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The effectiveness of nudges in improving the self-management of patients with chronic diseases: A systematic literature review☆

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ABSTRACT

In this systematic literature review, we identify evidence on the effectiveness of nudges in improving the self-management of adults with chronic diseases and derive policy recommendations. We included empirical studies of any design published up to April 12th, 2018. We synthesized the results of the studies narratively by comparing statistical significance and direction of different nudge types' effects on primary study outcomes. Lastly, we categorized the nudges according to their degree of manipulation and transparency.

We identified 26 studies, where 13 were of high or moderate quality. The most commonly tested nudges were reminders, planning prompts, small financial incentives, and feedback. Overall, 8 of 9 studies with a high or moderate quality ranking, focused on self-management outcomes, i.e., physical activity, attendance, self-monitoring, and medication adherence, found that nudges had significant positive effects. However, only 1 of 4 studies of high or moderate quality, analyzing disease control outcomes (e.g., glycemic control), found that nudges had a significant positive effect for one intervention arm.

In summary, this review demonstrates that nudges can improve chronic disease self-management, but there is hardly any evidence to date that these interventions lead to improved disease control. Reminders, feedback, and planning prompts appear to improve chronic disease self-management most consistently and are among the least controversial types of nudges. Accordingly, they can generally be recommended to policymakers.

1. Introduction

Since 2008 a growing number of international organizations and government bodies worldwide have begun to apply insights from behavioral science to public policy [1]. At the same time, the number of studies conducted by governmental behavioral science departments, or "nudge units" as they are known mainly in the United Kingdom and United States, increased tenfold between 2010 and 2016 [2]. According to Thaler and Sunstein [3], who introduced the concept in 2008, a nudge "is 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".

Nudges are attractive to policymakers because they attempt to steer individuals in a desired direction, but by definition should be easily avoidable and not impinge upon freedom of choice [3]. These features distinguish them from behavioral economic-informed coercive measures by the government such as smoking bans (so-called 'shoves') and regulatory interventions against the 'behavioral economic-informed harmful manipulation of consumers by private organizations' (so-called 'budges') [4–6]. While nudges are not a new policy instrument [7], they were not implemented as frequently or systematically, nor were they described using the term "nudge" or with explicit reference to behavioral economics, before 2008. Although the extent to which nudges do indeed fully preserve freedom of choice and are compatible with libertarian attitudes is subject to debate, they are generally thought to be less intrusive than conventional policy instruments, such as legal regulations, taxes, or other substantial financial incentives [8,9].

Cost-effectiveness studies on nudges are still sparse. Nevertheless, some of the first assessments of this nature suggest that nudges can be highly cost-effective compared to other public policy tools

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[10]. In addition, it has been shown that nudges can be effective in several different contexts, for example in increasing workplace pension savings, tax payments, organ donations, and vaccination uptake [2,11,12]. Finally, nudges do not necessarily compete with conventional policy measures, but rather can be used as complements to them [13].

There is evidence that improving the self-management of people with chronic diseases can prevent deterioration in patients' health and, in doing so, decrease future healthcare costs [14–19]. Interventions consisting exclusively of information provision and education have been shown to be effective at improving self-management in chronic disease only to a limited extent [20,21]. Behavioral scientists ,[e.g., 20–22] assume that this is due to the many decision biases people with chronic diseases face, such as ambiguity aversion [23,24], omission bias [25], status quo bias (inertia) [26,27], unrealistic optimism [28], hyperbolic discounting (present bias) [29] and loss aversion [30], leading them to behaving irrationally (see appendix: Table 4). They consider nudges to be a promising solution to counteract the adverse effects of these biases.

Evidence on the effectiveness of nudges in improving certain health behaviors is growing [31,32]. To date, however, systematic reviews of nudges have focused primarily on nudge interventions designed to improve individual health behaviors within the realm of primary prevention, such as healthy eating, smoking cessation, reducing alcohol consumption, or increasing physical activity [33–39]. To our knowledge, empirical evidence on the effectiveness of nudge interventions for enhancing the self-management of people with chronic diseases has not been synthesized in a systematic way. Filling this research gap is therefore the first objective of this paper. While different chronic diseases are comparable only to a certain extent, they share some common features, such as the lack of a cure, gradual disease onset and progression, and long-term consequences with uncertain prognoses [40]. People with chronic diseases must self-manage their disease continuously and at the same time deal with emotional distress and constant uncertainty. Due to these commonalities, we considered it meaningful to analyze studies that evaluated the effectiveness of nudges designed to improve the self-management of any chronic disease, with the exception of mental disorders, as including these in their complexity and heterogeneity would have gone beyond the scope of our analysis.

The second objective of our paper is to explore possibilities for policymakers to implement nudge interventions aimed at improving the self-management of people with chronic diseases. Accordingly, we not only give a comprehensive overview regarding the effectiveness of the identified nudge interventions, but, by mapping them according to their degree of manipulation and transparency onto an existing theoretical framework, we also take into account that the implementation of specific nudge types could be controversial in democratic societies.

2. Methods

2.1. Nudge definition

Thaler and Sunstein's [3] definition of a nudge is difficult to operationalize, as it states only that nudges (e.g., defaults, reminders or planning prompts) lead to predictable change in human behavior and are different from significant economic incentives (e.g., taxes, deductibles) or regulation [7]. Hausman and Welch [41] add further detail to this definition by emphasizing that nudges represent intentional attempts to prevent irrational decisions (e.g., nonadherence to medication, failure to implement lifestyle changes) by positively transforming the behavioral biases and heuristics upon which these are based [9]. We rely upon this definition of nudge in our systematic review.

Consequently, we were interested in any kind of nudge designed to intentionally influence the behavior of individuals in a specific decision situation characterized by biases or heuristics through the use of stimuli (for a list of relevant biases and heuristics for the self-management of chronic diseases see appendix: Table 4). Predictable changes we expected to find through the use of nudges are improvements in chronic disease self-management tasks, such as regular blood glucose monitoring, adhering to medication regimens, or implementing lifestyle adjustments, such as keeping to diet and exercising regularly.

In compliance with existing research [9,42], we do not consider the mere provision of factual information to be a nudge. Nudges we expected to find for improving self-management behaviors of individuals with chronic diseases included defaults, behavior contracts, reminders, feedback, planning prompts (e.g., asking someone about his implementation intentions or goals), peer comparisons, social norms, social support, and information design nudges (e.g., framing, priming, simplification) [e.g., 43].

Since Thaler and Sunstein [3] only exclude "significant economic incentives" in their definition of nudges, it is debated in the nudge literature whether, and which, financial incentives can be regarded as nudges [e.g., 44]. In line with several other researchers [e.g., 45–49] we consider small, non-substantial financial incentives (including lottery incentives, escalating incentives or fixed financial incentives) to be nudges if they aim to prevent irrational decisions by exploiting behavioral biases such as hyperbolic discounting [29] or loss aversion [30].

2.2. Search algorithm

We developed our search algorithm based on the PICOS framework (population, interventions, comparator, outcomes, study design) [50] (see appendix: Table 5).

To identify the population of interest, i.e., people with a chronic disease, we searched for the umbrella terms chronic disease, chronic condition, chronic illness, noncommunicable disease, and NCDs. Furthermore, we included additional specific search terms for common chronic diseases, i.e., cardiovascular diseases, cancers, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma), diabetes, and muscoskeletal diseases (such as rheumatoid arthritis and back pain) [51].

For the selection of search terms for the intervention category, we piloted the search with the terms "nudg*", "e-nudg*", "choice architect*" and "behavioral economic*". After realizing that, with this search strategy, we missed many relevant studies, we revised the search algorithm and decided to include relevant terms of nudge subcategories in combination with the umbrella term "behavioral intervention", in addition to the original search terms. The problem that many eligible studies do not refer to nudges, but instead use nudge sub-category terms has been identified previously by other authors of systematic literature reviews on nudge interventions [e.g., 33,38].

To develop a better understanding of relevant additional search terms in order to identify these studies, we consulted the literature on existing categorizations of nudges [43,46,49]. We consider the MINDSPACE (Messenger, Incentives, Norms, Defaults, Salience, Priming, Affect, Commitment and Ego) framework to be the most relevant for identifying nudge subcategory terms, as it is a popular policy 'toolkit' for the implementation of nudges, and the included terms for nudge subcategories are commonly used in the nudge literature [46]. In addition, we consulted Sunstein's list of the ten most important nudges [43] and the list of Münscher et al. on choice architecture techniques [49]. When comparing these two lists to the MINDSPACE framework, many similarities can be found. Based on the comparison of these categorizations, as well as our knowledge of the existing nudge literature, we included the following

additional terms for nudge subcategories in our search: incentives, defaults, salience, affect, norms, messenger, priming, reminders, commitment, ego, feedback, peer comparison, alerts, and framing.

The outcomes we searched for were changes in self-management behaviors (intermediate outcomes) and subsequent changes in disease control (end outcomes). According to Corbin and Strauss [52], self-management behaviors include medication and monitoring adherence, attendance (e.g., at screening visits, check-ups, exercise sessions), lifestyle changes (e.g., increased physical activity), and the processing of emotions that arise from having a chronic illness. Disease control parameters are objective endpoints (such as hospital admissions or disease-specific indicators like glycemic control) that provide meaningful information about the progression of a chronic disease. In addition to improving disease control, changes in self-management behaviors can also have an impact on patient-related outcomes, such as health-related quality of life [e.g., 53]. However, such outcomes are not the focus of this review.

To identify studies analyzing the effectiveness of nudges on chronic disease self-management we searched for relevant nouns and verbs associated with self-management behaviors or behavioral changes. We also searched for general adjectives indicating an improvement/increase or a reduction/worsening. The search terms for the outcome category built upon the search strategy of Hollands et al. [35].

Search limits were only applied for the Web of Science database, where we excluded articles of irrelevant Web of Science categories, such as chemistry, astronomy, engineering, biology, or physics, which use the term nudge in different contexts. In the appendix (Table 5) we present the detailed search strategy for the MEDLINE (PubMed) database. A full list of stepwise search results for each search engine is available upon request from the authors.

2.3. Inclusion and exclusion criteria

To be included, studies had to contain an analysis of the effect of nudging on adults (≥18 years) who had any type of chronic disease with the exception of mental disorders. We only included empirical research papers reporting on studies of any design, such as randomized controlled trials (RCTs), quasi-experimental studies, cohort studies, longitudinal studies, and cross-sectional studies.

We excluded reviews of existing evidence, duplicate reports, studies with an ineligible study design (e.g., pilot trials, study protocols, feasibility, descriptive/qualitative studies), and studies that analyzed an ineligible population (e.g., children, people without a chronic disease), focused on irrelevant outcomes (e.g., enrollment in a trial), or evaluated interventions that did not qualify as a nudge. Thus, we excluded studies analyzing other behavioral economic-informed measures, such as 'budges' or 'shoves'. Furthermore, we excluded interventions that focused on providers.

We did not restrict our search to any geographical or social setting, language, or length of follow-up.

2.4. Literature search and study selection

We searched in the databases Web of Science Core Collection, MEDLINE (PubMed), and PsycINFO from their start dates up to April 12th, 2018, the day we extracted our search results. In addition, we conducted keyword searches in Google Scholar and manually searched the reference lists of included articles and the websites of the governmental nudge units that had conducted the most behavioral trials between 2010 and 2016. These were the Behavioural Insights Team in the UK, the Social and Behavioral Science Team in the US, the Behavioural Economics Team of the Australian Government, the Ministry of Manpower in Singapore, and the Behavioural Insights Network Netherlands [2].

After removing duplicates, two researchers (MM and MZ) independently screened the titles and abstracts of the obtained records to determine which papers should be retrieved in full text and assessed. In cases where we were unable to access the full text, we requested this from the authors via ResearchGate or email. Disagreements about the inclusion or exclusion of a paper were resolved by consulting a third researcher (JS).

2.5. Data collection and study quality

Using a data extraction sheet, we extracted information from the included papers on study location, study design, intervention(s) (type, short description, duration, and follow-up period), study population (chronic disease type, sample size, mean age, gender), methods (recruitment of study participants, statistical methods), and main outcomes (reported as differences between the intervention and control groups). In the event of uncertainties or missing information on study characteristics, we contacted the study authors by email.

To judge the relevance of the identified studies for the research question, two researchers (MM and MZ) independently assessed the quality of the studies using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies [54]. As one of the tools recommended by the Cochrane Collaboration for evaluating the quality of primary quantitative public health studies, the EPHPP comprises component ratings of the extent of selection bias, study design, control of confounders, blinding of assessors and study participants, data collection methods, share of withdrawals and dropouts, intervention integrity, and appropriateness of data analysis [55]. In compliance with the EPHPP guidelines, we summed our assessments of each of these components to form an overall rating of each study using one of the three categories strong, moderate and weak.

2.6. Results and evidence synthesis

Due to the heterogeneity of study designs and outcome measures in the included studies, comparing effect sizes or conducting a meta-analysis would not have led to meaningful results. Instead, we compare the studies to each other in terms of the type of nudge intervention they assessed and the statistical significance and direction (positive/negative) of the effects they report for the primary outcome measure and synthesize these in a narrative fashion.

It has been disputed in the literature whether studies that receive a weak quality rating should be categorically excluded from the evidence synthesis of systematic reviews. The Cochrane Handbook for Systematic Reviews of Interventions [55] generally recommends that they should not be included. Other researchers have criticized this approach, however, as such studies might still contribute to the topic of concern, even though they come with a high risk of bias [56]. We decided to report the findings of these studies in our results section while highlighting their rating, and to exclude them from the evidence synthesis and evidence base from which we derive policy recommendations.

2.7. Framework for deriving policy recommendations

We evaluate the nudge interventions reported in studies of moderate or high quality in terms of their transferability to public policy. To do so, we classify the interventions according to the Framework for the Responsible Use of the Nudge Approach to Behaviour Change in Public Policy developed by Hansen and Jespersen [9] (Table 1). Serving as the basis for the policy recommendations we set out in this paper, this classification differentiates between four types of nudges within two dimensions.

Table 1
Framework for the Responsible Use of the Nudge Approach to Behaviour Change in Public Policy.

		Transparent	Non-transparent
System 2 thinking	*Definition*	*Transparent facilitation of choice:* Transparent type 2 nudges are the least invasive form of nudging as they empower the nudged individuals and enable them to choose freely by drawing attention to seemingly irrational behaviors and the consequences of these behaviors.	*Manipulation of choice:* Non-transparent type 2 nudges are highly invasive. They unconsciously manipulate the reflective thinking processes of the nudged individuals. Because their influence is often not recognized, it is difficult for individuals to avoid them.
	Examples	Prompts, reminders, feedback, commitment mechanisms	Framing, subtle substitution of goals, subconscious cues, anchoring, priming, lottery incentives
	Policy recommendations	The implementation of these nudges is the least controversial.	The implementation of these nudges is highly controversial in democratic societies. Even type-consent and active disclosure of these nudges do not justify their use.
System 1 thinking	*Definition*	*Transparent influence (technical manipulation of behavior):* Transparent type 1 nudges are more intrusive than transparent type 2 nudges. They influence automatic behaviors and the resulting consequences in a transparent way. Although the transparency aspect discloses the intention behind the nudge, these nudges are hard to avoid in practice as they are directed at unconscious behaviors.	*Non-transparent manipulation of behavior:* Non-transparent type 1 nudges are more intrusive than transparent type 1 nudges. They influence the behavior of citizens by subtle arrangements of the environment. Individuals are unlikely to be able to avoid these nudges in their everyday lives as they are unaware of their influence.
	Examples	Explicit defaults, explicit visual illusions, speed bumps	Implicit defaults, implicit visual illusions, implicit design or arrangements of the environment (e.g., food arrangement, plate sizes)
	Policy recommendations	The responsible use of these nudges is acceptable as long as policymakers can assure that they would be able or willing to defend their use publicly to their citizens.	Policymakers should always disclose the use of these nudges and obtain at least general consent for their use. Further, they should ensure that the implemented nudges are in line with individuals' interests and based on democratic procedures.

Source: Authors' own representation based on Hansen and Jespersen [9].

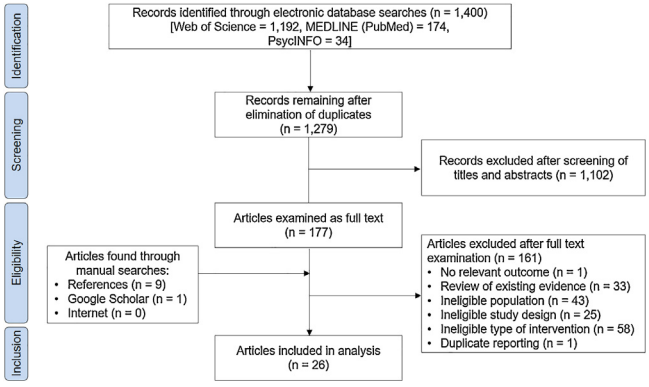

Fig. 1. PRISMA flow diagram.
Source: Authors' own representation.

The first dimension distinguishes between nudge types 1 and 2 [9]. Although both types address automatic thinking processes, type 1 nudges influence automatic thinking in order to change automatic behaviors, whereas type 2 nudges influence reflective choices by drawing attention to their specific aspects or affecting subjective assessments and premises. The second dimension distinguishes between transparent and non-transparent nudges [9]. While it can be assumed that people recognize a transparent nudge itself as well as the intention behind it, the opposite is true for non-transparent nudges.

3. Results

Of the 1400 records we identified, 1279 remained after the removal of duplicates. We excluded 1102 of these after screening titles and abstracts. We examined the full text of the remaining 177 records plus 10 articles found through manual searches to determine their eligibility. Overall, 26 articles met our inclusion criteria and were subject to further analysis (see Fig. 1).

3.1. Characteristics of the included studies

Of the included 26 studies, three explicitly use the term "nudge" [57–59] and two others refer to the broader concept of behavioral economics [60,61]. Although the remainder refer only to sub-categories of nudges, we chose to include these because they match our definition of a nudge.

Table 2 provides an overview of the number of included studies sorted by intervention type and primary outcome category. Among these, the most commonly studied nudges are reminders (n = 11), planning prompts (n = 9), small financial incentives (n = 8) and feedback (n = 5). Because many studies (n = 11) analyze the effects of more than one nudge type in different intervention arms or of combinations of different nudge types, the total number of nudge types exceeds the number of included studies. The most common primary outcomes are physical activity, disease control, and medication adherence. Most of the studies are concerned with improving the self-management of people with diabetes mellitus (n = 11), heart problems (n = 6), or respiratory diseases, such as asthma (n = 2) or chronic obstructive pulmonary disease (COPD) (n = 2). Other chronic diseases like stroke, multiple sclerosis, HIV/AIDS, or severe food allergies are covered by one study each.

Table 6 in the appendix gives an overview of the general characteristics of the studies, of which the majority were conducted in the US (n = 19). Besides the US, studies from Denmark (n = 2), Jordan (n = 1), Kenya (n = 1), Pakistan (n = 1), the Philippines (n = 1), and Portugal (n = 1) are included in the review. Furthermore, the most frequently used study designs are randomized controlled trials (RCTs) (n = 19), or slightly modified forms like one open RCT, one randomized experimental-control design or one mixed-methods RCT. In addition, two quasi-experimental designs, one follow-up study, and one retrospective cohort study are included in the review.

Table 7 in the appendix shows the detailed characteristics of the nudge interventions analyzed in the included studies.

Table 2
Studies by nudge intervention type and primary outcome category.

Nudge intervention type	Primary outcome category				
	Disease control	Self-monitoring	Medication adherence	Attendance	Physical activity
Financial incentives	4	1	1	2	–
Behavior contracts and commitments	1	–	–	–	2
Planning prompts	2	1	1	1	5
Reminders	3	–	4	1	3
Information design (e.g., framing, priming and simplification)	1	–	1	–	–
Positive affect and salience	–	–	–	–	2
Feedback	1	–	1	–	3
Peer comparison and social norms	–	–	–	–	1
Social support	3	–	1	–	–

Source: Authors' own representation.
Note: The total number of nudge intervention types exceeds the number of included studies, as many studies analyzed the effects of more than one nudge type or the effect of combinations of nudge types.

3.2. Quality of the included studies

We rate the quality of most of the included studies as either weak (n = 13) or moderate (n = 11). Only two studies receive a strong quality rating (see appendix: Table 8). Overall ratings of weak are due primarily to weak component ratings for selection bias, blinding or withdrawals, and dropouts.

Selection bias is a major concern for all of the included studies. The majority of these studies recruited participants from hospitals and office-based practices. Participants recruited in this manner may be less likely to be representative of the target population. In many of the other studies, there was also a potential for selection bias due to low participation rates when recruiting participants from more comprehensive sources, for example through registries or insurance claims data.

Furthermore, we give many studies a weak component rating for blinding, because the assessors and participants were not blinded to the intervention or the blinding procedure itself was not reported. Blinding participants to the research questions appeared to be difficult in many of the studies as the researchers had to obtain informed consent from them. It is unclear, however, whether participants' awareness of the research question would be problematic to begin with. Indeed, many nudges are transparent by nature, and evidence suggests that nudges work even if the people being nudged are informed about the interventions in advance [62]. Furthermore, in liberal democracies, it might be more acceptable to nudge people in a transparent way or to obtain consent before nudging them subconsciously in a particular direction (see policy recommendations). Weak component ratings for withdrawals and dropouts resulted, in almost all cases, from the failure to report the number of dropouts and reasons for them.

3.3. Results by nudge type and primary outcome

Table 3 provides an overview of the study results arranged by nudge type and primary outcome.

3.3.1. Disease control

Disease control parameters are objective endpoints that provide meaningful information about the progression of a chronic disease. We identify eight studies that assess the effects of nudge interventions on disease control [61,64,66,71,73,78,79,81]. In this category, we include studies that examine effects on blood glucose levels (HbA1c) (diabetes mellitus) (n = 6), time until first vascular readmission (heart disease) (n = 1), and an out-of-range international normalized ratio (below or above target range) accounting for poor anticoagulation control (heart disease) (n = 1).

In studies that use this outcome category, we rate the quality of one study as high [79], three studies as moderate [61,73,78], and four studies as weak [64,66,71,81]. The studies assess the effects of small financial incentives (n = 4), reminders (n = 3), planning prompts (n = 2), social support (n = 3), feedback (n = 1), behavior contracts and commitments (n = 1), and information design (n = 1). The majority of the studies (n = 6) do not find statistically significant differences between the intervention and control groups in this regard. Only two studies find statistically significant positive effects of nudge interventions on the corresponding disease control outcome for at least one intervention arm [71,79]. One of these studies, however, we judge to be of weak quality.

3.3.2. Self-monitoring

Self-monitoring is another relevant outcome for the self-management of chronic diseases, especially for insulin-treated patients with diabetes mellitus, as they need to measure their blood glucose levels regularly in order to calculate the necessary insulin doses. One of the included studies assesses the effects of financial incentives [80] and another the effects of planning prompts [72] on self-monitoring among patients with diabetes mellitus types 1 and 2. Both studies find significant positive effects on the outcome. We rate one study as being of moderate [80] and the other as being of weak quality [72].

3.3.3. Medication adherence

Evidence suggests that about one quarter of patients do not adhere to prescribed medication regimens or advice and that this can lead to unnecessary use of healthcare resources [14,15,84]. Improving medication adherence is therefore another important outcome of chronic disease self-management. We found five studies that analyze the effects of nudge interventions on medication adherence [57,58,59,68,70]. These are reminders (n = 4), social support (n = 1), small financial incentives (n = 1), feedback (n = 1), and information design (n = 1). Medication adherence was operationalized as daily openings of electronic pill bottles (heart disease) (n = 1), self-reporting of medication taken (stroke) (n = 1), a binary indicator of medication adherence above or below 90% measured by actual bottle openings (HIV/AIDS) (n = 1), or medicine dose count at clinical examinations (asthma) (n = 1). Even though these are validated, reliable, and commonly used measures of medication adherence, one needs to take into account that no ideal measure of medication adherence exists and each of these methods has potential caveats, which have been investigated elsewhere [85–87]. We included the carrying of an epinephrine auto-injector (food allergies) (n = 1) in the category of medication adherence, as it is important for patients with food allergies to have this available at all times.

The majority of the studies (n = 4) find that the tested nudge interventions had statistically significant positive effects on med-

Table 3
Overview of study results according to nudge type and primary outcome.

Nudge type	Chronic disease	Study	Primary outcome category				
			Disease control	Self-monitoring	Medication adherence	Attendance	Physical activity
Reminders	Diabetes mellitus types 1 & 2	**Austin and Wolfe [63]**				+ [b]	
	Diabetes mellitus type 2	*Arora et al. [64]*	*(+)* [a]				
		Tamban et al. [65]					*+* [b]
	Heart disease	*Kimmel et al. [66]*	*(+)* [b]				
		Reddy et al. [59]			+ [b]		
		Volpp et al. [61]	**(-)** [c]				
		Alsaleh et al. [67]					+ [a]
	Asthma	*Strandbygaard et al. [68]*			*+* [a]		
	Stroke	**Kamal et al. [58]**			+ [a]		
	Rheumatoid arthritis	**Thomsen et al. [69]**					+ [a]
	HIV/AIDS	*Pop-Eleches et al. [70]*			*(+)* [b]		
Planning prompts	Diabetes mellitus types 1 & 2	*Chamany et al. [71]*	*+* [a]				
		Nadkarni et al. [72]		*+* [b]			
	Diabetes mellitus type 2	**Trief et al. [73]**	**(+/-)** [a]				
		Weiss et al. [74]				*+* [b]	
	Heart disease	**Alsaleh et al. [67]**					+ [a]
	COPD	**Berry et al. [75]**					**(-)** [b]
		Cruz et al. [76]					+ [a]
	Rheumatoid arthritis	**Thomsen et al. [69]**					+ [a]
	Multiple sclerosis	*Pilutti et al. [77]*					*+* [b]
Small financial incentives	Diabetes mellitus types 1 & 2	**Misra-Hebert et al. [78]**	**(+)** [a]				
		Long et al. [79]	**(+)** [a]				
		Sen et al. [80]		+ [b]			
		Austin and Wolfe [63]				+ [b]	
	Heart disease	*Kimmel et al. [66]*	*(+)* [b]				
		Volpp et al. [61]	**(-)** [c]				
		Gaalema et al. [60]				*+* [b]	
	Food allergies	*Cannuscio et al. [57]*			*+* [b]		
Feedback	Heart disease	**Reddy et al. [59]**			+ [b]		
		Volpp et al. [61]	**(-)** [c]				
		Alsaleh et al. [67]					+ [a]
	COPD	**Cruz et al. [76]**					+ [a]
	Rheumatoid arthritis	**Thomsen et al. [69]**					+ [a]
Social support	Diabetes mellitus types 1 & 2	**Long et al. [79]**	+ [a]				
	Diabetes mellitus type 2	**Trief et al. [73]**	**(+/-)** [a]				
	Heart disease	**Reddy et al. [59]**			+ [b]		
		Volpp et al. [61]	**(-)** [c]				
Behavior contracts and commitments	Diabetes mellitus type 2	**Trief et al. [73]**	**(+/-)** [a]				
	COPD	**Cruz et al. [76]**					+ [a]
	Rheumatoid arthritis	**Thomsen et al. [69]**					+ [a]
Positive affect and salience	Heart disease	**Peterson et al. [82]**					+ [a]
	Asthma	*Mancuso et al. [83]*					*(-)* [a]
Information design (e.g., framing, priming and simplification)	Diabetes mellitus types 1 & 2	*Gopalan et al. [81]*	*(+/-)* [a]				
	HIV/AIDS	*Pop-Eleches et al. [70]*			*(+)* [b]		
Peer comparison and social norms	COPD	**Berry et al. [75]**					**(-)** [b]

Source: Authors' own representation.
Statistical significance: Brackets and no color: no statistically significant effect ($p \geq 0.05$); Green color: statistically significant positive effect ($p < 0.05$); Yellow color: statistically significant mixed effect ($p < 0.05$); Red color: statistically significant negative effect ($p < 0.05$).
Direction of effect: + positive; - negative; +/- mixed.
Study quality: Italic writing and light colors (if statistically significant): weak quality studies; Bold writing and dark colors (if statistically significant): moderate/strong quality studies.
Statistical tests: a Difference in change between control and intervention group; b Difference between control and intervention group at follow-up; c Difference between control and intervention group expressed as hazard ratio.
Notes: The total number of nudge interventions exceeds the number of included studies, as many studies analyzed the effects of more than one nudge intervention or the effect of combinations of nudge interventions.
For studies testing the same nudge type in multiple intervention arms, we report an overall result, giving statistically insignificant results more weight.

ication adherence. Only one study finds no statistically significant differences between the intervention and control groups. Three of the studies [57,68,70] are of weak and two are of moderate quality [58,59].

3.3.4. Attendance

The effectiveness of nudge interventions in increasing attendance is analyzed by three studies [60,63,74]. The interventions used are small financial incentives (n = 2), reminders (n = 1), and

planning prompts (n = 1). The primary outcomes are HbA1c and LDL-C screening (diabetes mellitus) (n = 1), dilated fundus examination (diabetes mellitus) (n = 1), and the number of cardiac rehabilitation exercise sessions completed (heart disease) (n = 1). All three studies find statistically significant positive effects on attendance. However, only the study by Austin and Wolfe [63] receives a moderate quality rating, whereas the other two studies are rated as weak [60,74].

3.3.5. Physical activity

Eight studies focus on the effectiveness of nudge interventions in increasing physical activity [65,67,69,75,76,77,82,83]. For this outcome, the studies analyze the following types of interventions: planning prompts (n = 5), reminders (n = 3), feedback (n = 3), positive affect and salience (n = 2), behavior contracts and commitments (n = 2), and peer comparison and social norms (n = 1). The primary outcomes are energy expenditure (kcals/week) (COPD, asthma and heart disease) (n = 3), physical activity level (min/week) (heart disease) (n = 1), self-reported physical activity (multiple sclerosis) (n = 1), daily physical activity (e.g., number of steps, time spent in moderate-to-vigorous physical activity) (n = 1) (COPD), and sitting time reduction (hours/day) (rheumatoid arthritis) (n = 1). Additionally, we include one study (n = 1) that focuses on the outcome "adherence to diet and exercise recommendations" in the category of physical activity (diabetes mellitus), as this intervention includes a physical activity component.

The majority of studies (n = 6) find that the nudge interventions have statistically significant positive effects on physical activity. Two studies find no statistically significant differences between the intervention and control groups. We rate the quality of one study as strong [82], four studies as moderate [67,69,75,76] and three studies as weak [65,77,83].

4. Discussion and conclusion

This systematic review provides an overview of evidence on the effects of nudging on the self-management of chronic diseases. The studies we identified are highly heterogeneous, both in terms of the design of the nudge interventions and the primary health outcomes. The findings of the studies are also mixed: Just over half find that nudge interventions lead to statistically significant improvements in self-management compared to the control groups. None of the included studies report statistically significant negative effects. Thus, all of the nudges examined in the included studies led either to improved chronic disease self-management or had no statistically significant effect in this regard. We find no systematic differences between the results of the studies whose quality we rate as weak compared to those whose quality we rate as moderate or high.

To our knowledge, this systematic review is the first to summarize and synthesize evidence on the effectiveness of nudges in improving tertiary prevention behaviors. Other systematic reviews, that look at nudge interventions designed to improve individual health behaviors, are either broad scoping reviews of general trends in the use of nudges – either domain-general [e.g., 32], in the field of primary prevention (e.g., diet, physical activity, alcohol and tobacco use [35]), or indication specific (e.g., diabetes mellitus [88]) – and disregard study quality, or they focus on primary prevention behaviors [33,34,36,37,39]. In addition, our review is one of the few to consider studies that use nudge principles without referring explicitly to nudges or nudge theory. While other systematic reviews [e.g., 33,38] also encountered difficulties in identifying studies that examine nudge interventions without making reference to nudge theory, they did not expand their search terms to include subcategories of nudges as we did in our approach.

4.1. Evidence synthesis

Excluding studies with weak quality ratings left 13 studies, eight of which find that the respective nudge interventions have statistically significant positive effects on chronic disease self-management (physical activity: n = 4; medication adherence: n = 2; self-monitoring: n = 1; attendance: n = 1). Four studies of high or moderate quality, however, find no statistically significant effects in this regard (disease control: n = 3; physical activity: n = 1). Furthermore, one high quality study finds statistically significant positive effects on disease control for one intervention arm and statistically non-significant effects for another.

A comparison of intervention types indicates that the nudges that have been studied the most are reminders, planning prompts, financial incentives, feedback, and social support. For reminders, planning prompts, and feedback, the number of studies reporting statistically significant improvements in chronic disease self-management was greater than the number of studies that did not find statistically significant effects (reminders: 5 out of 6; planning prompts: 3 out of 5; feedback: 4 out of 5). For financial incentives a slightly higher number of studies find non-significant effects, as opposed to significant positive effects (i.e., 3 out of 5). For social support, the evidence is balanced, with two studies finding statistically significant improvements resulting from the intervention compared to the control groups and two studies not finding any statistically significant differences. Due to the small number of studies and the heterogeneity of study designs and interventions, however, we cannot draw any reliable conclusions about differences in the effectiveness between the nudge types under study.

In general, we find no clear pattern in the various nudge interventions' designs that could explain why some interventions led to improvements in chronic disease self-management whereas others did not. For example, reminders led to statistically significant improvements in chronic disease self-management when implemented alone to improve medication adherence in stroke patients [58], in combination with feedback and social support to improve medication adherence in patients with coronary artery disease [59], and in combination with financial incentives to improve attendance for glucose screening in patients with diabetes mellitus types 1 and 2 [63]. However, another intervention, consisting of reminders combined with feedback, financial incentives, and social support (for disease control in patients with heart disease) [61], did not lead to statistically significant improvements in self-management.

We do find a pattern in the outcomes under study. While statistically significant positive effects are reported by the majority of studies of high or moderate quality that analyze the effects of nudge interventions on medication adherence, self-monitoring, attendance, or physical activity, the opposite is true for almost all of the studies that look at disease control outcomes. This finding is critical, as one of the main goals of improving the self-management of chronic diseases is the slowing or stopping of disease progression. The consideration of disease control parameters is crucial, as they are objective endpoints that provide meaningful information about the progression of a chronic disease. In addition, compared to the primary outcomes reported in the other included studies, disease control parameters can be associated most directly with healthcare costs. An explanation for this finding could be that improving disease control parameters, such as HbA1c, is ambitious, as these tend to be long-term outcomes that can further be influenced by confounders like stress or hormonal fluctuations. Because of this, the median follow up time of six months in the included studies, looking at disease control outcomes, might be too short and a measurement at only one point in time is unsuitable for capturing the full effects of nudge interventions.

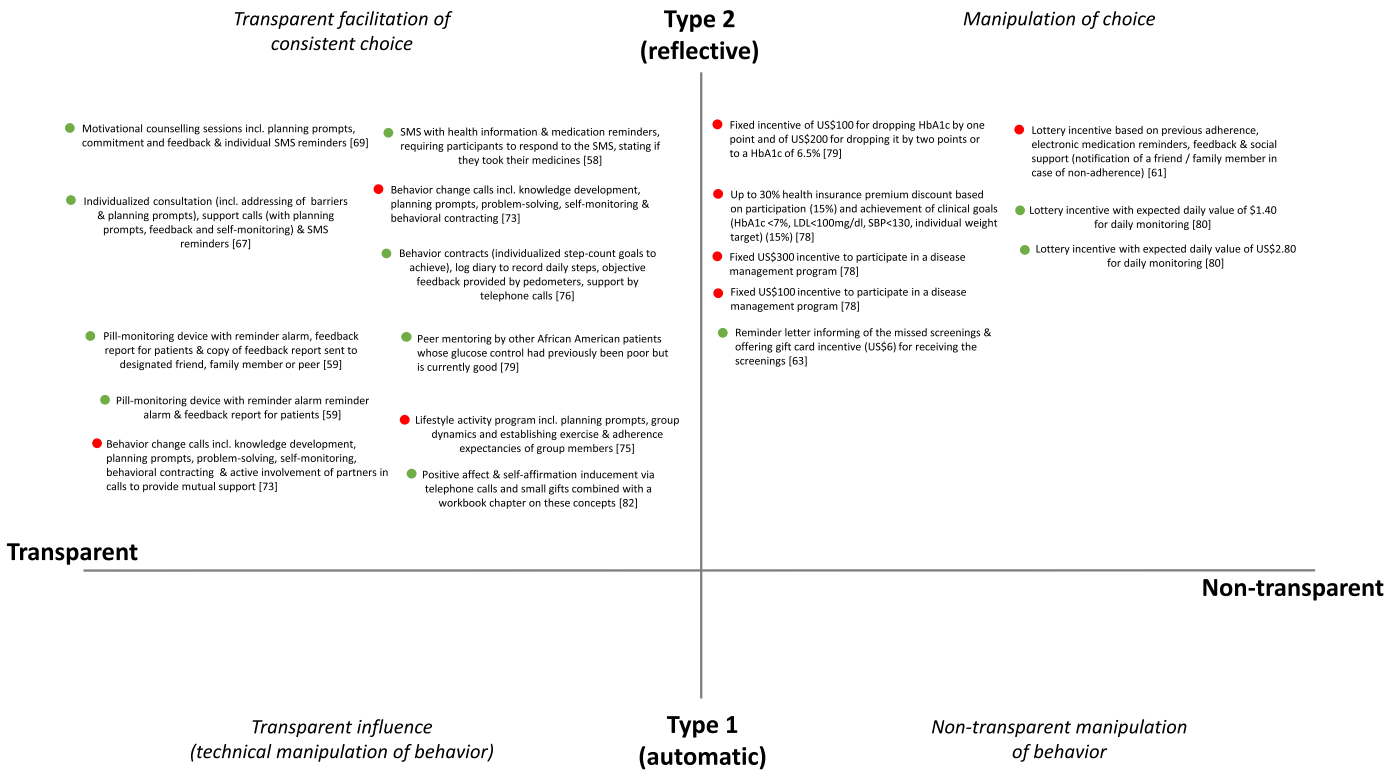

Fig. 2. Classification of nudge interventions according to the Framework for the Responsible Use of Nudging.
Notes: (1) Green = statistically significant positive effect of intervention on primary outcome; Red = no statistically significant differences between intervention and control group. (2) Exclusion of studies with a weak quality rating.

Source: Authors' own illustration based on the Framework for the Responsible Use of the Nudge Approach to Behaviour Change in Public Policy developed by Hansen and Jespersen [9].

4.2. Limitations

This study has several important limitations. First, there is no general consensus in the literature as to what kind of behavioral interventions should be regarded as nudges. Many of the studies that examine interventions that fit our definition of a nudge do not explicitly use this term or even refer to the broader field of behavioral economics. A major challenge of our review was, therefore, to develop a search algorithm that could identify all of the potentially relevant studies. We attempted to address this by including search terms covering sub-categories of nudges, but we cannot be certain that these covered all studies that have looked at interventions based on nudge principles. Second, the studies we ultimately include in our analysis and evidence synthesis are highly heterogeneous in terms of their design, the nudge types tested, and the outcome measures. As a result, we are unable to conduct a meta-analysis or compare effect sizes across studies. Third, we assign half of the studies that met our inclusion criteria (n = 13) a weak quality rating mainly due to high risk of bias in their selection of study participants, their blinding of participants and assessors to the study interventions, and missing information on reasons for withdrawals and dropouts of study participants. We did not consider these studies when drawing conclusions or deriving policy recommendations from the results of our review. Lastly, the evidence on nudge interventions to improve the self-management of chronic diseases is still very sparse. Our conclusions and policy recommendations have been developed with this caveat in mind, but they must nevertheless be interpreted with care.

4.3. Implications for future research

Research on the effectiveness of nudge interventions is still in an early phase, as the concept of nudges as an instrument of public policy only gained popularity in 2008. This is reflected in the small number of studies included in this review that explicitly linked their intervention to behavioral economics or nudge theory. Nevertheless, since Richard Thaler received the Nobel Memorial Prize in Economic Sciences for his work in the field of behavioral economics in 2017, we expect that the amount of research in this area will grow quickly.

To explore the potential of nudges to improve the self-management of chronic diseases further, future research may want to take the following points into consideration:

First, researchers should try to test the effects of different nudges separately within the same context. Individual nudge interventions should be tested first and only then combined with different types of nudges, added in a stepwise fashion, to allow the effects to be disentangled. Furthermore, measuring outcomes continuously over a longer period of follow-up will generate stronger evidence, particularly for disease control outcomes. Long-term interventions can also lead to improvements in this regard.

Second, the studies we identified did not explore potential negative side effects, such as crowding out effects on intrinsic motivation, habituation effects, or effects occurring after the removal of nudges. Future studies of nudges and chronic disease self-management should consider that any intervention can have unintended consequences.

Third, when designing and evaluating nudge interventions to improve the self-management of chronic diseases, it is important to understand disease control as a continuum. Different biases and heuristics are relevant at different stages of disease control [21] (see appendix: Table 4). Accordingly, nudge strategies will probably vary in their effects at different stages along this continuum. Evidence suggests that primarily a distinction needs to be drawn between the initial phases of disease control and continued disease control. Because insecurity and a lack of self-efficacy are common during the former, the corresponding nudge strategies might want to focus on planning prompts and social support, in order to help the individual realize that it is possible to gain control over their chronic condition [21]. At a later stage, the main challenge is to keep the individual motivated so that they will continue the efforts needed to control the disease over the long term. In this phase, nudges should focus on reminders and feedback.

Lastly, it would be useful to gain a better sense of whether the effectiveness of nudge interventions differs according to personal and cultural characteristics such as gender, age, ethnicity or religion, and the extent to which the interventions are grounded in theory.

5. Policy recommendations

Although the evidence is still sparse, the results of our systematic literature review suggest that nudges may be an effective policy tool to improve the self-management of people with chronic diseases. When implementing nudges, however, there are a few things that policymakers might want to consider. Although surveys suggest that public acceptance of nudges is generally high in industrialized Western democracies like Australia, Canada, France, Germany, the United Kingdom, and the United States, ethical concerns remain, particularly in regards to the potential for manipulation [89,90]. In the literature on the ethics of nudges, it is disputed whether, and to what extent, nudges restrict the decision-making autonomy of individuals [91,92]. Although they generally preserve the individual's freedom of choice, nudges can also be designed to exert subconscious influence that goes unnoticed by the individual and may limit his or her decision-making autonomy [93]. Health policymakers should therefore ensure that nudges are used in a responsible and transparent manner that is compatible with democratic values.

With this in mind, it is also important to consider that nudges differ in terms of their intrusiveness and the extent to which they can manipulate choices or behaviors [9]. In Fig. 2, we map nudge interventions from the moderate- and high-quality studies, included in our literature review, to the Framework for the Responsible Use of the Nudge Approach to Behaviour Change in Public Policy, which is explained in greater detail in the methods section of this paper. When sorting the nudge interventions according to their degree of transparency and the enabling of choice, we faced the problem of dealing with complex interventions that could not clearly be attributed to one category [cf. 9]. We addressed this by giving the more intrusive nudges more weight (e.g., an intervention including one transparent and one non-transparent nudge was classified as non-transparent).

It becomes apparent that all the identified studies focus on type 2 nudges designed to influence (reflective) choices of individuals. We categorize eight of the nudge interventions as "non-transparent, type 2 nudges". These consist of interventions that relied on fixed financial or lottery incentives. The lottery incentives, in particular, are considered by Hansen and Jespersen [9] to be manipulative, as people are likely to overestimate the chance of winning. While the fixed financial incentives are less manipulative in this regard, they still make use of subconscious decision biases such as the Ïoss aversionöf individuals – i.e. the fact that individuals perceive losses worse than profits – at least in some contexts [100]. In addition, fixed financial incentives can lead, unnoticeably, to a substitution of goals and could thereby undermine the individual's intrinsic motivation to manage their chronic disease. "Non-transparent type 2 nudges" are considered highly invasive and paternalistic (maybe even more so than traditional policy tools) because their influence is often not recognized [9]. These nudges unconsciously manipulate reflective thinking processes and are therefore unavoidable. Implementing these nudges, especially the lottery incentives, cannot be recommended to healthcare policymakers as they are highly controversial in democratic societies.

The majority of the nudges we identify can be categorized as "transparent type 2 nudges", however, as they consist of interventions such as reminders, feedback, goal-setting and implementation plans, and behavioral contracts, they only draw the attention of individuals to their own behaviors and the consequences of these, and are the least intrusive as they do not impinge upon individuals' freedom of choice. These nudges are the least controversial and can be recommended to policymakers. Indeed they are so trivial that they are often not even recognized as nudges by nudge critics [9].

In conclusion, many of the moderate- and high-quality studies included in our systematic review find that the investigated nudges significantly improved direct self-management outcomes, such as increasing physical activity, attendance (e.g., at screening visits), self-monitoring, and medication adherence in people with chronic diseases. However, almost none of the included studies find that nudges had significant effects on disease control outcomes like HbA1c or rates of rehospitalisation. Thus, nudges appear to be effective for improving chronic disease self-management, but these changes might not be substantial enough to affect disease control within a short observation period. Reminders, feedback, and planning prompts have been shown to improve chronic disease self-management most consistently. They also belong to the least controversial category of nudges and can therefore be recommended to policymakers. However, unless the evidence base grows to prove otherwise, policymakers should not have overly high expectations of how effective nudges can be in improving chronic disease control.

Declaration on transparency and protocol fidelity

The authors confirm that the manuscript is an accurate and transparent account of the study, that no important aspects of the study have been omitted, and that any differences between the review and the study as planned have been explained.

Declaration of Competing Interest

The authors have no conflict of interest to declare.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.healthpol.2019.09.008.

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