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A systematic review and meta-analysis of the effectiveness of nudging to increase fruit and vegetable choice

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Background: Nudging refers to interventions that organize the choice architecture in order to alter people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives. As a strategy to encourage healthy behaviour, nudging can serve as a complement to health education. However, the empirical evidence regarding the effectiveness of nudging as a way to influence food choice remains contradictory. To address this issue, a systematic review and meta-analysis was conducted to test the effects of nudging to encourage people to select more fruit and vegetables. **Methods:** A systematic literature search was performed on PubMed, Medline, PsycInfo, Cochrane library, Scopus and Google Scholar. After quality assessment, 20 articles (23 studies) were retained for narrative synthesis. Twelve articles (14 studies) contained enough information to calculate effect-sizes for meta-analysis using Comprehensive Meta-analysis software. **Results:** The meta-analysis shows that nudging interventions that aim to increase fruit and/or vegetable choice/sales/servings have a moderately significant effect ($d = 0.30$), with the largest effect for altering placement ($d = 0.39$) and combined nudges ($d = 0.28$). **Conclusion:** The results of this review provide an indication of the effectiveness of nudging on fruit and vegetable choice in terms of actual effect-sizes, while also highlighting the problems that must be addressed before more definitive conclusions can be drawn.

Introduction

Overweight and obesity are amongst the most pressing public health concerns worldwide.[1] With a prevalence that has more than doubled since 1980, more than half of the adult population in the USA and Europe are currently overweight or obese.[1] This poses serious public health threats and puts a considerable strain on healthcare and social resources. As overweight and obesity are primarily caused by a physical inactivity combined with an unhealthy diet, part of the answer to this epidemic consists of encouraging people to adopt healthier eating habits, including a higher consumption of fruit and vegetables. To reduce non-communicable diseases, the World Health Organization recommends eating at least 400 g or five portions of fruit and vegetables per day.[2]

To achieve this goal, health promotion strategies must be applied that are based on evidence and grounded in relevant theory. Over the past decades, health psychologists have developed, validated and applied a range of theories and models to predict and change people's health behaviour. Of these models, the ones that are most often used in public health and health promotion are social cognitive models (e.g. Health Belief Model, Theory of Reasoned Action/Planned Behaviour, Protection Motivation Theory, Social Marketing) or stage and process models (e.g. Stages of Change model, Diffusion of Innovation Theory).[3] More recently, however, environmental and associative learning approaches are increasingly finding their way into health promotion theory and practice.[4]

One of the environmental approaches that is receiving increased attention is *nudging*. The concept of nudging was first introduced in the behavioural economic field by Thaler and Sunstein.[5] Their definition of a 'nudge' is 'any aspect of the choice architecture that alters people's behaviour in a predictable way, without forbidding any options or significantly changing their economic incentives.' (p. 6) A nudge should be easy and cheap to avoid, and should not involve a restriction. An example of a nudge that aims to increase food choice is placing healthy foods at a closer distance compared with unhealthy foods, so that it is easier to reach them.[6]

The theory behind nudging is not new: the concept has its fundaments in Tversky and Kahnemann's[7] theory on heuristics and biases, which highlights the interplay between the automatic and reflective system. Most theories of information processing distinguish between two types of processing[8–10]: System 1 processes are unconscious, automatic, rapid and high in capacity, whereas system 2 processes are conscious, slow and deliberative. The distinction between these two system processes explains why people do not always make the choices that are best for them. To change health related behaviour, the challenge is therefore not only to increase peoples' intentions to behave in a healthy way through health education but also to translate these intentions into behaviour. The *intention-behaviour gap*[11] is one of the reasons why motivation-based techniques targeting system 2 processes to change health-related behaviour often have only modest results.[12]

In that respect, nudging can provide a valuable complement, as it targets automatic, affective processes by altering environmental cues. People often use heuristics and biases as a shortcut when making decisions. This is necessary because consciously reflecting on every alternative via a system 2 process would be too time-consuming. However, while heuristics often lead to choices that are unhealthy, nudging uses heuristics that rely on the automatic system to the benefit of people, by directing them towards the healthier behavioural options.

As nudges can be quite heterogeneous and focus on different types of heuristic mechanisms, in this review, we will discuss the findings of the literature distinguishing between three groups based on the typology proposed by Hollands et al.[6]: A category of 'altering properties; (labelling, sizing and functional design), a category of 'altering placement' (availability and proximity) and a category of 'altering both properties and placement' (priming and combined nudges).

The creation of 'healthy heuristics' to influence people's choices is the task of a choice architect, i.e. a person who organizes the context in which people make decisions. A crucial assumption in this regard is that there is no 'neutral' design.[5] Hollands et al.[6] define choice architecture as 'interventions that involve altering the properties or placement of objects or stimuli within micro-environments with the intention of changing health-related behaviour'. This intervention is usually aimed at influencing the behaviour of many people simultaneously and is thus not an individual approach. It is implemented in the environment where the target behaviour is performed, and requires minimal conscious processing. Nudging can be seen as a specific form of choice architecture that uses heuristics with the aim to promote healthy behaviour, while preserving free choice and leaving economic incentives unchanged.

However, while theoretically nudging is very appealing, the conclusions from existing systematic reviews point to inconsistent and weak findings of the effectiveness of nudging in particular settings. Libotte et al.[13] concluded from their review of 15 studies testing the effect of plate size on food consumption that results were mixed. Skov et al.[14] also concluded that the evidence for the effectiveness of choice architecture interventions to change food consumption in self-service settings is inconsistent, and that the 12 studies they reviewed generally were of low quality. Hu (unpublished) also concluded from nine experimental studies that the findings are inconsistent for different types of nudges although altering the availability of food presence seemed to be an effective way to change food behaviour. Similarly, Frerichs et al.[15] report mixed findings from cross-sectional studies on nudging as opposed to longitudinal and experimental studies, and Nornberg et al.[16] concluded from their review of 12 studies that the results regarding the effects of nudging on vegetable intake in the school setting were inconclusive, with a majority of studies showing a weak or moderate quality.

In contrast, Thapa and Lyford[17] concluded from 18 articles that nudging in the lunchroom effectively leads to healthier food decisions although these authors also mentioned the small number of published experimental studies and the limited number of researchers working in this area. Wilson et al.[18] concluded from their review of 13 articles that combined 'salience' and 'priming' nudges show a consistent positive influence on healthier food and beverage choice. Bucher et al.[19] found a positive effect of positional changes of food placements on food choice in sixteen out of 18 studies, but like Wilson et al.[18] also mentioned a need for higher quality studies in the field. In line with these reviews, Hollands et al.[6] underlined that there is not an absence of evidence, but rather a lack of definitional and conceptual clarity concerning the applications of choice architecture interventions and nudging and of high-quality systematic reviews in this area. Indeed, so far only one meta-analysis[20] has been conducted that investigated the efficacy of nudge theory strategies to change dietary choices for healthier ones, leading to the conclusion that nudges result in an increase of 15.3% healthier food choices. However, this meta-analysis did not include the calculation of an effect-size, which is needed to get a more precise idea of how strong the results are.

So although a number of systematic literature reviews of the effects of nudging or choice architecture on healthy food choice are available, only one of these include a meta-analysis. Moreover, most existing reviews focus on healthy diet in general, including both increasing healthy food choice and decreasing unhealthy food choice. Because an increase or decrease of food choice might be guided by different underlying processes, it is important to consider these separately, for instance, by only reviewing studies that aim to increase healthy food choices that include fruits and/or vegetables choice. In addition, several of the existing reviews restrict their research to a specific setting, such as lunch rooms[17] or self-service settings.[14] In order to be able to generalize these findings, one should consider nudges in several settings, assuming that in order to reach populations nudges should be applicable across settings.

In this article, we describe the results of a systematic review and meta-analysis of the effects of nudging to the choice/sales/servings of fruits and vegetables. The review aims to answer the questions: (i) whether nudging is effective in increasing the choice (i.e. choice/servings/sales) of fruit and vegetables compared with a control group/baseline; (ii) whether specific types of nudges are more effective than others in increasing fruit and vegetables choice and and (iii) whether nudging is more effective to increase the choice for vegetables or for fruit. It should be noted that in this review, we only consider studies with food choice, food servings and food sales as behavioural outcome measures. Food consumption is not considered because there are not enough articles that consider this outcome measure, and the effect on this outcome variable may differ from food selection.

Methods

Search strategy

To review the effects of nudging on healthy fruit and vegetable choice, we performed a systematic review involving two stages. The first stage, which took place in February 2015, was exploratory and served to see which key words were appropriate and which search databases could be used. The second stage, which took place in April 2015 with an update in December 2016, involved the actual research process. Both stages were conducted independently by two researchers (V.B. and C.B.), who both performed a systematic literature search on PubMed, Medline, PsycInfo, Cochrane library and Scopus. The update was performed by one researcher (VB). The (combinations of) search terms used were: *'"Nudg*" AND "food"' OR '"Nudg* AND "Diet"' OR '"Nudg*" AND "eat"' OR '"Nudg*" AND "Nutri*"' OR '"Nudg*" AND "fruit"' OR '"Nudg*" AND "vegetable*"' OR '"Choice Architecture" AND "food"' OR '"Choice Architecture" AND "fruit"' OR '"Choice Architecture" AND "vegetable*"'*. A total of 771 articles were found.

Google Scholar was used to find additional publications and non-published articles. Because Google Scholar was used to find additional papers and the aim was not to be exhaustive in its search and the lack of an extensive search field in this search engine, the key words that resulted in the most useful findings for other search engines were used. The key words for Google scholar were *'"Nudge" or "Nudging" AND "Food"'* and *'"Choice architecture" AND "food"'*. Because of the high number of publications that were found, many of which were not relevant, only the first 600 entries for each key word combination were considered as they were classified as the most relevant by Google Scholar. No language or date restrictions were applied to the systematic search in PubMed, PsycInfo, Medline, Scopus and Cochrane. In contrast, for Google Scholar date restrictions from 2000 to 2015 and language restrictions of French, English and Dutch were used because of the large number of publications. Patents and Citations were also excluded.

Article selection

The selection of articles for the review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[21] To be included in the review, studies had to comply with either the definition of nudging proposed by Thaler and Sunstein,[5] or the definition of choice architecture proposed by Hollands et al.,[6] as given in the Introduction. According to both definitions, a nudge should be easy and cheap to avoid, should not involve a restriction, be aimed at influencing the behaviour of many people rather than individuals, be implemented in the environment where the target behaviour is performed, and require minimal conscious processing. In addition to meeting either of these definitions, studies were included that met the following inclusion criteria: (i) the study design had to be experimental or cross-sectional; (ii) participants

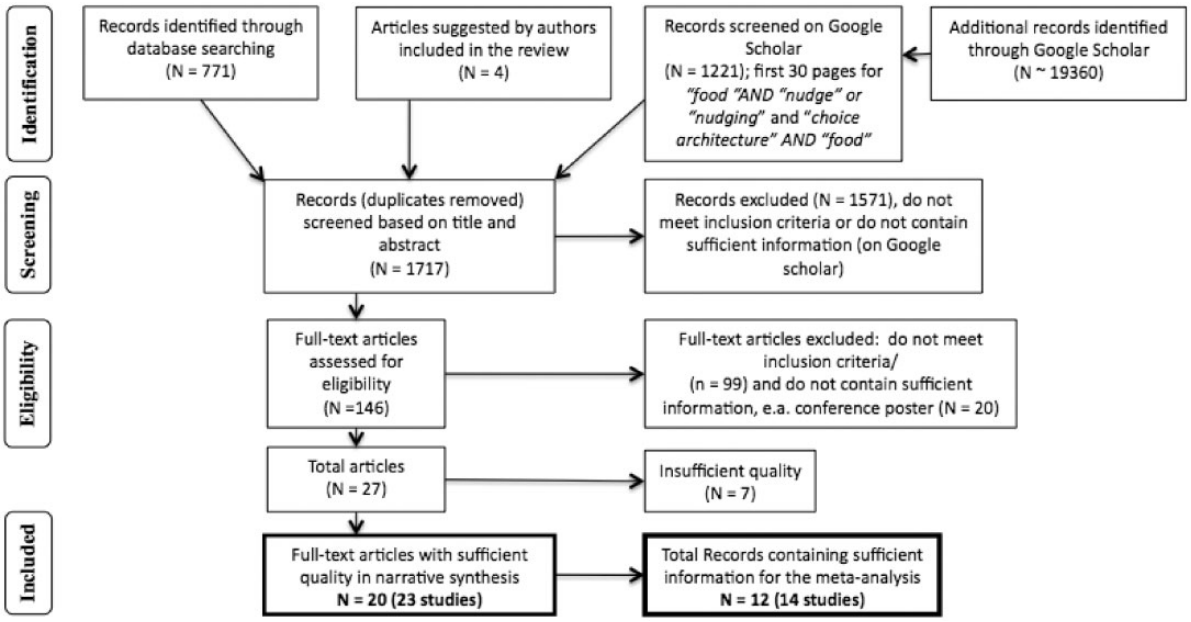

Figure 1 PRISMA flow diagram of study selection

had to be humans and (iii) the study outcomes had to consider the increase of healthy food choice/sales including fruit and/or vegetables.

Studies were excluded when (i) participants received financial incentives or prices of products were modified as part of the intervention; (ii) the intervention studied was aimed at changing beverage consumption; (iii) the intervention focused on food labelling which targeted conscious processing of information; (iv) the intervention aimed at decreasing unhealthy food or increasing healthy food choice that did not include fruits or vegetables and (v) the study only measured food consumption. The setting in which the nudging was applied was not a criterion of exclusion. Furthermore, studies that were described in articles that could not be obtained in full text, such as conference presentations, citations, abstracts or opinions, were excluded from the review.

Two researchers independently performed the first selection of articles from all primary publication databases. Reliability checks for the selection resulted in a Cohen's κ for the selections by both researchers varying from 0.67 to 0.98 per database. According to McHugh,[22] the first value can be considered as substantial and the second as almost perfect. For Google Scholar, the records were split in two and screened independently because of the reasonable inter-rater agreement. In case of disagreement, both researchers discussed the article and a joint decision was reached. The remaining articles were also screened by both researchers and discussed in case of disagreement.

Using the procedure and criteria mentioned above, 771 articles were identified using Pubmed, PsycInfo, Scopus, Medline and Cochrane Library. An additional 1221 articles were retrieved from the first 30 pages of Google Scholar (~19 360 records). After removing duplicates, 1717 articles were screened on the basis of the title and abstract, which resulted in 1571 articles being removed because they did not meet the inclusion criteria (not experimental, not about humans, not about healthier food choices, fruits or vegetables). The remaining 146 articles were assessed for eligibility by screening the full text. Ninety-nine articles were excluded because they did not comply with the inclusion criteria, and 20 articles were excluded because they contained unusable information (e.g. posters/flyers with not enough details, on-going research). As a result of this process, 27 articles were retained for quality assessment and further analysis (figure 1).

Quality assessment

The quality of the studies considered for inclusion in the review was assessed using the checklist with criteria proposed by Downs and Black.[23] This checklist was considered appropriate for the current review because it is designed for both randomized and non-randomized studies. The checklist allows researchers to calculate the overall quality, as well as the quality for the subgroups reporting, internal validity (bias and confounding) and external validity. Both researchers conducted the quality assessment and compared their results in case of disagreement. Only studies with a sufficiently high quality were included in the present review. To ensure a sufficient level of quality while retaining a sufficient number of studies for the analysis, the threshold was set at 60% positive answers in the quality assessment. Eight articles were excluded because they did not meet this requirement.

Data extraction and analysis

For the narrative synthesis, information was extracted regarding the year of publication, country, setting/design, type of nudge, duration, sample size, outcome measures and main findings. All articles were categorized under one of three types of nudging, i.e. (i) altering placement, (ii) altering properties or (iii) altering placement and properties.[6] The main findings were then summarized per type of intervention and per article and a conclusion provided per subcategory.

For the meta-analysis, Comprehensive Meta-Analysis Software[24] was used. This software allows calculating an effect size using different types of data, which is necessary as most studies did not report an effect size, and different studies reported different types of outcome data (e.g. percentage increase of sales or food choice, mean or cups of servings per day, grams, percentage of participants that select healthy food choice, . . .). Articles that did not provide enough statistical information to calculate an effect size (e.g. sample size) were not included in the meta-analysis. Only outcomes regarding food choice, sales or servings were included as this was the main outcome variable in most articles. When multiple dependent variables were measured, only one dependent variable was included in the meta-analysis—usually sales, which is the most objective one. Because of the heterogeneity of the studies and their

outcome variables, a random effects model was used for the analysis. A random-effects model assumes that the effects being estimated in the different studies are not identical, but follow some distribution.[25] Homogeneity tests were conducted and showed heterogeneity between studies, confirming that a fixed model would not fit the data. Moreover, as many articles mentioned separate results for fruits and vegetables and type of nudge, a subgroup analysis was performed for fruits and vegetables and type of nudge separately.

Results

Quality assessment

Overall, the studies obtained average scores for general quality ($M = 15$ out of 24, on average 62.5% positive answers). Most studies scored average on reporting quality ($M = 6.7$ out of 10, on average 67% positive answers), external validity ($M = 2.3$ out of 3, on average 76.7% positive answers) and internal validity (bias) ($M = 3.9$ out of 6, on average 65% positive answers). On the other hand, low scores were obtained for internal validity (confounding) ($M = 2.1$ out of 5, on average 42% positive answers). To ensure a sufficient level of quality while retaining a sufficient number of studies for the analysis, the threshold was set at 60% positive answers in the quality assessment. Seven articles were excluded because they did not meet this requirement.

Narrative synthesis

Table 1 summarizes the main findings for the studies included in this review. In the case of multiple interventions in the same publication, only the results for the first intervention in comparison with baseline are considered in order to enable a comparison of the intervention effects to each other.

The majority of studies (11 out of 20 publications) were conducted in the United States. Of the 23 experiments described in the 20 articles, 20 were field studies and three were conducted in a laboratory. The latter used a fake food buffet,[13] a Foodscape Laboratory[26] and an online shelf-display.[27] In the field studies, different settings were involved, including dining facilities or cafeterias in schools (11), cafeterias in hospitals (2) as well as restaurants, buffet lines at conferences (2; [28,29]), a cafeteria at a workplace,[30] a university,[31] a train station,[32] corner stores[33] and a swimming pool.[34] Most studies used a within subjects pre-post interventions design (10), or a between subjects design with a control and treatment group (9), while a minority used both a between- and within subjects design (4). Outcome measures were always behavioural measures in the form of food choice, food sales, food servings, voucher sales and selection in grams.

Meta-analysis

Healthy food choice

The results of the meta-analysis of the fourteen studies that provided sufficient statistical information to calculate effect sizes showed an overall significant effect for nudging for healthy food choice ($P < 0.001$), with a medium effect size, $d = 0.30$ [95% CI = 0.178–0.430].

As shown in figure 2, 9 out of 14 studies included in the analysis report a significant effect size (Adams et al.,[36] $P < 0.001$, $d = 1.79$ [95% CI = 1.585–1.988], Cohen et al.:[37] $P < 0.001$, $d = 0.28$ [95% CI = 0.174–0.377], Ensaff et al.,[38] $P < 0.001$, $d = 0.50$ [95% CI = 0.390–0.616], Kongsbak,[26] $P = 0.01$, $d = 0.72$ [95% CI = 0.220–1.224], Levy et al.,[42] $P < 0.001$, $d = 0.05$ [95% CI = 0.020–0.077], Libotte et al.,[14] $P = 0.02$, $d = 0.26$ [95% CI = 0.039–0.480], Hanks et al.,[39] $P < 0.001$, $d = 0.15$ [95% CI = 0.061–0.241], Van Kleef et al.,[27] $P < 0.001$, $d = 0.15$ [95% CI = 0.061–0.241] and Wansink and Hanks,[29] $P < 0.001$, $d = 0.61$ [95% CI = 0.245–0.957]). However, a visual inspection of the funnel plot (figure 3) suggests that the studies with the largest positive effect-size are smaller and less powerful, which could indicate that the results are biased. On the other hand, asymmetry can be expected due to the small number of studies included in the analysis. So, while publication bias cannot be completely excluded since articles with significant findings get published more often, there is no clear indication that publication bias would have affected the results.

Subsequent analysis of the studies that measure the effects of nudging on vegetables and on fruit choice separately revealed that the effects remained but were smaller than the effect for the combination. For fruits, seven studies were included ($P < 0.001$, $d = 0.10$ [95% CI = 0.047–0.143]), and for vegetables six studies ($P < 0.05$, $d = 0.10$ [95% CI = 0.001–0.205]).

Sub-group analysis by type of nudging

Altering properties: Two studies that applied nudging by altering properties showed significant effects (Levy et al.,[42] $P < 0.001$; Libotte et al.,[14] $P < 0.03$), but the effect sizes are very small (Levy et al.,[42] $d = 0.05$ [95% CI = 0.020–0.077]; Libotte et al.,[14] $d = 0.26$ [95% CI = 0.039–0.480]). The overall effect of nudging by altering properties of a product is not significant ($P = 0.220$, $d = 0.13$ [95% CI = -0.074 to 0.323]). However, as only two studies were included in this sub-group analysis, we cannot draw strong conclusions.

Altering placement: Four of the seven studies that studied the effect of altering the food placement show significant effects (Adams et al.,[36] $P < 0.001$; Hanks et al.,[39] $P < 0.001$; Van Kleef et al.,[27] $P < 0.001$; Wansink and Hanks,[29] $P < 0.001$), yet with generally low effect sizes (Hanks et al.,[39] $d = 0.05$ [95% CI = 0.020–0.077]; Van Kleef et al.,[27] $d = 0.17$ [95% CI = 0.059–0.281]; Wansink and Hanks,[29] $d = 0.26$ [95% CI = 0.039–0.480]) with exception of Adams et al.[36] ($d = 1.79$ [95% CI = 1.585–1.988]). Overall, the effect of nudging by altering the placement of a product is significant ($P < 0.001$), with a medium effect size ($d = 0.39$ [95% CI = 0.137–0.645]).

Altering properties and placement: Three out of five studies studying the combined effect of altering food properties and placement show significant results (Cohen et al.,[37] $P < 0.001$; Ensaff et al.,[38] $P < 0.001$; Kongsbak et al.,[26] $P = 0.01$), with a moderate effect size (Cohen et al.,[37] $d = 0.28$ [95% CI = 0.174–0.377], Ensaff et al.,[38] $d = 0.50$ [95% CI = 0.390; 0.616; Kongsbak et al.,[26] $d = 0.72$ [95% CI = 0.220–1.224]). The overall effect of nudging by altering properties and placement of a product is significant, with a medium effect size ($P = 0.02$; effect size $d = 0.28$ [95% CI = 0.050–0.499]).

Discussion

As a strategy to encourage healthy behaviour by way of triggering automatic processes through altering environmental cues, nudging can be considered as a theoretically grounded, potentially effective way to address the intention-behaviour gap in promoting healthy behaviour. As such, it can serve as a useful complement to health education to encourage people to eat more fruit and vegetables. However, the empirical evidence regarding the effectiveness of nudging has thus far remained contradictory. This meta-analysis of well-documented nudging interventions aiming to increase fruit and/or vegetable choice, sales or servings showed that the technique produces a medium ($d = 0.30$) significant effect. Moreover, separate subgroup analyses revealed that of the different types of nudging considered (i.e. altering properties, altering placement and altering properties and placement), only altering placement ($d = 0.39$) and combining altering properties and placement ($d = 0.28$) have a significant effect on food choice, again with a medium effect size. Separate sub-group analyses on fruit and vegetables showed that nudging has a significant but very small effect on fruit choice ($d = 0.10$) and vegetables choice ($d = 0.10$) separately. It is therefore reasonable to conclude that nudging does have an effect

Table 1 Summary of narrative synthesis of nudging studies aimed at increasing fruit and/or vegetable selection concerning author, year, country, setting/design, intervention, duration of intervention, sample size, outcomes measured and main findings

Author (Year) Country	Setting/ design	Intervention	Duration of intervention	Sample size	Outcomes measured	Main findings
1. Adams et al.[35] (2005) USA Included in meta-analysis	Field study at an elementary school Intervention (two schools) vs. control (two schools)	Placement Availability	Intervention/control: one day	Control: *n* = 141, Intervention: *n* = 147	Items taken (grams) Fruits/vegetables combined	No difference in items taken between intervention and control schools.
2. Adams et al.[36] (2016) USA Included in meta-analysis	Field study at middle schools Cross-sectional Intervention (three schools) vs. control (three schools)	Placement Proximity	Already existing interventions for several years	Control: *n* = 239, Intervention: *n* = 294	Selection fruit or vegetables (grams)	Students in intervention schools selected substantially more fruit/vegetables compared with the control schools.
3. Bangs (2012) USA Unpublished Included in meta-analysis	Field study at three different middle schools Baseline vs. intervention	Site 1: Placement Proximity Site 2: Properties and placement: Combined Site 3: Placement Availability	Intervention: Site 2: 22 days Site 3: 15 days Baseline: Site 2: 20 days Site 3: 20 days	(Average daily lunch participation) Site 1: *n* = 663 Site 2: *n* = 380 Site 3: *n* = 1500	Student selection in cups of servings(Fresh) fruit and vegetables separately	Site 1: No increase for fruit and vegetable selection during intervention. Site 2: No vegetable selection increase. Fresh fruit selection increased during the intervention in comparison to the baseline.*Site 3: No fruit/ vegetable increase.
4. Chapman and Ogden[31] (2012) United Kingdom	Field study at a university Baseline vs. Intervention	Placement Proximity	Baseline/ Intervention: 5 days each	*n* = ?	Weekly sales of fruit	Sales of fruit decreased during intervention in comparison to the baseline***. Results in the opposite direction.
5. Cohen et al.[37] (2015) USA Included in meta-analysis	Field study in school cafeteria Intervention vs. Control schools, Baseline vs. Intervention	Properties and placement Combined	Intervention/control: 4 months Baseline: 3 months	Six control schools (*n* = 936), four intervention schools (*n* = 651)	Selection of school meal components (% of students) Fruit/ vegetables	At intervention (smart café) schools, fruit and vegetable selection increased significantly in comparison with control schools.
6. Ensaff et al.[38] (2015) UK Included in meta-analysis	Field study in secondary school Baseline vs. intervention school vs. control school	Properties and placement Combined	Baseline: 29 weeks Intervention: 6 weeks	Intervention school: 980 students (year 1), 1132 students (year 2) Control school: *n* = ?	Selection of plant-based food	Plant-based food selection significantly increased during the intervention period compared with baseline.***
7. Hanks et al.[39] (2012) USA Included in meta-analysis	Field study in a school cafeteria Baseline vs. Intervention	Placement Proximity	Baseline/intervention: 8 weeks each	*n* = ? Observations: Baseline: 602 Intervention: 482	Healthier food items chosen per student	During intervention, chosen healthier food items per student increased in comparison to the baseline.***
8. Hanks et al.[40] (2012) USA	Field study at two school cafeterias Cross-sectional Baseline vs. Intervention	Properties and placement Priming	School 1/2: six data collection days in 4 months	*n* = ranging from 242 to 388 students per day	Likelihood of selecting specific fruit and vegetables	Likelihood of fruit and vegetable selection increased when tomato soup,** applesauce,*/** bananas* and peaches*/*** were offered.
9. Hansen et al.[28] (2016) Denmark	Field study at conference break Intervention vs. Control buffet	Properties Presentation	Intervention/control: 1day	Control: *n* = 189 Intervention: *n* = 202550 business leaders	Servings of apples (in grams)	In the intervention buffet apple consumption was significantly higher compared with the control buffet.

(continued)

Table 1 Continued

Author (Year) Country	Setting/ design	Intervention	Duration of intervention	Sample size	Outcomes measured	Main findings
10. Hubbard et al.[41] (2015) USA Included in meta-analysis	Field study at a school cafeteria Baseline vs. Intervention	Properties and placement Combined	Baseline: 1 month Intervention: 3 months	n = 43 students with intellectual and developmental disabilities	Selection of fruit and vegetable servings separately	During the intervention, rates of fruit selection increased.** Vegetable selection did not increase.
11. Kongsbak et al.[26] (2016) Denmark Included in meta-analysis	Lab study (Foodscape laboratory) at university Intervention vs. control	Properties and placement Combined	Intervention /control: 1 day	Control: n = 32 Intervention: n = 33 Male students	Selection of salad consisting of both fruit and vegetables(g)	In the intervention group the quantity of fruit and vegetable selection increased compared with control group.**
12. Kroese et al.[32] (2015) Netherlands	Field study at three train station shops Baseline vs. Intervention vs. Control	Placement Proximity	Baseline: 1 week Intervention: 1 week	n = ?	Sales of healthy food products (including fruits)	In the intervention shop sales of healthy food products increased compared with the control shop.**
13. Levy et al.[42] (2012) USA Included in meta-analysis	Field study at a hospital cafeteria Baseline vs. Intervention	Phase 1: Properties Labelling	Baseline/intervention: 3 months each	n = 4242 employees	Proportion of sales of green labeled items	During intervention, sales of green items increased in comparison with the baseline.**
14. Libotte et al.[13] (2014) Switzerland Included in meta-analysis	Lab study at a Fake Food Buffet (FFB) Control vs. Intervention	Properties Sizing	Intervention /control: 1 day	Control: n = 42 Intervention: n = 41	Servings per food category (kJ), vegetables and fruit separately	In the intervention condition, participants took more vegetables in kJ compared with control condition.* Fruit servings did not increase.
15. Olstad et al.[34] (2014) Canada	Field study at a swimming pool Baseline vs. intervention	Properties Presentation	Baseline/Intervention 1: 8 days each	n = ?	Sales healthy items	Sales of healthy items did not change during the intervention in comparison to the baseline.
16. Thorndike et al.[33] (2016) USA	Field study cornerstores Baseline vs. intervention vs. control	Properties and placement Combined	Baseline: 11 months; Intervention: 5 months	n = ?	Sales of fruit/vegetable voucher	WIC fruit/vegetable sales increased in intervention stores in comparison to control stores*
17. Van Kleef et al.[27] (2012) Netherlands Included in meta-analysis (lab study, main effects)	Lab study between-participants Field study in hospital Baseline vs. intervention	Placement Proximity and availability	Lab study: 1 day Field study: 1 week for each condition	Lab study: 158 undergraduate students Field study: +- 500 costumers per weekday	Lab study: healthy snack choice Field study: daily healthy snack sales	Lab study: Main effect of assortment structure.** No effect of shelf arrangement/no interaction. Field study: Main effect of assortment structure.* No other effects.
18. Vyth et al.[30] (2011) Netherlands	Field study at worksite Control vs. intervention cafeteria Baseline vs. intervention	Properties Labelling	Baseline/intervention: 3 weeks each	n = ?12 Control cafeteria's, 13 intervention cafeteria's	Sales fruit and salad items	In the intervention schools fruit sales increased compared with control schools.** No differences in sales for salads.
19. Wansink et al.[43] (2013) USA	Field study at middle school cafeterias Control vs. intervention	Properties Presentation	Intervention/control: 1 month	2150 students in three intervention/three control schools	Percentage of apple sales	Intervention schools: average daily apple sales increased compared with control schools.***
20. Wansink and Hanks[29] (2013) USA Included in meta-analysis	Field study at a buffet line at a conference Control vs. intervention	Placement Proximity	Intervention/control: 1 day	124 HR managers (59 intervention, 65 control)	Percentage of participants selecting fruit	More participants took fruit in the intervention condition compared with the control condition.***

*$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

Study name	Subgroup within study	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Adams et al. (2005)	Fruit +Vegetables	0,102	0,118	0,014	-0,129	0,333	0,867	0,386
Adams et al. (2016)	Fruit and vegetables	1,786	0,103	0,011	1,585	1,988	17,366	0,000
Bangs (2012) 1	Combined	0,045	0,027	0,001	-0,009	0,099	1,633	0,102
Bangs (2012) 2	Combined	0,025	0,036	0,001	-0,046	0,096	0,688	0,492
Bangs (2012) 3	Site 3 Vegetables	0,003	0,026	0,001	-0,048	0,054	0,113	0,910
Cohen et al. (2015)	Combined	0,276	0,052	0,003	0,174	0,377	5,334	0,000
Ensaff et al. (2015)	Fruits and vegetables	0,503	0,058	0,003	0,390	0,616	8,714	0,000
Hanks et al. (2012)	Healthier foods	0,151	0,046	0,002	0,061	0,241	3,292	0,001
Hubbard et al. (2015)	Combined	0,061	0,108	0,012	-0,151	0,273	0,565	0,572
Kongsbak et al. (2015)	Fruit and vegetables	0,722	0,256	0,066	0,220	1,224	2,819	0,005
Levy et al. (2012)	Phase 1	0,048	0,015	0,000	0,020	0,077	3,291	0,001
Libotte et al. (2014)	Combined	0,259	0,112	0,013	0,039	0,480	2,304	0,021
Van Kleef et al. (2012)	Combined	0,170	0,057	0,003	0,059	0,281	2,993	0,003
Wansink & Hanks (2013)		0,606	0,184	0,034	0,246	0,967	3,297	0,001
		0,304	0,064	0,004	0,178	0,430	4,716	0,000

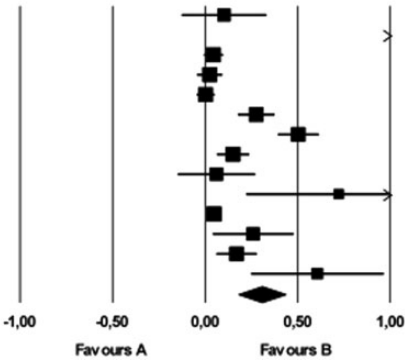

Figure 2 Results of the meta-analysis: effect sizes for nudging on fruit and vegetables

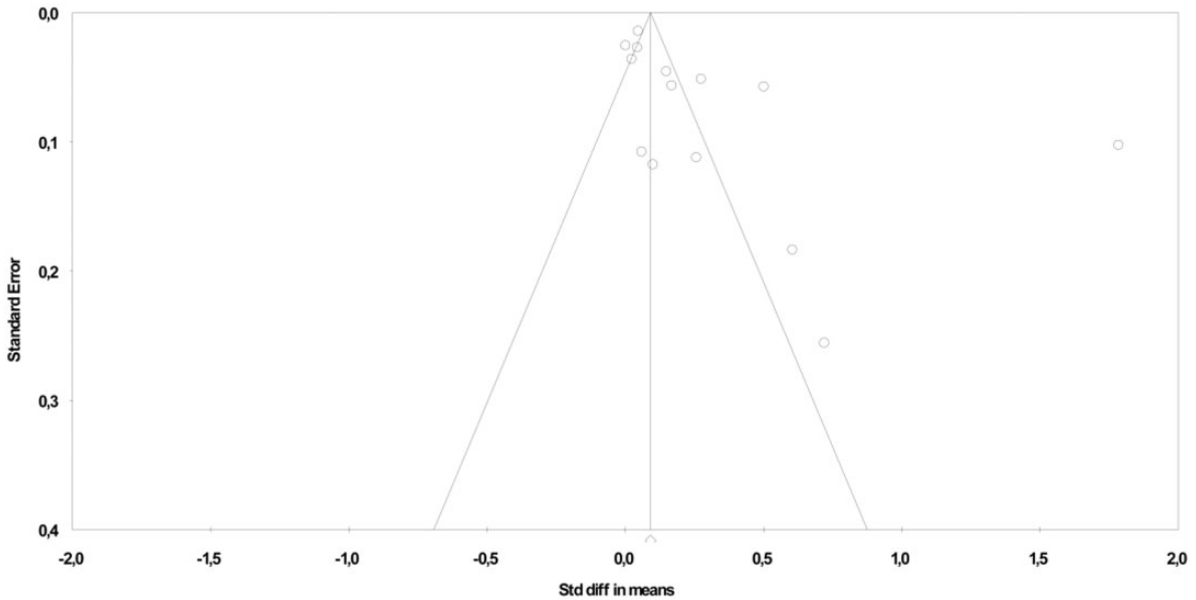

Figure 3 Funnel plot of standard error by standardized mean difference

on fruit and vegetable choice, sales or servings, and that among the different nudges, altering the placement and combined nudges seem to be the most effective one.

Limitations

The results of this review have to be interpreted with some caution. Given the small number of articles and experiments that were included in the meta-analysis, the results may have been biased. Of particular relevance here is the absence of reported sample sizes in most articles. This is a direct consequence of the fact that nudging studies are usually field studies, which makes them less controllable. The funnel plot indicates that studies with large effect sizes also have a larger standard error, which could mean that the significant effect is caused by smaller, less powerful studies. Another potential problem is publication bias, as articles with significant results are more likely to be published than those with nonsignificant results.[44]

This review is a systematic review, which not only increases the objectivity and transparency of the article selection and the (meta-)analysis but also implies that studies which did not use the exact search terms considered are not included. We are aware that in this review articles may be missing that used nudging or choice architecture techniques, but did not conceptualize them as such. The effects of techniques that manipulate particular types of heuristic have been reviewed elsewhere (e.g. the review of studies manipulating plate-size[13]). Contrary to those studies, however, the present review aimed to get more insight in the effects of interventions that used the definition of nudging, which includes multiple techniques under one name. As such, it tests the added value of using this definition. The results of the meta-analysis show that it is difficult to test the theory precisely, because the category 'altering properties' does not show a significant effect. However, it is not clear if this is due to the fact that there are not enough studies in this category, or because of conceptual differences between the studies.

An issue that deserves particular attention is the fact 52% of the studies took place in schools. This could imply that the results of nudging that have been reported are restricted to the school setting and that more studies should be conducted with older participants. On the other hand, there is no reason to assume that the effectiveness of nudges in schools would be different from that in other settings. It is clear that nudges should be adapted to the environment and target group in order to be effective, but as long as that is the case there is no reason why their effectiveness would be limited to schools and cannot be generalized to other environments.

As previous reviews asserted, the quality of nudging articles is often limited. However, biases are almost unavoidable in this field of study, as one of the key elements of nudging is that it takes place *in vivo*, which makes the technique vulnerable to internal biases. It is

nearly impossible to randomly assign people to conditions without harming the external validity. Furthermore, within subjects designs that measure outcomes before and after the intervention create huge dropout rates, because participants who are included at the baseline may not be included at the intervention. Regardless of the design used, keeping track of the sample size is problematic. Interventions usually last for several days and it is often unclear how many individual participants took part and how many observations were made per participant.

An important asset of field studies involving nudging is that the external validity is generally high and that the results can easily be generalized to real-life situations. In this review, all populations and types of nudges have been included to increase the generalizability. The results of this meta-analysis thus apply to all populations and all settings and provide a general idea of the effectiveness of this technique. The simple applicability of these interventions increases the chance that professionals in the field will implement these interventions in real life. Another advantage is the objectivity of the outcome measures in nudging studies. Measuring behaviour is always more exact than a proximal determinant, especially since there are no other measures that can predict behaviour perfectly. In the present review, we focused on fruit and vegetable choice and not on fruit and vegetable consumption because at the moment there are not sufficient nudging studies that measure actual consumption to give an indication of its effect. This is probably due to ethical and practical reasons, because it is only possible to measure this behaviour when participants are tracked (anonymously) which could increase their awareness regarding the intervention and hamper the automatic component of nudging. However, consumption measures do provide us with a better insight in the behaviour we aim to change so future nudging studies are invited to incorporate this measure.

Future directions

In order to fully demonstrate the effectiveness of nudging as a technique to enhance the selection of fruit and vegetables, it would be best to perform a meta-analysis with more studies, with a (somewhat) higher quality. In order to make this possible, future nudging interventions should reflect more on the study design, and provide more detail on the statistics used for the evaluation of their effects. To make a meta-analysis possible, sample sizes should be reported as precisely as possible, although an estimation would already be an improvement. New measurement techniques that allow tracking the food purchases of individual people (anonymously) would also enhance the quality of studies. Finally, as the medium effect sizes of nudging found in the current meta-analysis could be due to lack of power, future studies should use larger samples to increase the power.

To conclude, the current systematic review and meta-analysis adds to the literature regarding the effectiveness of nudging as a strategy to encourage fruit and vegetable choice. While the use of the definitions suggested by Hollands and colleagues[6] increased definitional and conceptual clarity for both the narrative synthesis and the meta-analysis, the latter is the first meta-analysis that calculated an effect-size of nudging on fruit and vegetable choice. Although only 12 articles (14 studies) are included, the results of this analysis provide an indication of the effectiveness of this technique, while at the same time highlighting the problems that have to be addressed before more definite conclusions can be drawn.

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Key points

- First meta-analysis to show promising medium effect sizes for the effectiveness of nudging to increase fruit and vegetable choices.
- Altering placement and combined nudges (placement + properties) have a significant effect on food choice.
- Nudging fruit and vegetables can serve as an effective complement to health education aimed at encouraging people to select more fruit and vegetables.

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