) lower fuel consumption while driving, (ii) use sustainable transportation, (iii) pay for carbon offsets, and (iv) save emission certificates. Seven studies focused on waste and resource efficiency with (i) printing double-sided, (ii) using a sustainable search engine, (iii) donating for tree planting, and (iv) switching to e-banking.

Types of Digital Nudges

Table 3 displays the six types of nudges we extracted from 64 interventions by providing examples from the review, the rationale underlying the type of nudge, and the effectiveness of their solo, combined, and overall (solo + combined) applications. The types of nudges we found in our review can be summarized into those that (i) structure the digital choice environment (i.e., defaults), those that (ii) signal non-personal or context information (i.e., priming, framing, social references), and those that (iii) provide personal information or assistance (i.e., feedback, goal-setting).

Defaults were the go-to nudge to structure a choice environment successfully—all 13 applications were effective in facilitating pro-environmental behavior, of which ten were applied solo (e.g., Ebeling & Lotz, 2015; Henkel et al., 2019) and three combined (e.g., together with social references; Jesse et al., 2021).

Type of Nudge	**Example**	**Rationale**	**Effective Nudge / Total**		
			Solo	**Comb**	**All**
Structuring of the Digital Choice Environment toward Pro-Environmental Behavior (PEB)					
Default	Pre-selection of the green energy program (Hedlin & Sunstein, 2016)	Defaults are preselected PEB options that provide structure for making a decision.	10/10	3/3	13/13
Presentation of Non-Personal or Context Decision Information toward PEB					
Priming	Multimedia cartoons to purchase premium sustainable products (Bimonte et al., 2020)	Primes are stimuli that activate associations regarding the PEB.	0/2	1/3	1/5
Framing	Financial, ecological, or health benefits of choosing a vegetarian dish (Krpan & Houtsma, 2020)	Framings highlight specific aspects of the PEB.	8/12	5/7	13/19
Social Reference	Cues related to others' behavior to reduce heating energy consumption (Kroll et al., 2019)	Social references orient toward other peoples' (i.e., the majority) PEB.	1/5	11/15	12/20
Presentation of Personal Information or Providing Decision Assistance toward PEB					
Goal-Setting	Commitment to reduce heating energy consumption (Wendt et al., 2021)	Goals are commitments to achieve a desirable personal PEB in the future.	1/2	4/7	5/9
Feedback	Display of personal consumption to reduce electrical energy (Grønhøj & Thøgersen, 2011)	Feedback causes reflection about personal PEB.	9/9	13/17	22/26

Table 3. Sample Analysis of Context, Target Behavior, and Type of Digital Nudge.

Non-personal or context information such as social references (comparing to a behavior most people engage in) or framings (highlighting specific information such as losses) was among the most prominent nudges in this category. In total, more than half of the social reference nudges were effective. Social references were combined with other nudge types, of which most combined nudges showed significant effects (e.g., Graml et al., 2011; Seidler et al., 2020). While social norms were more likely combined with other nudges, framings were instead applied solo (e.g., Ghesla et al., 2020; Chang et al., 2015). Since labels (e.g., Demarque et al., 2015; Bull, 2012) and decoys (Momsen & Stoerk, 2014) are tools to reframe information, we counted them as framing techniques. Priming was not often tested; out of five applications, one was successful (in combination with a framing nudge; Bimonte et al., 2020).

Personal information to give decision assistance toward pro-environmental behavior was facilitated through goal-setting and the provision of feedback. Most goal-setting nudges were effective, most of which were combined with other nudges. Goal-setting was applied successfully with a default and feedback nudge (Graml et al., 2011; Loock et al., 2013) and social references (Myers & Souza, 2020; Wendt et al., 2021). Out of all nudges, feedback was the most used nudge with 26 applications, of which the vast majority of nudges were effective. All nine solo applications for feedback nudges were effective, and most feedback nudges showed a significant effect when combined with other nudges. Warnings (e.g., feedback on carbon emission overconsumption) counted as a feedback instrument and were included in this cluster (Wyss et al., 2021).

Green Nudges Facilitate Distinct Behavior Change Outcomes

Green Nudges to Alter Existing Behaviors

24 studies we reviewed sought to alter a target behavior by replacing an existing behavior with a more sustainable one (Table 4). Most of these studies focused on target behaviors related to electrical energy conservation (e.g., Bonan et al., 2021). Close to electrical conservation is the target behaviors of heating energy conservation (e.g., Wendt et al., 2021) and water conservation (e.g., Schultz et al., 2016), as all three categories focus on energy and resource conservation in a household setting. The studies used actual consumption data (e.g., Schultz et al., 2016) or aimed to approximate consumption utilizing a questionnaire (e.g., Wendt et al., 2021).

The sets of behaviors entail a variety of actions by which the goal of decreasing consumption can be achieved. For example, lower heating energy consumption may be performed by lowering the thermostat or opening or shutting the windows and doors. It was a common practice to give participants conservation tips and provide concrete calls to action (Loock et al., 2013). However, studies that focused outside the domain of energy and water conservation primarily addressed sustainable mobility and feedback mechanisms to lower fuel consumption (e.g., Graham, 2011). Two studies coupled consumption feedback with abstract vs. concrete frames (Dahlinger, Wortmann, et al., 2018) and numerical vs. symbolic frames (Dahlinger, Tiefenbeck, et al., 2018). For example, the symbolic feedback decreased driving fuel consumption by 2-3 percent, while numerical feedback did not (Dahlinger, Tiefenbeck, et al., 2018).

The personal feedback mechanism was the most prominent type of nudge for altering existing behaviors. Studies transmitted feedback nudges for energy and water consumption via interactive posters (Agha-Hossein et al., 2015), in-home displays (Aydin et al., 2018; Grønhøj & Thøgersen, 2011, Tiefenbeck et al., 2018, 2019), home energy reports (Bonan et al., 2021), questionnaires (Brandsma & Blasch, 2019 on conservation behavior; Buchan & Russo, 2019 on electrical appliances), web interfaces (Emeakaroha et al., 2014; Graml et al., 2011; Loock et al., 2013; Lossin et al., 2016), mobile apps (Kroll et al., 2019; Wemyss et al., 2019), or e-mail (Klege et al., 2022; Myers & Souza, 2020; Schultz et al., 2016). All eight solo feedback nudges were effective, while eight of the 11 feedback nudges combined with other types of nudges (predominantly social references) were effective. For example, in a scenario-based hotel setting, a social feedback nudge from a virtual assistant increased intentions to conserve water and energy (Tussyadiah & Miller, 2019). In such environments, the presence of agents led to normative behavior. In contrast, a social feedback nudge in the form of weekly energy reports did not impact the conservation behavior of students who had no financial incentive since their rent covered their energy use (Buchanan & Russo, 2019).

Another type of nudge for altering behavior is goal-setting. In five of the studies in which it was used, goal-setting nudges demonstrated effectiveness for lowering in-home energy consumption (electricity and heating). For example, combining a goal-setting nudge with a social reference nudge led to a significant

increase in efficient heating behavior (Wendt et al., 2021), and combining goal-setting, feedback, and default nudges, particularly medium-level default conservation goals (Loock et al., 2013), decreased energy consumption. Compared to a self-set goal, default goals set too low (0%) or too high (30%) had detrimental effects on conservation behavior; a realistic goal of 15 percent provided the best results (Loock et al., 2013).

Target Behavior	Publication	Default	Priming	Framing	Social Ref.	Goal Set.	Feedback
Conserving electrical energy	Agha-Hossein et al. (2015)						√
	Aydin et al. (2018)						√
	Bonan et al. (2021)		~		~		
	Brandsma & Blasch (2019)			~		~	~
	Buchanan & Russo (2019)			x	x		x
	Emeakaroha et al. (2014)						√
	Ghesla et al. (2020)			√			
	Graml et al. (2011)	√			√	√	√
	Grønhøj & Thøgersen (2011)						√
	Lossin et al. (2016)						√
	Loock et al. (2013)	√				√	√
	Staples et al. (2017)					√	
	Tussyadiah & Miller (2019)				√		√
	Wemyss et al. (2019)				√		√
	Klege et al. (2022)				√		√
Conserving heating energy	Kroll et al. (2019) 1/3				√	√	
	Kroll et al. (2019) 2/3					x	
	Kroll et al. (2019) 3/3				x		
	Myers & Souza (2020)				x		x
	Wendt et al. (2021)				√	√	
Conserving water	Schultz et al. (2016)				√		√
	Tiefenbeck et al. (2018)						√
	Tiefenbeck et al. (2019)						√
Lowering fuel consumption from driving	Dahlinger, Tiefenbeck, et al. (2018)			√			√
	Dahlinger, Wortmann, et al. (2018)			√			√
	Graham et al. (2011)						√
Effective solo applications / Total		0/0	0/0	1/1	0/1	1/2	8/8
Effective combined applications / Total		2/2	0/1	2/4	7/10	4/6	8/11
Effective green nudges / Total		2/2	0/1	3/5	7/11	5/8	16/19

Note: √ = effective, x = ineffective, ~ = mixed results.

Table 4. Effectiveness of Green Nudges for Altering Behavior.

Green Nudges to Reinforce Existing Behaviors

15 of the 55 studies we analyzed investigated nudges' effectiveness in reinforcing existing pro-environmental behaviors (Table 5). The most common target behaviors focused on familiar behaviors, such as choosing a vegetarian dish (e.g., Jesse et al., 2021), choosing sustainable products (e.g., Taube & Vetter, 2019), or groceries (e.g., Berger et al., 2021). Other target behaviors included double-sided printing to reduce waste and using sustainable transportation.

Reinforcing consumption of sustainable products and food was frequently induced with framing and social reference nudges. Framing nudges were used in four solo applications, two of which produced mixed results (Berger et al., 2020; Wensing et al., 2020). For example, framing in the form of simplification had a significant effect only on environmentally conscious participants in an online grocery shopping environment (Berger et al., 2020). In four studies, negatively framed messages were more effective than their positively framed counterparts, and this effect was moderated by guilt, an emotional reaction after the nudge (Amatulli et al., 2019). Besides frames, social references like stated norms influenced pro-

environmental choices in two experiments. In an online shopping environment that tested eco-labeled product purchases, a strong social norm ("For your information, 70% of previous participants purchased at least one ecological product") proved to be effective (Demarque et al., 2015).

Double-sided printing to reduce resource consumption was achieved by setting the default option from duplex to simplex, which reduced paper consumption by 15 percent (Egebark & Ekström, 2016). A significant reduction in the number of print jobs was also achieved through information democratization (i.e., exchanges in an online forum) and reflective disclosure (i.e., a weekly report of printed pages compared to peer averages; Degirmenci & Recker, 2018).

A combination of priming, goal-setting and social reference nudges that attempted to persuade people who use their cars to commute to switch to public transportation were ineffective (Lieberoth et al., 2018). Doran et al. (2017) combined social references and feedback nudges in an online experiment to influence travel choice and found mixed results. In the same study, participants who received feedback that their ecological footprints were more extensive than the norm for their peer group showed stronger pro-environmental intentions than participants who received congruent feedback. However, the authors did not replicate these results in a second experiment. Even so, framing by indicating that environmentally friendly modes of transport were subsidized while presenting less sustainable options as taxed produced a significant effect in favor of train travel over plane travel (Hilton et al., 2014).

Target Behavior	Publication	Default	Priming	Framing	Social Ref.	Goal Set.	Feedback
Purchasing sustainable product(s)	Amatulli et al. (2019)			√			
	Berger et al. (2020) 1/3	√					
	Berger et al. (2020) 2/3			~			
	Berger et al. (2020) 3/3				x		
	Chang et al. (2015)			√			
	Demarque et al. (2015)				√		
	Sutanto et al. (2021)			√			√
	Taube & Vetter (2019)	√					
	Wensing et al. (2020)			~			
Choosing a sustainable dish	Jesse et al. (2021)	√			√		
	Shreedhar & Galizzi (2021)			√			
	Vogelaar & Priante (2021)				x		
Printing double-sided	Degirmenci & Recker (2018)				√		√
	Egebark & Ekström (2016)	√					
Using sustainable transportation	Doran et al. (2017)				~		~
	Hilton et al. (2014)			√			
	Lieberoth et al. (2018)		x		x	x	
Effective solo applications / Total		3/3	0/0	4/5	1/3	0/0	0/0
Effective combined applications / Total		1/1	0/1	1/1	2/3	0/1	2/3
Effective green nudges / Total		4/4	0/1	5/6	3/6	0/1	2/3

Note: √ = effective, x = ineffective, ~ = mixed results.

Table 5. Effectiveness of Green Nudges for Reinforcing Behavior.

Green Nudges to Form New Target Behaviors

16 of the 55 studies we analyzed tested green nudges to facilitate the formation of new but uncommon target behaviors (Table 6). Such behaviors are rarely executed (e.g., downloading an annual energy report or purchasing a premium sustainable product), are once-off behaviors (e.g., switching to e-banking, choosing a green energy program, or joining the smart grid), or predominantly occur for the first time (e.g., using a sustainable search engine or paying for carbon offsets). The formation of such behaviors was achieved predominantly through default and framing nudges.

The default nudge was often used to form target behaviors (e.g., Ebeling & Lotz, 2015). Among the four types of nudges, the default nudge was the only intervention that led participants to contract with a green

energy program (Momsen & Stoerk, 2014). Moreover, the default nudge successfully persuaded participants to use a sustainable search engine in a laboratory experiment, while the priming condition was not (Henkel et al., 2019). Another study manipulated the choice to pay a carbon offset with a default option and found that the amount of compensation paid correlated with the proposed default (Székely et al., 2016). A numerical default served as an anchor, which influenced participants' bids.

Framing nudges were the most frequently deployed type of nudge for forming these target behaviors (8/24). In an online experiment, framed scenarios (i.e., focusing on cost, social, or environmental aspects) did not change participants' flexibility regarding charging electric cars; Huber et al., 2019). However, frames that highlighted emissions as losses rather than gains yielded a significant increase in willingness to purchase more expensive, more sustainable washing machines by disclosing emissions from the appliance over its lifecycle (Bull, 2012). The findings support the view that loss aversion is an effective element of framing because only the loss-framed ecological prime increased the probability that a participant would purchase a premium sustainable product; the gain frame did not yield such results (Bimonte et al., 2020).

Target Behavior	Publication	Default	Priming	Framing	Social Ref.	Goal Set.	Feedback
Choosing a green energy program	Ebeling & Lotz (2015)	√					
	Hedlin & Sunstein (2016)	√					
	Momsen & Stoerk (2014) 1/4		x				
	Momsen & Stoerk (2014) 2/4	√					
	Momsen & Stoerk (2014) 3/4				x		
	Momsen & Stoerk (2014) 4/4			x			
Using a sustainable search engine	Henkel et al. (2019) 1/2	√					
	Henkel et al. (2019) 2/2		x				
	Seidler et al. (2020) 1/2			√			√
	Seidler et al. (2020) 2/2				√		√
Paying for carbon offsets	Kim & Hyun (2021)			x			
	Krpan & Houtsma (2020)			√			
	Székely et al. (2016)	√					
Purchasing a premium sustainable product	Bimonte et al. (2020)		√	√			
	Bull (2012)			√			
Joining a smart grid	Broman Toft et al. (2014)	√					
Downloading an energy report	Rosenkranz et al. (2017)			√			
Increasing charging flexibility	Huber et al. (2019)			~			
Donating for tree planting	Staudt et al. (2021)				√		√
Saving emission certificates	Wyss et al. (2021)						√
Switching to e-banking	Theotokis & Manganari (2015)	√					
Effective solo applications / Total		7/7	0/2	3/6	0/1	0/0	1/1
Effective combined applications / Total		0/0	1/1	2/2	2/2	0/0	3/3
Effective green nudges / Total		7/7	1/3	5/8	2/3	0/0	4/4

Note: √ = effective, x = ineffective, ~ = mixed results.

Table 6. Effectiveness of Green Nudges for Forming a Target Behavior.

Discussion

Our research set out to outline the directions of digital nudging research in the realm of pro-environmental behavior. Our systematic review and categorization of the empirical literature yielded three classes of behavior change outcomes that can be achieved using green nudges: altering existing behaviors, reinforcing existing behaviors, and forming new behaviors. We found that different types and combinations of nudges and that combinations of these types of nudges versus solo applications are especially prevalent and suitable for bringing about effective changes in pro-environmental behaviors. For example, while feedback and social reference nudges (often in combination) were highly successful in altering existing behaviors, new target behaviors were more likely to be formed using default nudges as a solo artifact.

While the specific target behaviors were set in various contexts (e.g., enhancing the efficiency of printing in a university context; Degirmenci & Recker, 2018, paying carbon offsets for air travel; Székely et al., 2016, and conserving water in a residential setting; Schultz et al., 2016), most nudges were tested for resource conservation (e.g., electricity; e.g., Loock et al., 2013) and sustainable alternatives (e.g., consumption, modes of transportation; e.g., Krpan & Houtsma, 2020). We provide a unified overview of green target behaviors that can be achieved using digital nudges, but contexts still require adaption (Mirsch et al., 2018).

We derived six types of nudges from the literature we reviewed to provide a consistent reference. The types of nudges we identified were priming, goal-setting, default, feedback, social reference, and framing. The literature has followed various approaches in describing nudge interventions, as some authors focused on the actual artifact deployed to targeted individuals (Sunstein, 2014), while others focused on the psychological mechanisms and effects harnessed by the nudge artifact (e.g., Mirsch et al., 2017), and still others used both concepts (e.g., Lehner et al., 2016). We decided to focus on the artifact (i.e., types of nudges) instead of the psychological mechanism because nudge artifacts hold encoded design information that makes imitating nudge applications more straightforward—while psychological mechanisms do not store this information. For instance, the status quo bias can be harnessed as a default nudge (e.g., Hedlin & Sunstein, 2016) or counteracted with a feedback nudge (e.g., Tiefenbeck et al., 2019).

Our findings indicate that individual applications of the nudges we identified were just as prominent as combined applications. Some nudges seem predestined to function as vessels for additional nudges to trigger heuristic decision-making. The feedback and goal-setting nudges were often combined with social reference nudges, while framing and default nudges tended to be used individually. Socially normative content was a recurring theme in the literature we reviewed and was used in various target behaviors and combination with other types of nudges. Since pro-environmental action is considered welfarist pro-social behavior (Barton & Grüne-Yanoff, 2015), social reference nudges can motivate individuals to conform to societal standards or follow socially acceptable behaviors (Cialdini & Goldstein, 2004). However, our findings also indicate that the effectiveness of social reference nudges in reinforcing behaviors can vary greatly: While some studies have shown promising effects (e.g., Demarque et al., 2015), others did not (e.g., Berger et al., 2020). Demarque et al. (2015) translated social references into concrete messages like "For your information, 70% of previous participants purchased at least one ecological product" (p. 169), while Berger et al. (2020) used banners indicating that a product was "popular" or that "more and more customers choose this sustainable product" (p. 6). The effectiveness of Demarque et al.'s (2015) nudges could be due to their social references being built on successful psychological studies in the domain of PEB (e.g., Nolan et al., 2008) and providing concrete quantifiers for the group behavior (i.e., 70%). Therefore, the social cues in Berger et al. (2020) may have been too abstract. However, the authors suggested that their social reference nudge had no effect because social references are especially effective in high uncertainty, which online grocery shopping is not.

Implications for Research

Our synthesis of the literature on digital nudging for pro-environmental behaviors reveals several avenues for follow-up research, two of which are particularly promising for advancing research in this area. First, our review highlights that some nudges have been widely applied in studies (e.g., default, social reference). In contrast, other types of nudges were less frequently used (e.g., priming) or not experimented with at all (e.g., reminders). For a more holistic picture of how to nudge pro-environmental behaviors, scholarship could apply less popular types of nudges and psychological mechanisms and test their effectiveness empirically. Second, our review indicates that nudges can be used successfully as solo applications and in combination with other types of nudges. However, we lack insight into why this is the case and would benefit from foundational research on what distinguishes the heuristic decision routes triggered by solo versus combined nudges. Research in this area will help to advance research on decision-making and digital nudging research by providing guidelines and rules regarding the circumstances under which each design should be chosen.

Synthesizing and comparing empirical research on green nudging proves difficult, as it lacks unified reporting and structuring. As the ambition to contribute to solving the global climate crisis becomes more pervasive, empirical findings on green nudges can inform policy-making if the results are universally accessible and applicable. The dimensions on which we based our categorizations of green digital nudges will help scholars in the field report their nudge applications in a unified manner if they adhere to five

guidelines. First, scholars should describe the *target behavior* they seek to address and elaborate on individuals' inclination (e.g., motivation and ability; cf. Fogg, 2009) to perform the target behavior, which may entail categorizing it about previous behavioral sequences. For example, scholars might use Oinas-Kukkonen's (2013) classifications of behavior change outcomes, which we used as our analytical framework in this review. Second, scholars should outline their *application context*, including the domain, the study's setting, and idiosyncrasies. For example, nudges for saving heating energy might follow different routes for low-income households, luxury hotel residents, and employees in an office building. Third, scholars should indicate the *psychological mechanisms* (e.g., status quo bias, hyperbolic discounting, anchoring) that underlie their nudge interventions and the direction in which the nudge seeks to harness the mechanism (i.e., exploiting or counteracting the psychological mechanism). Fourth, scholars should classify the specific *nudge artifact* they use in their intervention to reveal the design of the interventions they developed to induce the target behavior, perhaps drawing on the non-comprehensive list of types of nudges (e.g., default, feedback, social reference) provided in this review. Finally, disclosing the *design process* as part of the research approach helps to make nudges imitable so larger audiences can benefit from their effects. While some papers undertake sound practices in disclosing the design process (e.g., Beermann et al., 2022; Haki et al., 2022), most of the empirical literature remains opaque, mainly in terms of their design choices and methods.

Designing Effective Green Nudges

Besides providing a clear, unified overview of the green nudging literature, we seek to offer empirically informed design guidance for choice architects. While the application of digital nudges in the realm of pro-environmental behavior has virtually no limit, and we encourage creativity in the development process and context-sensitive adaptations (cf. Mirsch et al., 2018), practitioners and researchers who are designing nudges can benefit from our synthesis of the knowledge gained from this literature review into practical choice guidelines. Using the framework in Table 7, which is based on empirically successful applications of digital green nudges, choice architects can start from the concrete target behavior, which they can categorize after the behavior change outcome (i.e., altering, reinforcing, forming), to deduce the most promising types of nudges and combination options and, thus, streamline their efforts.

Behavior Change	Effective Types of Nudges	Combination Options
Altering an existing behavior (mainly resource conservation)	• Feedback • Social reference	• Feedback and social reference • Goal-setting and social reference
Reinforcing an existing behavior (mainly choosing sustainable alternatives)	• Default • Framing • Social reference (results vary)	• None
Forming a new behavior (new, uncommon behaviors)	• Default • Framing • Feedback	• None

Table 7. Designing Effective Green Nudges.

Our findings indicate that digital nudges for pro-environmental action are incredibly successful in resource conservation (e.g., electricity, water, fuel) and the choice of sustainable alternatives (e.g., consumption, transportation modes). Extant studies typically achieved resource conservation by altering existing behaviors, such as causing participants to take shorter showers and optimizing heating and electrical consumption. Choices of sustainable alternatives in these studies were typically achieved by reinforcing existing behaviors. For example, participants who were doing familiar behaviors like grocery shopping were nudged to select a sustainable alternative over a less sustainable option. The same approach was applied in choosing a mode of transport, although with ambiguous results. Arguably, the less long-lasting and the more reversible the choice, the more likely individuals were to follow a nudge to choose the sustainable alternative (Gao et al., 2019).

Table 7 shows the tendencies we identified in our review of the literature on green nudges. Among these tendencies, the table indicates that choice architects who seek to *alter* users' existing behaviors should consider employing feedback and social reference nudges, as they proved highly effective in the literature we reviewed. We also recommend combining social reference nudges with feedback or goal-setting nudges.

On the other hand, choice architects who seek to *reinforce* users' existing behaviors consider employing default and framing nudges. At the same time, social reference nudges can also be highly effective in reinforcing behaviors, but their effects (and effectiveness) vary. We recommend solo applications of these types of nudges. Finally, choice architects who seek to *form* novel behaviors with users should consider employing default, framing, and feedback nudges in solo applications.

Limitations and Future Research

We set out to answer the research question concerning which types of digital nudges can facilitate pro-environmental behavior. By analyzing the current empirical literature through the theoretical lens of behavior change outcomes, we sought to develop insights regarding the application contexts and effects of green nudges. While most studies have used feedback nudges to alter behavior in the context of energy conservation, we found that other contexts, such as waste and resource efficiency, and different types of nudges, such as priming, have not been as widely investigated. From our literature analysis, we inferred practical guidelines for designing successful green nudges, thus equipping choice architects with the means to address the time-pressing challenge of climate change using nudges.

Like all studies, our research is subject to limitations. First, as we limited the scope of the review to a specific timeframe and a narrow definition of digital nudging and pro-environmental behavior, our study is not exhaustive. Second, we applied the theoretical framework of behavior change outcomes to structure our analysis, limiting our insights to this framework's boundaries. Third, the studies we analyzed did not provide longitudinal data about their participants' target behavior. We based the behavior change outcomes on estimates of the study population, introducing fuzziness into the categorizations. Future studies should assess how participants have related to the target behavior in the past so that insights regarding the behavior change outcomes can be generated empirically. Moreover, we require more longitudinal investigations of nudges. To support behavior change, digital choice designers need to know (i) how often nudge interventions need to be applied for a given effect and (ii) how long the behavior change will persist after the intervention. Fourth, we assessed the effectiveness of the nudges despite varying sample sizes, intervention types, and contexts in the studies we analyzed. However, we set the inclusion criteria to aim for generalizability (e.g., empirical studies with control groups, sample size larger than 30). Future studies could investigate green nudges with a quantitative meta-analysis approach to identify the effect sizes of green nudge outcomes. Fifth, our results may suffer from publication bias, as published work describes only effective interventions, not ineffective ones, which distorts the holistic evaluation of green nudges. Given the global relevance of the climate crisis, the research community would benefit from knowing about *unsuccessful* nudging applications so we can learn from failed attempts.

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