

A meta-analytic cognitive framework of nudge and sludge

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Abstract

Public and private institutions worldwide have gained considerable traction in developing interventions to alter people's behaviors in predictable ways without limiting the freedom of choice or significantly changing the incentive structure. A nudge is designed to facilitate actions by minimizing friction, while a sludge is an intervention that inhibits actions by increasing friction. While the terms nudge and sludge have garnered significant attention, the underlying cognitive mechanisms behind these interventions remain largely unknown. Here, we develop a novel cognitive framework by organizing these interventions along six cognitive processes: attention, perception, memory, effort, intrinsic motivation, and extrinsic motivation. In addition, we conduct a meta-analysis of field experiments (i.e., randomized controlled trials) that contained real behavioral measures ($n=188$ papers, $k=188$ observations, $N=2,209,334$ participants) from 2008 to 2021 to examine the effect size of these interventions targeting each cognitive process. Our findings demonstrate that interventions that change effort are more effective than interventions that change intrinsic motivation to alter behaviors. Nudge and sludge interventions had similar effect sizes. This new meta-analytic framework provides cognitive principles for organizing nudge and sludge with corresponding behavioral impacts. The insights gained from this framework help inform the design and development of future interventions based on cognitive insights.

Keywords: nudge, sludge, meta-analysis, cognition, behavior change

Introduction

Behavior change approaches have been extensively explored and tested in both public and private sectors that involve human choices. Traditionally, governments implement laws, regulations, taxes, or financial subsidies to promote or inhibit citizens' behaviors to achieve desirable outcomes. These interventions are considered as "hard" paternalism given that they aggressively restrict people's freedom to choose. Although these paternalistic interventions are useful, many theorists have criticized them for violating people's autonomy. To address this concern, Sunstein and Thaler (2003) introduced the concept of libertarian or "soft" paternalism that allows planners to affect people's behaviors in a way that increases people's welfare while respecting their freedom of choice. Furthermore, they introduced the term 'nudge' which was defined as a change in the choice architecture (i.e., the context in which choices are presented to people) that alters people's behaviors without limiting the freedom to choose or significantly changing the incentive structure (Thaler & Sunstein, 2008).

Since the introduction of nudge, choice architects from public and private institutions have gained considerable traction in developing and testing nudges to facilitate actions. More recently, several scholars have introduced another term, sludge, to refer to situations where the context impedes behavior by increasing friction (Soman et al., 2019; Sunstein, 2019; Thaler, 2018). The theoretical origins of nudge and sludge are rooted in the field theory proposed by Kurt Lewin (1939) which suggests that behaviors are facilitated by driving forces that help people make progress toward a goal, but are hindered by restraining forces. As such, here we define *nudge* as an intervention that facilitates actions by reducing friction, while *sludge* is defined as an intervention that impedes actions by increasing friction.

An important feature of nudge and sludge is that interventions facilitating or impeding actions can help or harm consumers (Soman et al., 2019; Sunstein, 2019). For example, automatically enrolling employees into a pension plan helps them by facilitating the action of saving for retirement and presenting an “Are you sure?” warning message helps consumers by impeding the action of making an impulse purchase. On the other hand, automatically subscribing to a magazine harms consumers by facilitating the action of paying for unnecessary fees and filling out complex forms harms consumers by deterring them from getting a rebate.

As most practitioners are interested in solving real-world problems with limited resources, they tend to prioritize the process of identifying effective interventions over understanding why an intervention works or fails (Osman et al., 2020). Consequently, little research has explored the psychological mechanisms underlying these interventions. Moreover, there are no systematic comparisons of the effectiveness of nudge and sludge under a common framework. To address these knowledge gaps, we propose a new cognitive framework categorizes interventions that facilitate or impede actions based on six key cognitive processes. In addition, we conduct a meta-analysis to examine the effect size of the interventions targeting each cognitive process, with the goal of identifying which intervention is the most effective.

A cognitive framework

Our cognitive framework is organized along three dimensions: The first dimension is the type of intervention (facilitating vs. impeding actions); the second is whether the intervention helps or harms the consumers; and the third dimension is the cognitive processes involved in eliciting the desired behavior change intended by the intervention (see Table 1 for definitions of cognitive processes and a list of common interventions).

Table 1: Definitions of the six cognitive processes and common interventions that help or harm consumers by facilitating or impeding actions.

Cognitive Process (definition)	Helps Consumers		Harms Consumers	
	Facilitate Actions	Impede Actions	Facilitate Actions	Impede Actions
Attention (using stimulus features to increase or decrease the salience of an option)	<ul style="list-style-type: none"> • Abrupt onset • Cueing • Highlighting • Visibility 	<ul style="list-style-type: none"> • “Are you sure” alert • Color warning • Increased font size of calories label 	<ul style="list-style-type: none"> • Color (e.g., brand logo) • Sensory cues in casinos 	<ul style="list-style-type: none"> • Concealment • Distracting notification • Reduced font size
Perception (framing the content of information to influence the conscious interpretation of the information)	<ul style="list-style-type: none"> • Appearance • Assortment size • Availability • Feedback • Gain framing • Graphics • Information 	<ul style="list-style-type: none"> • Loss framing • Smaller portions 	<ul style="list-style-type: none"> • Bundle pricing 	<ul style="list-style-type: none"> • Decoy option • Price partitioning (e.g., taxes, shipping fees)
Memory (using encoding cues or retrieval cues to alter subsequent decisions)	<ul style="list-style-type: none"> • Anchoring (e.g., suggested donation amount) • Reminder (e.g., promoting college enrollment) • Priming • Visual prompt 	<ul style="list-style-type: none"> • Reminder (e.g., reducing water consumption) 	<ul style="list-style-type: none"> • Anchoring (e.g., maximum deposit amount) • Repetitive advertising • Subliminal advertising 	<ul style="list-style-type: none"> • Absence of reminder at the end of trial periods
Effort (changing cognitive or physical ease associated with an option)	<ul style="list-style-type: none"> • Accessibility • Convenience • Default • Simplification 	<ul style="list-style-type: none"> • Active choice • Inconvenience 	<ul style="list-style-type: none"> • Accessibility to unhealthy food • Convenience (e.g., tabletop ATMs in casinos) • Default (e.g., overdraft protection) 	<ul style="list-style-type: none"> • Complex cancellation procedures • Mail-in rebates • Non-transparent privacy settings
Intrinsic motivation (influencing inherent interests toward an option in the absence of external factors)	<ul style="list-style-type: none"> • Commitment making • Goal setting • Implementation intention • Motivational intervention • Social norm (e.g., promoting donation) 	<ul style="list-style-type: none"> • Self-control tools • Social norm (e.g., reducing electricity consumption) 	<ul style="list-style-type: none"> • Junk food advertising • Vaping norms for non-smokers 	<ul style="list-style-type: none"> • Vaping norms for smokers who want to quit

Extrinsic motivation (imposing external rewards or punishments to alter decisions)	<ul style="list-style-type: none"> • Financial incentives • Non-financial incentives (e.g., smiley stamps) 	<ul style="list-style-type: none"> • Conditional incentives • Small fees for no-shows 	<ul style="list-style-type: none"> • Micro-incentives to gamble 	<ul style="list-style-type: none"> • Membership fees
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The six cognitive processes are motivated by the pioneering work of Maule (1985) who proposed that cognitive psychology serves as a foundation for decision making research. In particular, decision making is determined by different stages of information processing, from encoding sensory inputs which are heavily influenced by attention, to consolidating and storing inputs in memory. In what follows, we will discuss how each cognitive process is targeted in the interventions.

An attention intervention in the current framework is defined as *an intervention that uses stimulus features to increase or decrease the salience of an option*. This is supported by the theories proposing that attention is controlled by top-down and bottom-up factors (Corbetta & Shulman, 2002; Pashler et al., 2001; Posner, 1980). However, bottom-up attention is relatively easier to target by using salient stimuli to exogenously draw attention, such as color (Nagy & Sanchez, 1990), motion (Dick et al., 1987), size (Treisman & Gormican, 1988), and abrupt onset (Yantis & Jonides, 1984). For example, drawing attention to the license renewing message helps consumers by facilitating their renewal actions (Castelo et al., 2015). Color can also help consumers by holding people back from potential risks, such as a red warning sign before opening a phishing website (Egelman & Schechter, 2013). A harmful intervention that facilitates actions is red and yellow colors frequently used as part of fast-food brand logos to draw consumer attention, which may increase the temptation for junk food (Singh, 2006). Another harmful intervention is displaying resort fee disclosures in a small font to deter people from noticing the fees.

A perception intervention is defined as *an intervention that frames the content of information to influence the conscious interpretation of the information*. Perception is commonly known as the organization, identification, and interpretation of sensory inputs to create a mental representation of external information (Schacter et al., 2011). In the nudge literature, to change perception, interventions often present messages by reconstructing information under a specific frame intended to influence subsequent behaviors. A popular perception intervention is framing the benefits or costs of an action, such as framing the beneficial outcomes of climate change mitigation to facilitate pro-environmental actions (Spence & Pidgeon, 2010) or displaying adverse consequences of smoking on cigarette packages to impede smoking (Bonfrer et al., 2020; Stead et al., 2013). Framing can also be used for harm. In a field experiment, Ganzach & Karsahi (1995) found that conveying the losses of not using a credit card to cardholders doubled the percentage of cardholders starting to use their credit, and more than doubled the expenditures of these cardholders. This framing intervention is harmful as it facilitates overspending. A harmful intervention that impedes actions is to add a decoy option inferior to a target option, preventing consumers from choosing the option best suited to their needs (Huber et al., 1982).

A memory intervention is defined as *an intervention that uses encoding cues or retrieval cues to alter behaviors*. This definition is supported by the multi-store model of memory which explains how external information is transferred and stored into long-term memory (Atkinson & Shiffrin, 1968). Priming and anchoring interventions can influence the encoding process to enhance the registration of new information, and a reminder intervention can prevent forgetting. Choice architects often use retrieval cues, such as reminders or visual prompts, to encourage or discourage subsequent actions. For example, visual prompts can encourage people to turn off lights in unoccupied washrooms (Feng & Zhang, 2019; Sussman & Gifford, 2012). Visual

prompts also deter people from making undesirable decisions, such as signs that ask people to rethink their reason to smoke (Hodges et al., 1999). Presenting a numerical anchor at the encoding stage can bias consumers' purchasing decisions against their own interests by facilitating spending. A lab study showed that participants were willing to spend more money in a restaurant that had a name associated with a higher number (e.g., Studio 97) than a lower number (e.g., Studio 17; Critcher & Gilovich, 2008). Moreover, a potentially harmful memory intervention is the absence of reminders before the end of a free trial which impedes the action of cancelling by preventing consumers from remembering to perform an important action.

An effort intervention is defined as *an intervention that modifies the cognitive or physical ease associated with an option*. The definition of effort is derived from "the law of less work" suggesting that people tend to choose an option that requires minimum cognitive or physical effort (Kahneman, 2011; Kool et al., 2010), and people prefer to maintain the status quo instead of switching to an alternative choice (Kahneman et al., 1991; Samuelson & Zeckhauser, 1988; Shah & Oppenheimer, 2008; Shugan, 1980). For example, a default intervention facilitates employees' savings by automatically enrolling them in a retirement saving plan (Choi et al., 2004). In contrast to default, active choice requests people to explicitly accept or decline an option. Hedlin and Sunstein (2016) showed that when participants were told that green energy was more expensive, active choosing was associated with a higher enrollment rate than the default. Another common effort intervention is convenience, but it can be used against consumers' interests as a harmful intervention. For instance, modern gambling machines with touchscreen buttons require less physical effort during long gambling sessions, compared to traditional machines with a lever (Newall, 2019). Complex redemption rules for mail-in rebates is an example of effort intervention that harms consumers by deterring redemption.

An intrinsic motivation intervention is defined as *an intervention that influences the inherent interests toward an option in the absence of external factors*. This definition is derived from the self-determination theory (Ryan & Deci, 2000). Interventions that facilitate actions aim to increase people's inherent interest to engage in new behaviors, and those that impede actions undermine people's inherent interests to deter them from undesirable behaviors. Goal setting has been used as an intervention to facilitate actions by identifying clear goals. Social norm messaging has been used as a popular intervention to facilitate actions by increasing the intrinsic motivations to do better based on information on how others are doing.

In contrast to intrinsic motivation, an extrinsic motivation intervention is *an intervention that imposes external rewards or punishments to alter behaviors*. Interventions that facilitate actions typically provide incentives to promote desirable actions, while interventions that impede actions impose punishments to deter undesirable actions. A common example is to provide a small financial reward to facilitate actions or impose financial penalties to deter actions. Financial incentives can also be used as a harmful intervention that facilitates actions to induce impulsive behaviors, such as online gambling platforms that offer sign-up incentives to attract gamblers. Moreover, charging costs associated with an option can be a harmful intervention that impedes actions, such as retailers charging a membership fee to prevent customer attrition.

Meta-analysis

We have thus far outlined the cognitive framework and provided examples of interventions targeting the six cognitive processes. As a critical empirical evaluation of the framework, we will examine the effect size of these interventions by conducting a meta-analysis in the next section.

There are several meta-analyses on nudge but they primarily focus on studies from the health sector. For example, one meta-analysis (Cadario & Chandon, 2020) on healthy eating showed that interventions targeting motor responses (e.g., increase ease of accessing healthy foods) had a larger effect size than interventions that influence consumers' knowledge (e.g., nutrition labeling) or feeling (e.g., attractive graphics). Two additional meta-analyses examined interventions across multiple domains, such as energy, environment, finances, health, and policy-making, and found that default had the largest effect size among other interventions (Hummel & Maedche, 2019), and that interventions that used automaticity had a larger effect size than those that did not use automaticity (Beshears & Kosowsky, 2020; Hummel & Maedche, 2019). A recent meta-analysis also found that interventions that target the structure of choice alternatives (e.g., default) outperformed those that describe alternatives or reinforce behavioral intentions (Mertens et al., 2022).

The existing meta-analyses had several limitations. First, the meta-analyses included mixed interventions that combined multiple interventions in a single condition, which makes it impossible to identify the impact of a single intervention. Second, the meta-analyses included a mixture of self-reported surveys, lab studies, and field experiments, which makes it difficult to tease out the causal effect of interventions on real behaviors (Barker et al., 1994; Gatersleben et al., 2002). Third, the meta-analyses mixed the results of quasi-experiments with randomized controlled trials, which makes it difficult to cleanly identify the causal factor. Finally, the meta-analyses did not separate nudge from sludge, therefore could not identify whether interventions that facilitate or impede actions had different impacts on behavior. To address these limitations, we conduct a meta-analysis with only field experiments (i.e., randomized controlled trials) with

actual behavioral measures instead of self-reports to examine the effectiveness of interventions targeting each of the six cognitive processes outlined in the cognitive framework.

Methods

All of the data and code of the meta-analysis are available here:

<https://doi.org/10.7910/DVN/N9EJNR>. To create the data set, we conducted a literature search in seven databases across multiple disciplines: Web of Science, PubMed, PsychInfo, Business Source Ultimate, PsychExtra, Google Scholar, and Proquest. The last two databases were used to include grey literature, such as non-academic articles, business reports, and unpublished dissertations. The first search term was “nudge,” “nudging,” “sludge,” or “sludging,” and the second joint search term was “randomized controlled trial”. Given the large number of search results on Google Scholar, the second term was changed to “field” to limit the number of articles. Moreover, disciplines such as physics and meteorology that use the terms nudge and sludge based on other definitions were excluded from the search. The publication year was restricted from 2008 to 2021 as the term nudge was popularized after the publication of the book *Nudge* in 2008 (Thaler & Sunstein, 2008).

After removing duplicates from the initial search, we analyzed the titles and abstracts to exclude review articles or studies reporting qualitative data. In the full-text assessment stage, articles were selected based on four criteria: field experiments, single interventions, randomized controlled trials, and actual behavioral measures. Articles that tested multiple single interventions in separate conditions were included as distinct observations. Articles that used mixed interventions (e.g., reminders with social norm messaging) in one condition were excluded from the analysis. Actual behavioral measures were defined as objective measures of

behaviors (e.g., actual percent change in energy consumption) rather than self-reported behaviors.

In searching for the articles, we only found three published articles on nudge and one on sludge that harmed consumers. Specifically, among the three articles on harmful nudge, one used a memory intervention (i.e., priming, $d=0.17$, Högberg et al. 2020) and two intrinsic motivation interventions (i.e., both social norms messaging, $d=0.54$ and $d=0.91$; Hou 2015; Ranson & Guttentag, 2019), and the article on harmful sludge used an attention intervention (i.e., visibility, $d=0.02$, Ferman, 2016). We only found a total of four articles possibly due to the ethical concerns with conducting studies with harmful interventions, or to the unavailability of data from authors. Thus, a systematic comparison between interventions that help and harm consumers was not feasible. We therefore excluded the four articles that involved harmful interventions from the meta-analysis. In other words, the current meta-analysis only contained interventions that benefited consumers.

In total, $n=188$ articles met all criteria, and $k=188$ observations and $N=2,209,334$ participants were included in the meta-analysis (see details of the selected articles in Supplementary Materials). Figure 1 presents the PRISMA flow diagram showing the four stages of article selection with the number of articles at each stage.

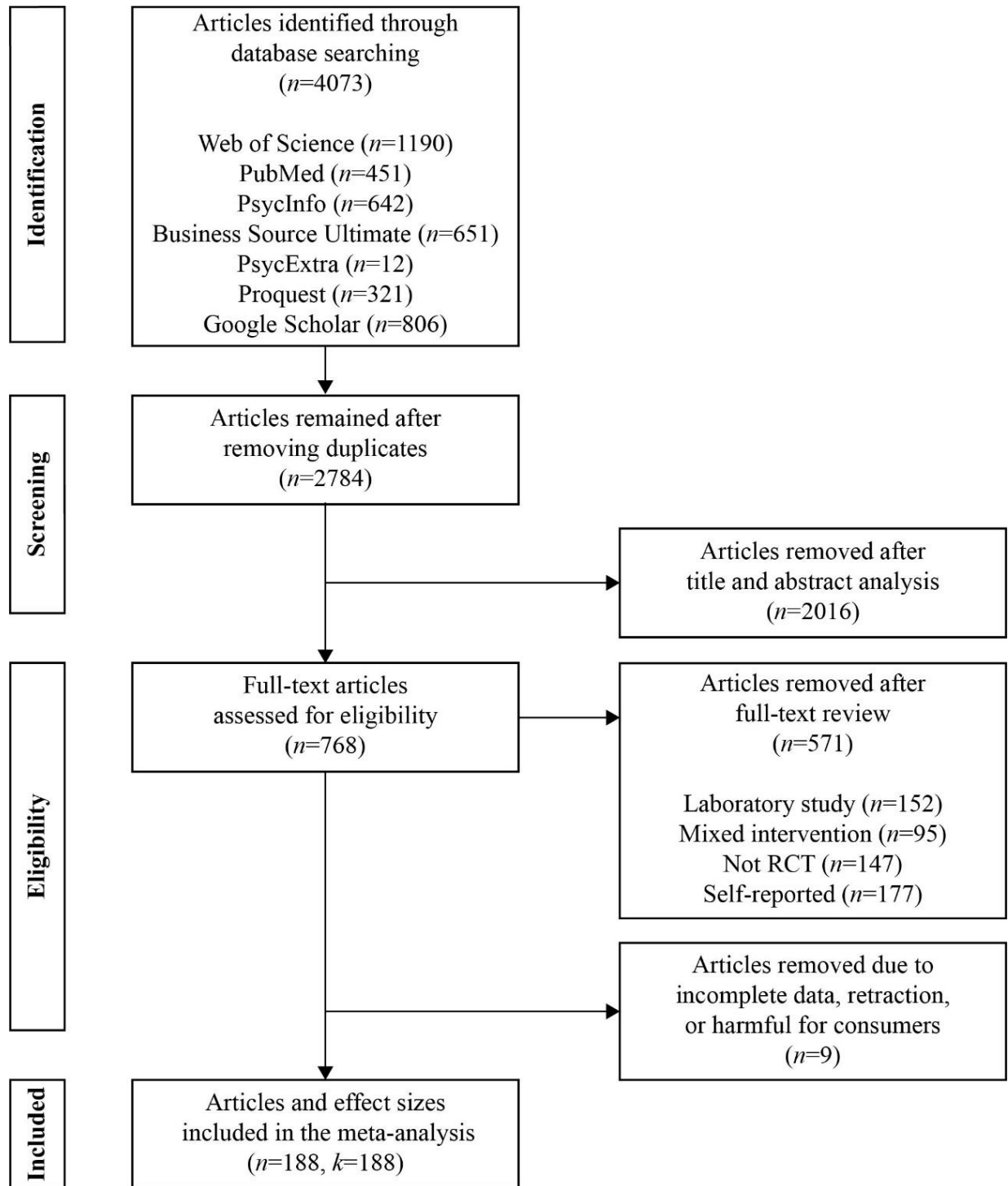


Figure 1. A PRISMA flow diagram showing the four stages of article selection with the number of articles in each stage.

Since we did not limit our search to a specific discipline, studies from education, environment, finance, health, and policy-making sectors were included in the meta-analysis. By

analyzing the number of articles published per year among the articles included in the meta-analysis, more articles were published from 2017 to 2021, showing an increased interest in examining the effect of nudge and sludge on actual behavior change in field experiments (Figure 2). A decrease in the number of field experiments published in 2021 could be due to the lockdowns in the COVID-19 pandemic.

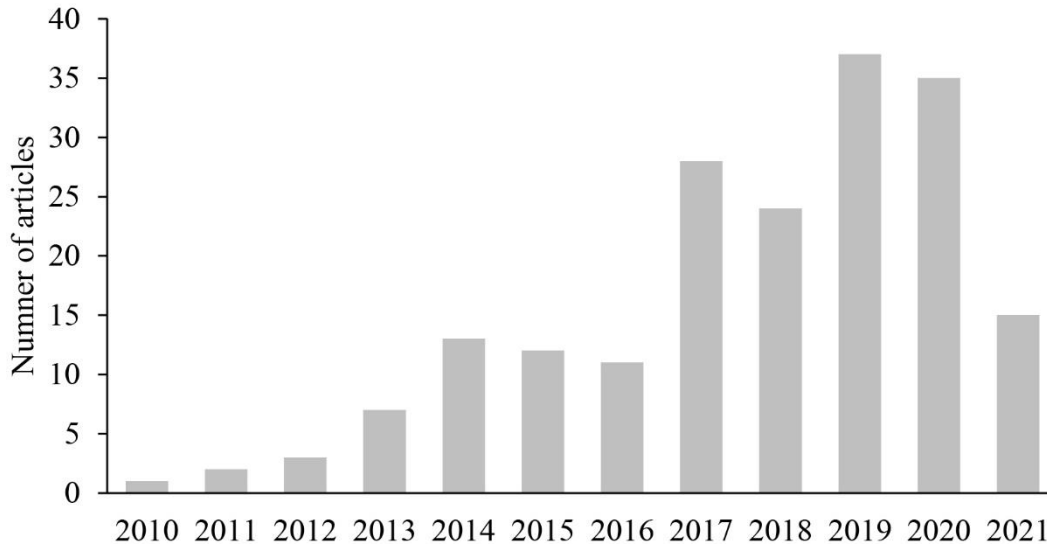


Figure 2. The number of selected articles per year in the meta-analysis.

The 188 observations were further categorized into one of the six cognitive processes based on the definitions discussed in the cognitive framework. Two coders independently categorized each intervention into one of the six cognitive processes and there was a 95% agreement among the coders. Each intervention was classified as nudge or sludge, depending on whether the intervention facilitates or impedes actions.

Since different studies used different outcome measures, we converted the various effect sizes to a standardized measure following the guidelines provided by Harrer et al (2019). Specifically, we converted the mean difference between the treatment condition and the control condition to Cohen's d by dividing the pooled standard deviation for continuous variables. If a

study did not provide sufficient information on the means, standard deviations, and sample sizes, the raw data were requested and obtained, and manually analyzed to obtain the relevant statistics. Studies that failed to report the complete set of statistics and did not provide the raw data were excluded. When studies used dichotomous variables, the odds ratio was computed and then converted to Cohen's d . Several studies used dummy coding for the dichotomous variable and reported the relative difference between the treatment condition and the control condition, and the relative difference was converted to Cohen's d . Several studies reported a raw comparison between the treatment and control condition, and additional comparisons after controlling for covariates. To minimize biases in the results, only comparisons without controlling for covariates were included in the meta-analysis. Moreover, some observed reductions in undesirable behaviors (e.g., reduced water consumption) were coded as positive although the original effect size was negative.

Results and Discussion

After pooling the effect sizes using the random-effects model, the overall effect size was 0.32 (Cohen's d) from the meta-analysis. Interventions that reduce friction ($k=147$) had an average effect size of 0.33 and interventions that increase friction ($k=41$) had an average effect size of 0.27. Across the six cognitive processes (Table 1), effort interventions had the largest effect size ($d=0.56$), followed by attention interventions ($d=0.37$), memory interventions ($d=0.33$), perception interventions ($d=0.32$), extrinsic motivation interventions ($d=0.31$), and intrinsic motivation interventions ($d=0.11$).

Table 1: Effect size (Cohen's d) of interventions that reduce friction (here, nudge) or increase friction (here, sludge) by cognitive processes

Cognitive process	Type	k	d [95% CI]	Combined d [95% CI]
Attention	Nudge	12	0.38 [-0.02, 0.77]	0.37 [0.05, 0.69]
	Sludge	3	0.27 [-0.94, 1.48]	
Perception	Nudge	32	0.35 [0.18, 0.51]	0.32 [0.19, 0.45]
	Sludge	10	0.25 [0.03, 0.47]	
Memory	Nudge	34	0.26 [0.16, 0.36]	0.33 [0.17, 0.48]
	Sludge	4	0.41 [-2.26, 3.08]	
Effort	Nudge	26	0.62 [0.37, 0.86]	0.56 [0.37, 0.76]
	Sludge	9	0.39 [0.06, 0.71]	
Intrinsic motivation	Nudge	28	0.12 [0.05, 0.2]	0.11 [0.05, 0.16]
	Sludge	12	0.07 [0.02, 0.12]	
Extrinsic motivation	Nudge	15	0.33 [0.14, 0.52]	0.31 [0.15, 0.48]
	Sludge	3	0.24 [-0.62, 1.1]	
Overall	Nudge	147	0.33 [0.26, 0.41]	0.32 [0.26, 0.39]
	Sludge	41	0.27 [0.12, 0.42]	

To test the difference in effect sizes across the six cognitive processes, a 2 (intervention type: nudge and sludge) \times 6 (cognitive process: attention, perception, memory, effort, intrinsic motivation, and extrinsic motivation) ANOVA was conducted. The analysis revealed a main effect of cognitive process [$F(5, 176)=3.36, p=.006, \eta_p^2=.09$] but no main effect of intervention type [$F(1, 176)=1.28, p=.25, \eta_p^2=.007$] and no interaction between intervention type and cognitive process [$F(5, 176)=0.08, p=.99, \eta_p^2=.002$]. Post-hoc Tukey's HSD tests were conducted to reveal that the only reliable difference was that the effort interventions had significantly larger effect sizes than intrinsic motivation interventions ($p=.002$; Figure 3a).

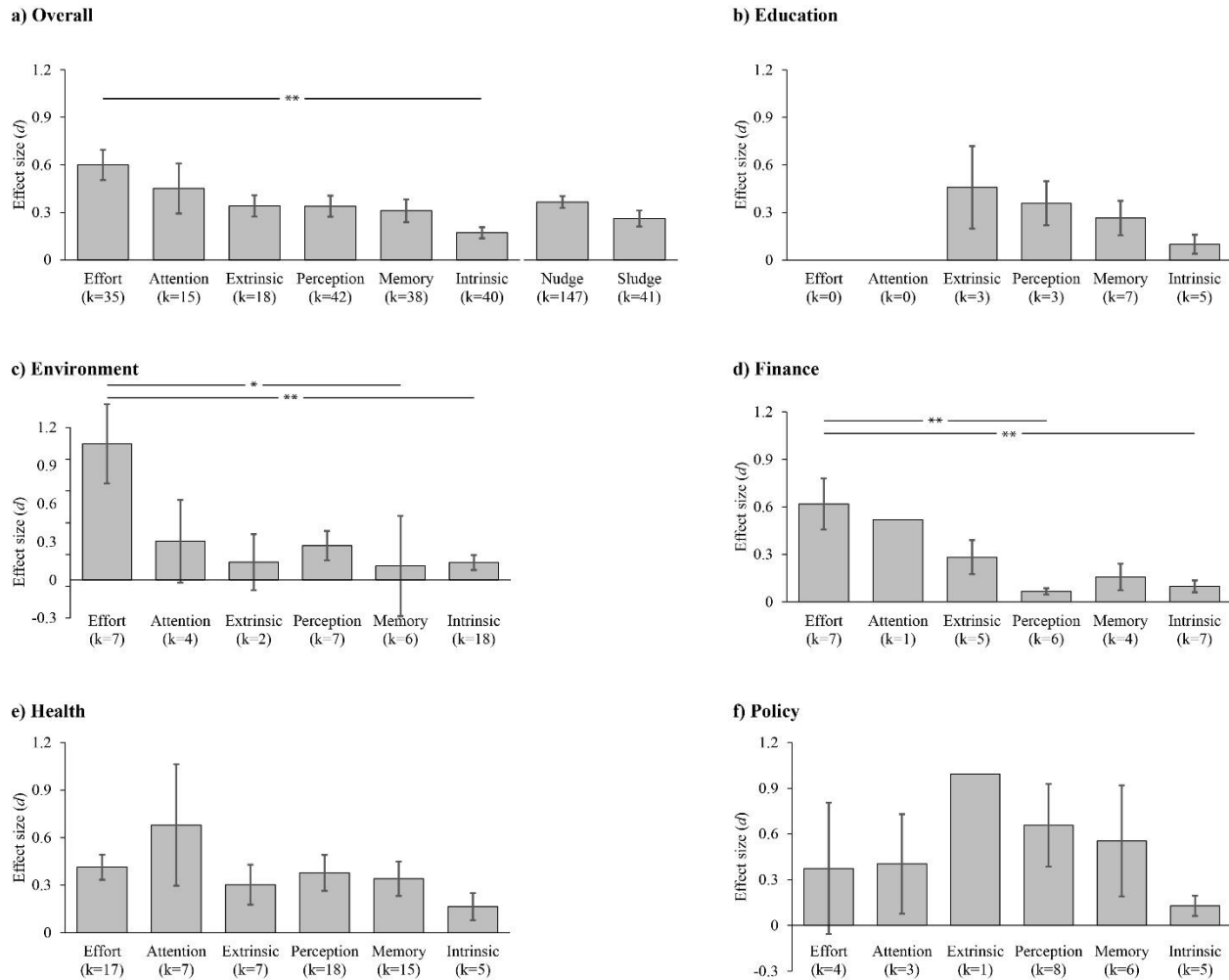


Figure 3. Comparisons of effect sizes across the six cognitive processes (a) and in each domain (b-f) (** $p < .01$, * $p < .05$, error bars mean $1 \pm SE$).

We also examined the effect sizes across the six cognitive processes by domain. A 5 (domain: education, environment, finance, health, and policy) \times 6 (cognitive process: attention, perception, memory, effort, intrinsic motivation, and extrinsic motivation) ANOVA was conducted. The analysis revealed a main effect of cognitive process [$F(5, 160) = 3.42, p = .006, \eta_p^2 = .10$] but no main effect of domain [$F(4, 160) = 0.67, p = .61, \eta_p^2 = .02$] and no interaction between domain and cognitive process [$F(18, 160) = 1.02, p = .44, \eta_p^2 = .10$]. Numerically, interventions targeting policy decisions ($d = 0.45$) had the largest effect size, followed by

environmental decisions ($d=0.34$), health care decisions ($d=0.31$), financial decisions ($d=0.25$), and educational decisions ($d=0.22$). We also conducted a one-way ANOVA in each domain. In the environment domain, there was a main effect of cognitive process [$F(5, 38)=3.16, p=.02, \eta_p^2=.29$], and post-hoc Tukey's HSD tests revealed that the effort interventions had significantly larger effect sizes than memory interventions ($p=.04$) and intrinsic motivation interventions ($p=.007$; Figure 3c). In the finance domain, there was a main effect of cognitive process [$F(5, 24)=4.61, p=.004, \eta_p^2=.49$], and post-hoc Tukey's HSD tests revealed that the effort interventions had significantly larger effect sizes than intrinsic motivation interventions ($p=.007$) and perception interventions ($p=.006$; Figure 3d). However, there was no effect of cognitive process in the education [$F(3, 14)=1.17, p=.36, \eta_p^2=.20$], health [$F(5, 63)=0.79, p=.56, \eta_p^2=.06$], and policy domains [$F(5, 21)=0.47, p=.80, \eta_p^2=.10$] (Figure 3b, 3e, and 3f, respectively).

To examine which specific intervention had the largest effect size, we conducted a one-way ANOVA on the common interventions that had at least two observations in the meta-analysis. This is because a minimum of two data points per intervention was required to conduct the ANOVA (see Table 4). There was a significant difference between the common interventions [$F(31, 156)=2.04, p=.002, \eta_p^2=.29$]. Post-hoc Tukey's HSD tests revealed that the highlighting intervention had a larger effect size than implementation intention ($p=.049$), visibility ($p=.04$), reminder ($p=.03$), and social norms interventions ($p=.003$), and all the other comparisons were not significant ($p's>.05$). Numerically speaking, convenience ($d=1.18$), highlighting information ($d=1.07$), changing the appearance of an option ($d=0.92$), using anchors ($d=0.78$), making a commitment ($d=0.36$), and rewarding with non-financial incentives (e.g., stamps with smiley faces, $d=0.41$) had the largest effect sizes in interventions targeting effort, attention, perception,

memory, intrinsic motivation, and extrinsic motivation, respectively (Table 4). This said, these results need to be interpreted with caution due to the small number of studies in each category.

Table 2. Effect sizes of common interventions

Intervention	Cognitive process	<i>k</i> (>1)	<i>d</i> [95% CI]
Convenience	Effort	3	1.18 [-0.38, 2.74]
Highlighting	Attention	4	1.07 [-0.51, 2.64]
Appearance	Perception	2	0.92 [-5.86, 7.71]
Anchoring	Memory	2	0.78 [-8.51, 10.07]
Inconvenience	Effort	5	0.71 [0.28, 1.14]
Default	Effort	14	0.66 [0.26, 1.06]
Informational feedback	Perception	5	0.59 [0.31, 0.87]
Accessibility	Effort	7	0.42 [0.16, 0.69]
Non-financial incentives	Extrinsic	5	0.41 [0.01, 0.81]
Informational messaging	Perception	11	0.4 [0.12, 0.68]
Conditional incentives	Extrinsic	2	0.36 [-3.09, 3.82]
Availability	Perception	5	0.36 [-0.36, 1.08]
Commitment making	Intrinsic	5	0.36 [-0.05, 0.76]
Priming	Memory	6	0.31 [-0.06, 0.68]
Reminder	Memory	30	0.3 [0.12, 0.48]
Gain framing	Perception	8	0.3 [-0.16, 0.76]
Financial incentives	Extrinsic	10	0.29 [0.03, 0.55]
Graphic	Perception	2	0.26 [-3.63, 4.15]
Goal setting	Intrinsic	2	0.25 [-0.97, 1.46]
Visibility	Attention	8	0.13 [-0.06, 0.32]
Motivational intervention	Intrinsic	3	0.1 [-0.09, 0.29]
Active choice	Effort	4	0.09 [-0.06, 0.24]
Social norm	Intrinsic	25	0.07 [0.01, 0.12]
Loss framing	Perception	5	0.05 [-0.01, 0.11]
Simplification	Effort	2	0.04 [-0.09, 0.17]
Implementation intention	Intrinsic	5	0.03 [-0.02, 0.09]
Assortment size	Perception	3	0 [-0.5, 0.51]

To examine any publication bias in the meta-analysis, a funnel plot was created. Egger's test showed that there was a significant asymmetry in the funnel plot ($b=2.31$, 95% CI [0.97, 3.64], $t=3.38$, $p<.001$, Figure 4), suggesting that a publication bias in reporting successful interventions over unsuccessful interventions may exist. The publication bias found here was consistent with the recent meta-analysis on the effectiveness of nudge that also showed a publication bias (Mertens et al., 2022).

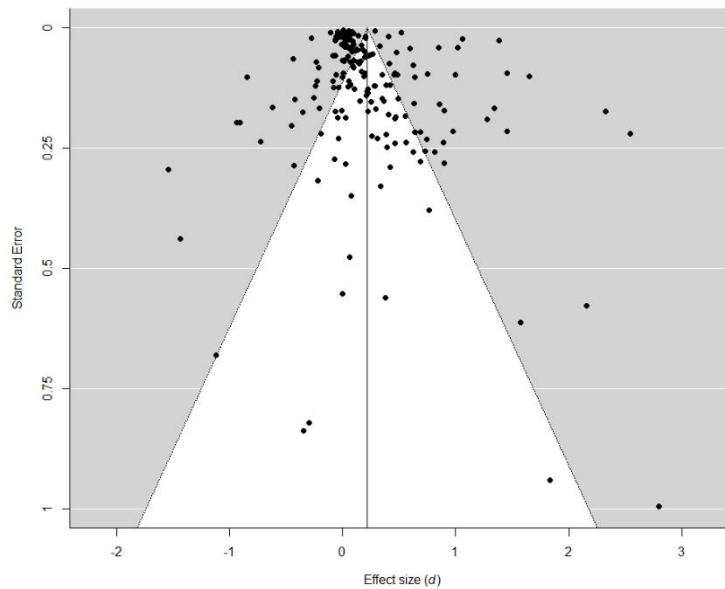


Figure 4. The funnel plot appears to be asymmetrical.

General Discussion

The current paper first proposed a new cognitive framework to categorize interventions that facilitate or impede actions based on six underlying cognitive processes of attention, perception, memory, effort, intrinsic motivation, and extrinsic motivation. The current framework is more comprehensive containing more interventions organized by cognitive principles, compared to past frameworks. For example, the current framework overlaps with the nine categories in the MINDSPACE framework (Dolan et al., 2012). However, effort, memory,

and perception interventions in the current framework are more inclusive than default, priming, affect, and messenger interventions in MINDSPACE. For example, effort interventions include not only default but also interventions manipulating the degree of convenience. Memory interventions contain reminders in addition to priming, and perception interventions extend to informational and real-time feedback. Likewise, the current framework includes similar interventions as the EAST framework (Service et al., 2014), but offers cognitive insights on Easy (effort), Attractive (attention), Social (intrinsic motivation), and Timely (memory). Therefore, the current framework provides new theoretical insights on how interventions facilitate or impede actions through which cognitive processes. In addition, the current framework also provides useful cognitive guidelines to choice architects in terms of how to choose interventions based on the targeted cognitive process. For example, if the choice architects identify that the lack of attention is a barrier to action, they can use the interventions in the attention category to change behavior.

The current paper also examined the effect size of the interventions targeting each cognitive process in a meta-analysis containing only field experiments with real behavioral measures. The meta-analysis showed that the interventions that targeted effort (e.g., convenience, default) had the largest effect size compared to the other interventions. This finding was supported by previous meta-analyses that demonstrated default and automaticity interventions were the most effective (Beshears & Kosowsky, 2020; Hummel & Maedche, 2019). Interventions targeting intrinsic motivation (e.g., goal setting, implementation intention, social norms) had the smallest effect size in comparison. The effect size of intrinsic motivation interventions found in the current meta-analysis was comparable to the findings of a recent meta-analysis of randomized controlled trials on pro-environmental behaviors (Nisa et al., 2019).

The results of the meta-analysis help rank the interventions in previous frameworks. For example, the authors of MINDSPACE claimed that the ordering of the nine categories in the acronym was not meaningful. According to the current meta-analysis, the nine categories can be ordered based on the effectiveness of the interventions. Specifically, choice architects should consider default (effort) as their first intervention, then salience (attention), priming (memory), messengers and affect (perception), incentives (extrinsic motivation), and lastly ego, commitment, and norms (intrinsic motivation) interventions.

Since the meta-analysis included interventions from multiple domains, the average effect size of interventions varied across domains, which is consistent with Mertens et al.'s meta-analysis (2022). We found that effort interventions had the largest effect size in the environment and finance domains, but extrinsic motivation interventions had the largest effect size in the education and policy domains, and attention interventions had the largest effect size in the health domain. This said, the current findings by domain need to be interpreted with caution given the small sample size in each domain.

The current meta-analysis was the first to compare the impact of nudge and sludge and found that the effect size of nudge and sludge were not significantly different. This suggests that interventions that facilitate actions and those that impede actions had similar efficacy in promoting behavior change. However, the sample size of interventions that impede actions was considerably smaller ($k=41$) than those that facilitate actions ($k=147$), suggesting that the effect size of interventions that impede actions should be interpreted with caution. This also calls for the need for more research to examine the impact of interventions that impede actions.

This new meta-analytic cognitive framework has several theoretical, empirical, and practical contributions. First, it provides cognitive insights on nudge and sludge by explaining

which cognitive process is involved in a given intervention. Second, the framework allows comparisons of impact between interventions that target different cognitive processes. For example, reducing effort by making an option more convenient or drawing attention by highlighting the option were more impactful in achieving behavior change than increasing intrinsic motivation by using social norm messaging. Third, the meta-analysis excluded self-reported data and laboratory studies, permitting comparisons using only behavioral measures in field experiments, which is important to demonstrate real-world impact. Fourth, since only randomized controlled trials were included in the analysis, the effect of the interventions demonstrates a causal impact of the interventions on real behavior change. Finally, the framework offers a ranking of interventions based on cognitive processes and the associated behavioral impact, which can guide the development of future interventions.

Although the theoretical, empirical, and practical contributions of the current review are prominent, the current framework has some limitations. First, the categorization of the interventions based on the cognitive processes and the type of intervention (facilitating vs. impeding actions) was subjective. Future studies can seek further support for the categorization with empirical data, for example, by inviting other researchers who are familiar with cognitive concepts to classify the interventions based on the definitions discussed in the current review. The consensus among these experts will reduce the subjectivity of this cognitive framework. Second, in the meta-analysis, 91% of the selected studies were conducted in developed countries which limits the generalizability of the effects of nudge and sludge to developing countries. Moreover, the number of studies on sludge is relatively scarce in the literature. Given the limited number of observations, the effect sizes of these interventions need to be interpreted with caution.

In conclusion, the current meta-analytic cognitive framework provides new insights on how nudge and sludge can be categorized based on cognitive dimensions and it also demonstrates the effectiveness of the interventions targeting each cognitive process. This review paper can help inform the development of future interventions and improve the impact of these interventions by targeting effort or attention mechanisms.

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Supplementary Materials

Legend of Table S1:

Category:

1st letter represents the type of intervention:

N = nudge

S = sludge

2nd letter represents the cognitive process:

At = attention

Pe = perception

Me = memor

Ef = effort

In = Intrinsic motivation

Ex = extrinsic motivation

Length:

The duration of the interventions is shown in the number of months. Zero indicates a one-time intervention.

Data:

b = unstandardized regression coefficient

beta = standardized regression coefficient

OR = odds ratio

BP = binary proportions

2x2 = 2 by 2 frequency table

M&SD = mean and standard deviation

MG&SD = mean gain scores and standard deviations

M&SE = mean and standard error

t = *t*-test

F = one-way ANOVA with two independent groups

Table S1: Complete list of studies in the meta-analysis:

Author	Category	Intervention	Behavioral measure	Length	Location	Data
Ahomaki et al. (2020)	N_Pe	Informational messaging	Opioid prescribing rate	0	Finland	b
Allan & Powell (2020)	N_Me	Reminder	Reduction in calorie content of purchased items	3	UK	b
Altmann & Traxler (2014)	N_Me	Reminder	Dental check-up appointment	0	Germany	BP
Andor et al. (2020)	S_In	Social norm	Electricity consumption	6	Germany	b
Araña & León (2013)	N_Ef	Default	Carbon offsetting purchase	0	Gran Canaria	BP
Avdeenko et al. (2019)	N_In	Goal setting	Amount of savings	12	Ethiopia	b
Ayal et al. (2021)	S_Me	Priming	Fare evader rate	1	France	2x2
Ayala et al. (2017)	N_At	Highlighting	Weekly number of healthy items sold	2	US	b
Baca-Motes et al. (2013)	N_In	Commitment making	Towel reuse	0	US	BP
Baggio & Motterlini (2019)	N_Me	Anchoring	Amount of donation	0	Italy	M&SD
Baker et al. (2016)	N_In	Implementation intention	Watch lecture video	0	US	BP
Bartke et al. (2017, descriptive)	N_In	Social norm	Number of donations	0	Germany	BP
Bateson et al. (2015)	N_Me	Priming	Percent of cyclists littered	0	UK	2x2
Bauer et al. (2019)	N_In	Social norm	Click on resource link	0	US	2x2

Author	Category	Intervention	Behavioral measure	Length	Location	Data
Bennion & Nickerson (2021)	N_Ef	Convenience	Voter registration	0	US	BP
Bergh et al. (2019)	N_Me	Reminder	Voter turnout	0	Norway	b
Bernedo et al. (2014)	S_In	Social norm	Water consumption (gallons)	0	US	b
Bertoni et al. (2020)	N_Pe	Loss framing	Screening takeup	0	US	BP
Bhatti et al. (2015, traditional vs. control)	N_Pe	Gain framing	Turnout rate	0	Denmark	BP
Biswas et al. (2017)	N_Me	Priming	Healthy food choice	0	US	BP
Blaehr et al. (2018)	S_Ex	Fine	Non-attendance rate	0	Denmark	2x2
Bollinger et al. (2020, self-interest vs. control)	N_Pe	Gain framing	Rooftop solar PV installation	12	US	t
Bracha & Meier (2015)	N_Me	Reminder	Average change in credit score	12	US	M&SD
Bradley et al. (2018)	N_Ex	Financial incentives	Number of visit to primary care provider	6	US	M&SE
Brandon et al. (2019)	S_In	Social norm	Electricity consumption at peak hours	2	US	b
Brannan (2012)	S_Pe	Informational feedback	Fuel economy (miles per gallon)	0	US	b
Brent et al. (2020)	S_In	Social norm	Percent of water consumption	2	US	b

Author	Category	Intervention	Behavioral measure	Length	Location	Data
Bronchetti et al. (2013)	N_Ef	Default	Savings bond participation rate	2	US	b
Bronchetti et al. (2015, peer vs. control)	N_In	Social norm	Flu vaccine take-up	2	US	BP
Brune et al. (2017)	N_Ef	Default	Amount of savings	1	Malawi	b
Bucher et al. (2014)	N_Pe	Availability	Total energy from vegetables	0	Switzerland	M&SD
Bulte et al. (2020)	S_Ex	Conditional incentives	Number of envelopes folded	0	Uganda	M&SD
Byerly et al. (2019)	N_In	Social norm	Number of owners requested more information on conservation program	3	US	BP
Campbell-Arvai et al. (2014) (default)	N_Ef	Default	Choice of meat-free meal	0	US	2x2
Capraro et al. (2019, study 5)	N_In	Motivational intervention	Amount of donation	0	US	M&SD
Carpena et al. (2019)	N_Ex	Financial incentives	Financial numeracy scores	1	India	b
Carrera et al. (2018)	N_In	Implementation intention	Total gym visits	0	US	b
Castleman & Page (2015)	N_Me	Reminder	College enrollment	4	US	b
Castleman & Page (2016)	N_Me	Reminder	College enrollment persistence	8	US	BP

Author	Category	Intervention	Behavioral measure	Length	Location	Data
Chareyron et al. (2018, simplified)	N_Ef	Simplification	Social assistance benefits take-up	6	France	b
Chirico et al. (2019, reminder only vs. reminder+treatment)	S_Pe	Loss framing	Tax compliance (full payment)	0	US	BP
Choudhary et al. (2019, location A)	S_Me	Reminder	Vehicle inspection prior a trip	1	Canada	NA
Clark et al. (2014)	N_Pe	Informational messaging	Retirement plan registration	0	US	BP
Coffino et al. (2020)	N_Ef	Default	Servings of healthy food	0	US	M&SE
Costa & Kahn (2013)	S_In	Social norm	Electricity consumption	0	US	b
Cotterill et al. (2013)	N_In	Commitment making	Percent of household donated a book	0	UK	M&SE
Coucke et al. (2019)	N_Pe	Availability	Sales of poultry products	1	US	M&SD
Courtright et al. (2017)	N_Pe	Availability	Advance directives completion rate	0	US	BP
Crago et al. (2020)	S_Pe	Informational feedback	Electricity consumption	1	US	M&SD
Cranor et al. (2020, penalty)	S_Pe	Loss framing	Tax payment rate	0	US	BP
Dai et al. (2021)	N_Me	Reminder	Vaccination rate	1	US	BP
Dallas et al. (2019)	N_At	Visibility	Lower calories food choice	0	US	M&SD

Author	Category	Intervention	Behavioral measure	Length	Location	Data
Dalrymple et al. (2020)	N_Ef	Default	Selection of lower-energy-dense items	0	US	2x2
Damgaard & Gravert (2018)	N_Me	Reminder	Number of people donated	0	Denmark	BP
de Wijk et al. (2016)	N_Ef	Accessibility	Whole wheat bread sales	2	Netherlands	2x2
Didero (2019)	N_Pe	Graphic	Coupon redemption rate	5	US	BP
dos Santos et al. (2018)	N_At	Highlighting	Meal choice	4	Denmark	2x2
Dur et al. (2019)	N_In	Social norm	Amount of savings	0	Netherlands	b
Dur et al. (2021)	N_In	Social norm	Amount of savings	9	Netherlands	b
Earnhart & Ferraro (2020)	S_In	Social norm	Wastewater discharge ratio	0	US	b
Ebeling & Lotz (2015)	N_Ef	Default	Percent of consumers purchased green energy	1	Germany	BP
Eguino et al. (2020, request vs. control)	N_Pe	Informational messaging	Online tax registration	1	Brazil	BP
Engstrom et al. (2019)	N_Pe	Informational messaging	Housing allowance application	0	Sweden	BP
Eskreis-Winkler et al. (2019, target)	N_In	Motivational intervention	Target class grades	1	US	M&SD
Essl et al. (2021)	N_Me	Reminder	Return rate of plastic bag	1	Switzerland	b
Figuroa et al. (2019)	N_Ex	Financial incentives	CFL uptake	1	Kenya	b

Author	Category	Intervention	Behavioral measure	Length	Location	Data
Fox et al. (2019 (study 1))	S_Ef	Inconvenience	Number of napkin per person	3	US	t
Franssens et al. (2021)	N_In	Social norm	Transit use	6	Netherlands	b
Friis et al. (2017, default)	N_Ef	Default	Vegetable consumption	0	Denmark	M&SD
Gallus (2017)	N_Ex	Non-financial incentives	Retention rate	11	Online	M&SD
Garnett et al. (2019)	N_Pe	Availability	Vegetarian meal sale	0	US	BP
Ghose et al. (2019)	N_Ef	Accessibility	Coupon redemption rate	0	US	BP
Giaccherini et al. (2021)	N_In	Social norm	Use of doggy bag	0	Italy	M&SD
Gillitzer & Sinning (2019)	N_Me	Reminder	Tax payment rate	0	Australia	b
Gold et al. (2019)	N_Pe	Loss framing	Number of patients who attended an NHS health check	6	US	2x2
Goldin et al. (2020, baseline vs. control)	N_Me	Reminder	Enrollment in Thrift Savings Plan	0	US	BP
Grieco et al. (2018, Info+choice)	S_Ef	Active choice	Consent to donate cord blood	0	Canada	2x2
Grinstein-Weiss et al. (2017, expl: emergency vs. control)	N_Pe	Gain framing	Tax saving choice	0	US	BP
Gupta et al. (2016)	N_Ex	Financial incentives	Colorectal cancer screening uptake	0	US	2x2

Author	Category	Intervention	Behavioral measure	Length	Location	Data
Gwozdz et al. (2020)	N_Ex	Non-financial incentives	Vegetable consumption	0	US	M&SD
Hainmueller et al. (2018, voucher)	N_Ex	Financial incentives	Naturalization application rate	0	US	BP
Hansen et al. (2019)	N_Ef	Default	Vegetarian meal choice	0	Denmark	2x2
He et al. (2021)	N_Ef	Default	Attempted to chose harder tasks	0	US	2x2
Hirst et al. (2017)	N_Me	Reminder	Colorectal cancer screening uptake	2	UK	BP
Hou (2017)	N_Me	Anchoring	Number of cookies ordered	0	US	M&SD
Huang et al. (2019)	N_At	Visibility	Online registration rate	0	US	BP
Huf et al. (2020)	N_Me	Reminder	Cervical screening uptake	3	UK	BP
Inkelaar & Simpson (2015)	N_In	Motivational intervantion	Distant education retention rate	0	UK	BP
Jakobsen & Serritzlew (2016)	N_Pe	Informational messaging	Knowledge test	0	Denmark	BP
Jespersen (2018)	S_In	Social norm	Litigation in consumer disputes	0	Denmark	BP
John & Blume (2017, collective)	N_Pe	Gain framing	Usage of online service	4	UK	BP
Joo et al. (2018, commitment)	N_In	Commitment making	Water consumption	0	Korea	M&SD
Júdice et al. (2015)	S_At	Alert	Sitting time (hr)	4	Portugal	M&SD

Author	Category	Intervention	Behavioral measure	Length	Location	Data
Kallbekken & Saelen (2013, sign vs. control)	S_Me	Reminder	Reduce food waste	2	Norway	MG&SD
Kanchanachitra et al. (2020)	S_Ef	Inconvenience	Fish sauce consumption	1	Thailand	M&SD
Kažukauskas et al. (2017, electricity)	S_In	Social norm	Electricity consumption	12	Sweden	MG&SD
Keller et al. (2015)	N_Ef	Accessibility	Healthy snack choice	0	Switzerland	2x2
Kersbergen et al. (2018)	S_Pe	Portion size	Alcohol consumption	0	UK	M&SD
Kettle et al. (2017, public good vs. control)	N_In	Social norm	Tax liability declared	0	Guatemala	b
Kim & Kaemingk (2021)	N_In	Social norm	Electricity use	0	Moldova	b
King et al. (2016)	N_Me	Priming	Number of people performed hand hygiene	3	UK	2x2
Knowles et al. (2020, study 1)	N_Ef	Accessibility	Food consumption	0	US	M&SD
Kongsbak et al. (2016)	N_Ef	Accessibility	Fruit and vegetable consumption (g)	0	Denmark	M&SD
Kosite et al. (2019)	S_Pe	Portion size	Calories consumption	0	UK	M&SD
Kristal & Whillans (2020, study 3a)	N_Ex	Financial incentives	Purchase of subsidized transit cards	3	US	M&SD
Kristal et al. (2020)	N_At	Visibility	Percent of people cheating	0	US	t
Kroese et al. (2016)	N_Ef	Accessibility	Healthy snack purchase	0	Netherlands	2x2

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Kurz (2018)	N_At	Highlighting	Vegetarian meal sale	4	Sweden	M&SE
Larkin et al. (2018, salience)	N_At	Highlighting	Tax payment rate	0	UK	BP
Lattarulo et al. (2017)	N_Ex	Non-financial incentives	Museum visit	0	Italy	BP
Lesner & Rasmussen (2014, identifiable vs. neutral)	N_Pe	Identifiable victim	Amount of donation	0	Denmark	M&SD
Libotte et al. (2014)	S_Pe	Portion size	Total energy meal (kj)	0	US	M&SD
Lieberoth et al. (2018)	N_Me	Reminder	Number of transit card uses	1	Denmark	M&SD
Liebig & Rommel (2014)	N_Ef	Default	Attached sticker on mailbox	2	Germany	2x2
Linos et al. (2020, study 2)	N_Ef	Simplification	Compliance	11	US	BP
List & Samek (2017)	N_Ex	Non-financial incentives	White milk choice	NA	US	b
Lott (2017)	S_In	Social norm	Percent of water consumption	5	US	b
Luo et al. (2019)	N_Pe	Loss framing	Online purchase decision	1	Asia	b
Luong et al. (2021)	N_Me	Reminder	Filled all gapping medications	1	US	2x2
Marx & Turner (2019)	N_Ex	Financial incentives	Student loan uptake	0	US	BP
Marzilli Ericson et al. (2017)	N_Pe	Gain framing	Switch health insurance plan	2	US	BP

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McCrackin (2012)	N_Ex	Financial incentives	Garden dimension	0	US	MG&SD
Meeker et al. (2014)	N_In	Commitment making	Inappropriate antibiotic prescription	3	US	BP
Merkelbach et al. (2021)	S_Me	Reminder	Number of days with garbage found	0	Netherlands	MG&SD
Mikkelsen & Quinto Romani (2017)	S_Ef	Inconvenience	Number of butter packs consumed	0	Denmark	2x2
Milkman et al. (2011)	N_In	Implementation intention	Number of employees vaccinated	0	US	2x2
Milkman et al. (2021)	N_Me	Reminder	Getting a flu shot	0	US	M&SD
Miller et al. (2016)	N_Pe	Informational feedback	Number of meals contained healthy food	0	US	BP
Missbach & König (2016)	N_At	Visibility	Healthy food choice	0	Austria	2x2
Mors et al. (2018)	N_Me	Priming	Food choice	0	Netherlands	2x2
Moseley & Stoker (2015)	N_Ef	Default	Actual organ donor registration	0	UK	2x2
Moseley et al. (2018)	N_In	Social norm	Volunteering hours	1	US	MG&SD
Mundt et al. (2020)	S_Ef	Inconvenience	Straw consumption	0	Germany	2x2
Myers & Souza (2020)	S_In	Social norm	Energy conservation	4	US	b
Nickerson & Rogers (2010)	N_In	Implementation intention	Turnout rate	0	US	BP
Niza et al. (2014)	N_Ex	Financial incentives	Chlamydia screening uptake	0	UK	BP

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Oppezzo et al. (2019)	N_Me	Reminder	Treatment adherence (class attendance)	6	US	M&SD
Otaki et al. (2019)	S_At	Color	Household water consumption	5	Japan	2x2
O'Connell & Lang (2018)	N_Me	Reminder	Exam score	0	US	b
O'Hara & Sparrow (2019)	N_Me	Reminder	College reenrollment	0	US	BP
Page & Gehlbach (2017)	N_Me	Reminder	College enrollment	4	US	BP
Patel et al. (2017)	S_Ef	Active choice	Number of patient vaccinated	7	US	BP
Pugatch & Schroeder (2021)	N_Pe	Informational messaging	Major switch	1	US	BP
Pugatch & Wilson (2018, information)	N_Pe	Informational messaging	Tutoring take-up	0	US	BP
Raj Chetty et al. (2014 (cash vs. 4 weeks))	N_Ex	Financial incentives	Review time in days	2	Worldwide	M&SD
Reddy et al. (2017)	N_Pe	Informational feedback	Adherence rate	3	US	M&SE
Reiley et al. (2018)	N_Ef	Convenience	Percent of donation	0	US	2x2
Robitaille, House, et al. (2020)	N_In	Implementation intention	Days taken to file overdue taxes	0	Canada	M&SD
Robitaille, Mazar, et al. (2020, information)	N_Pe	Informational messaging	Organ donor registration	0	Canada	BP
Rodriguez-Priego et al. (2016)	N_At	Visibility	Amount of personal information disclosed	0	Europe	b

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Rohde & Verbeke (2017, 1st quarter)	S_Ex	Conditional incentives	Number of gym visits	3	Netherlands	b
Rolnick et al. (2020)	N_Ef	Convenience	Advance directives completion rate	0	US	2x2
Rommel et al. (2015)	N_Pe	Gain framing	Usage of no junk mail sticker	2	Germany	2x2
Samek (2019, gift vs. control)	N_Ex	Non-financial incentives	Healthy food choice	0	US	BP
Santana et al. (2019)	N_Me	Reminder	Math grade	1	Chile	beta
Schein et al. (2020)	N_Me	Reminder	Voter turnout	0	US	2x2
Schippers et al. (2020)	N_In	Goal setting	Number of course credits	10	Netherlands	M&SD
Schoar & Tantia (2014)	N_Pe	Informational messaging	Amount of savings	0	Pacific Northwest	M&SD
Schwartz et al. (2017, quantitative)	N_Pe	Informational messaging	Colorectal cancer screening uptake	7	US	2x2
Sharps et al. (2020 (study 1))	N_Pe	Graphic	Fruit consumption (grams)	0	UK	F
Shearer et al. (2017)	N_Me	Reminder	Weight of food waste	4	UK	M&SD
Somville & Vandewalle (2018)	N_Ef	Default	Amount of savings	2	India	b
Steinberg et al. (2013)	N_Me	Reminder	Weight loss	6	US	M&SD
Stoffel et al. (2021)	S_Ef	Active choice	Participation rate in colorectal	1	Malta	BP

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Stutzer et al. (2011)	S_Ef	Active choice	cancer screening Actual blood donation	0	US	M&SD
Sudarshan (2017)	S_In	Social norm	Electricity consumption	4	India	b
Sutter et al. (2020)	N_In	Commitment making	Punctual dues payment rate	1	Austria	BP
Tal & Wansink (2015)	N_Me	Priming	Amount of fruit and vegetable purchased	0	US	M&SD
Tassiello et al. (2018)	S_Ef	Inconvenience	Online ratings of hotel	0	UK	b
Tiefenbeck et al. (2018)	S_Pe	Informational feedback	Energy use per shower	2	Switzerland	b
Tonke (2020)	N_Pe	Informational messaging	Water consumption	0	Nambia	b
Torres & Carlsson (2018)	S_In	Social norm	Water consumption	11	Columbia	MG&SD
Tyers (2018)	N_In	Social norm	Purchase of carbon offset	0	UK	2x2
van Bavel et al. (2019)	S_Pe	Gain framing	Probability of suffering a cyberattack	0	Europe	M&SD
van Gestel et al. (2020, study 2)	N_Ef	Accessibility	Target food choice	0	Netherlands	2x2
van Kleef et al. (2012)	N_Pe	Availability	Daily sales of healthy snacks	1	Netherlands	M&SD
van Kleef et al. (2014)	N_Pe	Appearance	Whole wheat bread consumed per child	0	Netherlands	M&SD
van Teunenbroek & Bekkers (2020)	N_In	Social norm	Amount of donation	0	Netherlands	M&SD

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Vandenbroele et al. (2019)	N_At	Visibility	Sales of meat-free sandwiches	1	Belgium	2x2
Vandenbroele et al. (2021)	N_At	Visibility	Purchase of meat substitutes	1	Belgium	2x2
Vasiljevic et al. (2019)	S_At	Font size	Total calories of sold items	4	UK	b
Wagstaff et al. (2019)	N_Me	Reminder	Treatment follow-up	0	US	2x2
Weijers & de Koning (2020, frame)	N_Pe	Gain framing	Dispenser use rate	0	Netherlands	2x2
Wilson et al. (2017, boxed vs. unboxed)	S_Pe	Appearance	Uptake of the targeted good	0	US	BP
Wright et al. (2017, study1)	N_Me	Reminder	Medicaid enrollment	1	US	BP
Wyse et al. (2019)	N_At	Visibility	Target food choice	0	Australia	OR
Zarghamee et al. (2017, study 1)	N_Ef	Default	Amount of donation	0	US	b
Zhang et al. (2020)	N_Me	Reminder	Reported any countable earnings	0	US	b