Title:

Nudging consumers towards healthier choices: A systematic review of positional influences on food choice

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Abstract

Nudging or 'choice architecture' refers to strategic changes in the environment that are anticipated to alter people's behaviour in a predictable way, without forbidding any options or significantly changing their economic incentives. Nudging strategies may be used to promote healthy eating behaviour. However, to date the scientific evidence has not been systematically reviewed to enable practitioners and policy makers to implement, or argue for the implementation of, specific measures to support nudging strategies.

This systematic review investigates the effect of positional changes of food placement on food choice. Seven scientific databases were searched using relevant key words to identify interventions that manipulated food position (proximity or order) to generate a change in food selection, sales or consumption, amongst normal weight or overweight individuals across any age group. From 2576 search identified, 15 papers comprising 18 studies met the inclusion criteria.

This review has identified that manipulation of food product order or proximity can influence food choice. Such approaches offer promise in terms of impacting on consumer behavior. However, there is a need for high quality studies that quantify the magnitude of positional effects on food choice in conjunction with measuring the impact on food intake, particularly in the longer term. Future studies should use outcome measures such as change in grams of food consumed or energy intake to quantify the impact on dietary intake and potential impacts on nutrition related health. Research is also needed to evaluate potential compensatory behaviors secondary to such interventions.

Introduction

In recent years there has been shift away from solely targeting individuals to change their eating behaviours, to an approach that addresses wider, population-level factors, and involves other environmental components and stakeholders [1]. Foodscapes [2] and food environments contribute to the so-called "obesogenic environment" [1, 3] and influence food choices. Epidemiological data suggests that numerous small changes towards a healthier behaviour, such as improving diet quality, have the potential to have a positive impact on reducing mortality risk [4]. Most healthy eating interventions in Europe have been successful in providing consumers with information to enable them to make better-informed food choices [5]. While they have been successful in creating awareness among consumers, there has only been modest success in terms of actual lifestyle changes and measurable health indicators in the sample populations, such as weight reduction [6]. Individualised behaviour change is ineffective unless it becomes habit-forming, which requires support and reinforcement through structural or environmental change so that the new behaviour is sustained. Although behavioural economics have impacted on some policy interventions, the case for food related interventions remains under development, constituting a promising area that could potentially achieve high social benefits [7, 8].

Therefore, innovative intervention strategies that are able to effectively improve food behaviours, dietary intake and impact on health status need to be investigated and implemented. The majority of interventions have an underlying assumption that people make conscious and reasoned food choices, most of the time [9]. This paradigm has been questioned following the limited impact of information based campaigns in achieving behaviour change, and the subsequent rise in the prevalence of obesity and other chronic diseases [10]. Furthermore, current paradigms place the burden and responsibility for all food choices on the individual, with the justification that everyone is free to make healthy choices once informed [6, 11].

Dietary habits and food choices are the result of decisions and actions that are based on routines that require very little active decision-making as well as reflective, elaborate decision-making where choice options are carefully considered. Choice architecture, inspired by behavioural economics, describes the way in which decisions are influenced based on how choices are presented within meal environments [12]. The meal environment has been defined as the room, the people, the food, the atmosphere and the management system, particularly when eating out-of-home. This suggests that

the meal environment can be modified to be more or less conducive to supporting the required behaviour and, as such may lead to weight changes, either through promotion of healthier choices or decreased intake [12-15].

Choice architecture is often used interchangeably with other terms such as nudging, libertarian paternalism and behavioural economics. Choice architecture is a subset of non-regulatory behavioural interventions. Choice architecture can include one or more of the following: provision of information (e.g. to activate a rational choice), changes in the physical environment (e.g. light, décor, placement, etc.), changes in the default policy (e.g. pre-weighed salad portions vs. free serving of a salad bowl) and, use of social norms and salience (e.g. comparison with average consumers) [16]. Nudging has been defined as 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 [15]. Within the public health nutrition area this could mean altering the food environment, such as product placement or labelling or even encouraging consumers to sit together for their meal (social facilitation). Furthermore, nudging interventions consist of provision of information, changes to physical environment, changes to the default policy and the use of social norms and salience [16].

Previous studies have shown that nudging practices are promising measures that can be used to support the promotion of healthy eating. An example of nudging is that by changing the size of dishware, portion sizes may be reduced leading to unconscious changes in actual food intake [17] and meal composition [18]. Similarly, food positioning is thought to influence food choice. Studies have shown that people eat more unhealthy food, such as chocolate if it is located more prominently [19]. However, it is less clear, whether minor changes in food position or item placement, which are not accompanied by changes in effort, also promote healthier food choices [13, 20].

Existing systematic reviews, which have investigated the effectiveness of choice architecture interventions, mainly focused on the effectiveness of labelling and prompting (see for example [21, 22]). However, these types of interventions are more closely related to the traditional behavioural interventions of information-giving [23]. To date, there is no systematic review that has assessed the influence of food placement within microenvironments on product choice and on food intake [23]. This

information is relevant for the support of public health interventions and relevant for operations in the foodservice sector.

The aim of this systematic review was to evaluate the published research that investigated the effect of positional changes within micro-environments on food choice by healthy weight and overweight individuals across all age groups, and to derive recommendations for future research in the area.

For the purpose of this review, we have defined a nudging intervention as any intervention that involves altering the non-economic properties, or placement of objects or stimuli within micro-environments with the intention of changing health-related behaviour. Such interventions are implemented within the same micro-environment in which the target behaviour is performed and require minimal conscious engagement. In principle, these interventions can influence the behaviour of many people simultaneously, and they are not targeted or tailored to specific individuals (adapted from [23]). The present review focuses on positional changes that affect immediate food consumption or choice decisions of individuals (e.g. eating out of home in a food service outlet), rather than the consumption pattern of a family or a household over time, as it would be the case in 'assortment structure' experiments within supermarket settings.

Methods

Details of the protocol for this systematic review were registered on PROSPERO and can be accessed at http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42015016277

Criteria for study inclusion

The PICOS (Problem, Intervention, Comparison, Outcome, Setting) approach [24] was used to frame the research question. We defined 'food choice' as all outcome measures that assessed food selection or probability of food choice, including product sales and food consumption (in grams or energy intake). Positional changes were defined as all manipulations of food order or variations in the distance of food placement relative to consumers within microenvironments. Microenvironments were

155 defined as the immediate surroundings of the individuals, such as within the home,
156 workplace, or cafeterias [25].
157 The types of studies to be included were randomised controlled trials/ experiments,
158 pre-post experimental studies, quasi experiments and naturalistic observations where
159 at least one research aim was to assess the influence of food positioning within a
160 microenvironment, on food choice (selection) or sales (grams, number) and intake
161 (grams, energy).
162 Studies where multiple variables were manipulated simultaneously along with the
163 food position were not included. For example, studies where foods were added or
164 removed from the selection or where portion sizes of healthy or unhealthy offers were
165 altered along with a positional change were excluded. Study participants included
166 only healthy normal weight or overweight/obese individuals. There was no age
167 restriction with studies on both children and adults included. The search included full-
168 text articles that were published in peer-reviewed journals in the English language.
169
170 *Literature search*
171 A systematic search was conducted using electronic databases (Medline, Pre-Medline,
172 Embase, CINAHL, Scopus, The Cochrane Library and PsycINFO) until February
173 2015. No limit was placed on publication date. The search term list included the
174 following items: choice architecture OR accessib*OR nudg* OR position* OR
175 (serving AND (direction OR distance)) OR proximity OR distance AND food OR diet
176 OR food choice OR energy intake OR caloric restriction OR fruits OR vegetables OR
177 health* OR food choice. Reference lists of included articles and key reviews in the
178 area were also manually searched for additional articles.
179
180 *Review procedure*
181 Two independent reviewers (TB and NdV/DvdB) screened the titles and abstracts of
182 all search results. Full-text of all papers that appeared to potentially meet the inclusion
183 criteria were retrieved. The retrieved full-texts were assessed by two independent
184 reviewers (TB and NdV) to determine inclusion. In case of disagreement a third
185 independent reviewer made the final decision (MR).
186
187 *Data extraction and synthesis*

188 Quantitative data on study participants (age, gender, weight status), the design (type
189 of study, setting, manipulated variables) and the outcomes (finding, main effect,
190 conclusions), from the included articles data was extracted by TB and checked by
191 MR. To distinguish between the magnitude of the change in effort that was involved
192 in the intervention, we differentiated between minor changes (mere order change or
193 very small distance change within reach), medium (change of position to food that
194 required only a small effort; e.g. standing up, bending down) or major positional
195 changes (manipulations that involved a major increase/reduction in effort, e.g.
196 walking across a room).
197
198 *Quality assessment of included studies*
199 The quality of the included studies was assessed by two independent reviewers
200 (TMcC and HT) using the review evidence analysis manual published by the
201 Academy of Nutrition and Dietetics [(26)]. The quality scores can be found in the
202 supplementary material (Table S1).
203

204 **Results**

205 The database search identified 2540 unique entries, which were combined with
206 another 36 articles of interest that were identified by screening reference lists. A total
207 of 62 full-text articles were retrieved and assessed against the inclusion criteria.
208 Fifteen articles, comprising 18 studies met the inclusion criteria and the data of these
209 was extracted and evaluated in this review (see Figure 1).
210 The majority (n=10) of the studies were conducted in the United States. Seven were
211 conducted in Europe, of which four were conducted in the Netherlands. In one study,
212 the country was not reported [27]. There was only one study in children [28]. Ten studies
213 were conducted with university students or staff and for five studies the subjects were
214 customers of hospital cafeterias. One was conducted in an army research centre [29]
215 and one was conducted with attendees of a health conference [30].
216 The foods involved in the studies varied and included single healthy or unhealthy
217 items (water, fruit and vegetable, cereal bars, chocolate candy or crackers) to more
218 complex selections within canteens buffets with between eight and eleven products
219 repositioned.
220
221 Seven studies reported participants' weight status, however only two considered it in
222 the analysis [27, 31]. Levitz [27] reported that a change in dessert order affected normal
223 and overweight people differently. In particular the author found that obese adults
224 selected a greater amount of low-energy dessert if it was made more salient. No
225 changes were observed if the high-energy desserts were made more salient [27].
226 The characteristics of the included studies are summarized in Table 1.
227 Of the eighteen studies that were included, only one received a positive quality rating
228 [32] with 14 studies being assessed as neutral, and three as negative because study
229 procedures were not described in detail and several validity questions could not be
230 answered clearly (Table S1).
231 Of the 18 studies, nine investigated the effect of distance/proximity changes on food
232 choice, such as placing unhealthy foods further from the consumer. The other half
233 assessed whether changes in product order, such as for example the food sequence on
234 a buffet could have a beneficial influence on food selection.
235 In summary, 16 of the 18 studies concluded that positional changes had a positive
236 influence on food choice. The only two studies, which did not find an effect,
237 manipulated the product order of snacks on a computer screen (Van Kleef Study 1), as

well as within a shelf at a checkout counter in a cafeteria (Van Kleef Study 2). However, in the field study they found a trend towards sales of healthy food being positively affected [32].

It was not possible to quantify and directly compare the effect sizes of the included studies, as the study designs were too variable. Most studies were randomised controlled experiments and only one study used correlation analysis to study the relationship between distance and snack selection [28]. This study found that the distance from the serving bowl significantly predicted the number of crackers and carrot slices consumed by children [28].

Between subject experiments were the most common study design, while within subject, repeated measures designs were rarely used. Only one study employed a longitudinal design [33], which was a follow up assessment of the intervention described by Thorndike et. al. and was based on the same choice architecture intervention [34]. Both of these studies were retained in the review because they had assessed different outcome measures and were complementary.

Most studies assessed food selection or choice probability using Chi Square tests, while only few studies objectively measured actual food intake in terms of food weight (grams) or energy (kcal or kJ) content. The intervention description and findings of the included studies are summarized in Table 2.

Discussion

Out of 18 studies where food position or order was manipulated, 16 showed a positive effect on food choice, meaning the participants were nudged towards a more healthy food choice. In the two experiments [32] where positional changes had no impact on food choice, the degree of manipulation was only a minor change in position, with all the foods remaining within reach. This indicates that the strength of the effect appears to depend on the type of positional manipulation (order vs. distance), as well as the magnitude of the change, or how far away foods are placed.

One study assessed compensatory food choices [35], showing that changes in position resulted in compensatory choices within same food categories. Further, movement of potato chips to a more distant location, and hence a reduction in chips selection, was accompanied by an increase in starch selection choices among the foods that still remained proximal [35]. For portion size changes, there is some evidence from

previous research that reducing offered portion sizes does not result in immediate compensation [36]. However, in that particular study the intervention was conscious, and consumers' self-control was activated by having servers ask customers in a fast food restaurant, if they wanted to downsize portions. Other studies, in which the overall energy of a meal bundle for children was reduced, without the participants being aware, found that the overall energy intake was significantly reduced [37]. More research on compensatory behaviours is required to implement effective interventions in practice.

The overall quality of the included studies was neutral. Only a few papers described the procedures sufficiently well to allow a clear evaluation of all validity questions. In particular, the questions that related to subject selection, recruitment procedures and comparison of study groups were unclear or not applicable. Studies were classified as unclear or not being free from bias due to the use of cash incentives or course credit being offered to participants. This may be an artefact of the naturalistic setting of the studies, such as universities and workplace canteens.

There is a lack of research that investigated long-term outcomes of positional interventions, and it's not clear whether changes in product order or distance would have sustained effects. Specifically, it is unclear whether a potentially positive effect of a position change, such as placing healthy foods in obvious positions and very close to cafeteria check-out lines, would potentially diminish over time and that customers would return to selecting a favoured unhealthy snack. To investigate this, more studies need to be conducted that evaluate this. Changes in choice need to be assessed at different time points, ideally over several weeks and months e.g. using data from a customer loyalty card scheme to determine sustainability of the intervention.

Furthermore, only one study [38] assessed the effect of potential covariates such as food preferences, restrained or disinhibited eating styles, or health consciousness on the outcomes of position choice architecture interventions. It therefore remains unclear which individuals are susceptible to nudges. Further insight on these covariates, as well as potential influences of habit strength, is required to design effective interventions.

A reason for these data not being reported may be that it is important to ensure participants are not aware of the nudging intervention, and this is likely to be the reason most field studies did not collect this information from participants. One

306 method that could be used to address this limitation in future research would be to
307 implement interventions within settings where customer loyalty cards are used to
308 collect additional data on participants' actual purchases. For this purpose,
309 collaborations with industry or supermarket chains could be effective. This would also
310 have the advantage that potential product price and positioning interactions could be
311 assessed.
312 Previous literature suggests that nudges could be inexpensive approaches to positively
313 impact behaviours [15]. In the studies included in this review however, there were no
314 calculations on potential costs and benefits. Factual data on previously hypothesised
315 benefits are required to make effective recommendations for policy makers.
316 Only two studies differentiated between healthy and overweight consumers and
317 whether positional interventions were different based on body weight [27, 31]. They
318 both concluded that the positional nudges were effective irrespective of weight status.
319 Further, one study assessed socioeconomic status and reported that it had no influence
320 on whether positional interventions were effective [33]. These findings concur with
321 previous literature, which suggest that nudging effects work via subconscious
322 mechanisms and therefore have equal impact regardless of weight and socioeconomic
323 status [39].
324 Food position can be manipulated by changing the order of food products or by
325 changing the distance between the food and the consumer. Both of these nudges
326 operate in different ways. The mediating factor for the effect of distance on choice is
327 thought to be effort, while for change in order it is reported to be salience [38].
328 Changes in order normally constitute only a minor change in effort, whereas changes
329 in distance affect the effort required in order to obtain a food at various levels.
330 However, more research is needed to evaluate these two aspects in detail. Future
331 research should also clearly distinguish between studies that examine nudging in
332 terms of food order versus food proximity or distance.
333 To date, very little is known about why positional nudges could be effective, and in
334 particular, it remains unclear how effects are moderated. The dual-process model [40]
335 states that human behaviour largely results as a function of two interacting systems:
336 the reflective system, which generates decisions based on knowledge about facts and
337 values; and the impulsive system, which elicits behaviour through affective responses.
338 The first system requires cognitive capacity, while the second system requires no
339 cognitive effort and is driven by feelings and immediate behaviours in response to the

environment. Nudging is thought to operate mainly through the second, automatic system and affects all individuals equally. However, it remains to be elucidated whether, and how factors such as health consciousness, habits, or strong preferences for specific products interact with the effects. The research of Levy et al. (2012) suggests that once the social gradient effects are taken into consideration, there is still an effect towards the desired outcome in terms of food choices [33]. This indicates that these interventions could be powerful and that cheap nudging interventions could potentially yield more than other elaborate expensive campaigns do. However, further research is required to explore this in detail.

It was not possible to conduct a meta-analysis of effect sizes as a wide range of outcome measures were reported across studies. Although the evidence that food position influences food choice was consistent across studies, it was not possible to evaluate the impact and effect size of these types of choice architecture interventions on actual food consumption and subsequent health outcomes. As has been advocated previously [6], harmonized indicators are required that would allow comparability between experiments or interventions. We therefore strongly recommend the use of energy (kJ/kcal) or weight (grams) as outcome measures of changes in food selection and/or intake in future studies.

Strengths and limitations

This is the first systematic review that has assessed the influence of position interventions (proximity and order) on food choice. In addition to the terms 'nudging' and 'choice architecture', we used search terms such as 'distance' and 'position'. This strategy located many articles that were beyond the topic of interest such as access to fast foods outlets, but ensured that older literature published before the terms 'choice architecture' and 'nudging' became popular were included.

For the purpose of this review, we defined nudging as any intervention that involved altering the non-economic properties, or placement of objects or stimuli within microenvironments, with the intention of changing health-related behaviour (adapted from [23]). We acknowledge that varying definitions of this term exist and that a disparate definition of the term might have led to the inclusion of different studies and hence influence the conclusions drawn.

Literature investigating the effect of the assortment structure on buying behaviour within supermarkets was not identified with the present search strategy. The authors

are aware that supermarket related shopping behaviour has been extensively described in the marketing literature, and that it is one of the venues where behavioural interventions may have a socially relevant outcome [7, 41]. This aspect was beyond the scope of the present study, which focused mainly on out-of-home meal service situations like cafeterias or canteens. Factors affecting selection at the time of consumption and the time of purchase may differ in this situation.

In addition, it is relevant to note that there could be differences between nudges that aim to increase or decrease consumption, as well as between nudges that promote the choice of healthy foods versus nudges that discourage the consumption of unhealthy foods. As an example, it might be easier to promote the consumption of more (healthy) food, compared to discouraging the consumption of unhealthy (or preferred) food by positional changes. Studies in which the position of unhealthy and healthy foods are simply switched are particularly problematic, as they lack a neutral control group, which would enable researchers to disentangle whether there was a potential bias in effectiveness of nudging depending on the food. In the present literature, studies that strategically investigated the efficacy of the positional intervention depending on food type are missing.

This review did not specifically consider any grey literature. Given the heterogeneity and the limited number of studies retrieved via the search strategy, it is plausible that a positive publication bias exists, although this was not assessed by the authors. It is interesting to note that the paternalistic nature of the concept of nudging has been discussed. In particular, it can be argued that a positional change that results in high effort to obtain an unhealthier food may be seen as a reduction in freedom of choice [42-45]. However, owing to the ethical nature of this discussion, it is beyond the scope of this review.

The synthesis of the study findings was undertaken in a narrative format as the data aggregation was limited by the heterogeneity of the research in this field. Nevertheless, the current review identified gaps in the existing literature and where further research is needed.

Recommendations for laboratory studies

Although laboratory settings are limited, well-planned experiments could give insight on the strength of positional effects and therefore help to estimate the cost effectiveness of choice architecture interventions in practice, particularly if repeated measures are applied. Laboratory settings allow the follow-up of the same individuals for data collection. Quantifiable outcome measures such as change in energy (kJ/kcal) or weight (grams) of food selection or consumption should be used. Strong experimental evidence, including estimations of the potential health benefits secondary to a reduction in energy intake or consumer weight loss over time are needed to inform policy makers in terms of implementing choice architecture interventions in public health settings.

Recommendations for field experiments

Although previous research suggested that substitution might occur within the same product category following a choice architecture intervention [35], a trial in the Belgian city of Ghent showed that meal choices were not compensated for later in the day [46]. Hence, future research should address the issue of compensation at the design stage and consider that compensatory behaviours could occur after a nudge intervention. As for laboratory settings, we also strongly recommend the use of energy or grams of food selected/consumed as an objective outcome measure, to estimate effect sizes and potential health benefits.

Furthermore, insight into factors (e.g. preferences, habit strengths, health consciousness) that potentially influence the effectiveness of positional interventions could be gained by collecting more information on customers in cafeteria-style settings, for example via a loyalty card scheme. This would further allow exploration of the sustainability (decay of effect over time, or potential compensatory choices) over time in these settings.

Reporting Recommendations

The 18 studies included in this review did not consistently describe the choice architecture intervention that was being assessed, for example whether 'the nudge' was a change in distance or in product positioning. On the other hand the inclusion of the distance in combination with food resulted in a large number of search results that were not relevant for the purpose of this study.

We suggest that standardised keywords and vocabulary could assist this field of research. Researchers should carefully consider the wording for their reports and could adopt the terminologies suggested by Hollands et. al. to classify choice architecture interventions [23] more clearly.

Advice for practice (policy makers, food retailers)

Choice architecture recommendations could support existing dietary guidelines, and so potentially contribute to the adherence and compliance. Although more research is required to quantify the magnitude of positional influences on health outcomes, it is evident that choice architecture is important and that food retailers influence consumption by organizing and displaying their products. Therefore, persons in charge of food organization or food outlet design (e.g. workplaces) need to be aware of their responsibility to organize "foodscapes" in an optimal way, for example to stimulate consumption of healthy foods and to reduce the consumption of unhealthy foods that then could support healthy workplace initiatives. In practical terms this means that low energy, nutrient dense products, such as fruits and vegetables should be placed in easy accessible and prominent positions. This is particularly applicable in large self-serving setting such a school or work canteens or the canteens of residences for the elderly.

Policymakers could integrate choice architecture nudging measures to augment their existing policy documents, as an important measure to enhance the effectiveness of healthy eating policies and procedures. In particular, this review provides evidence for policy makers, and specifically supports the use of positional changes as an effective manner to alter food choice in a desirable way.

Furthermore, the results of this review could be used for developing official recommendations regarding the implementation of choice architectural nudge interventions, and to harmonise the indicators for evaluation of the effect. A good practice example would be to place salad at the beginning of the buffet in school canteens in those countries where meals are provided at school.

Conclusions

Although the evidence that food position influences food choice is consistent, it is difficult to quantify the magnitude of impact on food choice and intake and the effect size of these choice architecture interventions on actual food consumption and subsequent health outcomes. Use of harmonized terminology and indicators would allow comparability between experiments or interventions and assist in moving this field forward.

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Conflict of Interest

None.

Authorship

TB, NdV and DvB screened the abstracts, TB and MR extracted the results, TMcC and HT performed the quality assessment. TB and APC jointly wrote the manuscript under incorporation of critical input from CC, HT, MR and TMcC.

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624 **Tables and figures**

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626 **Figure 1. Flow of information through the different phases of the review.**

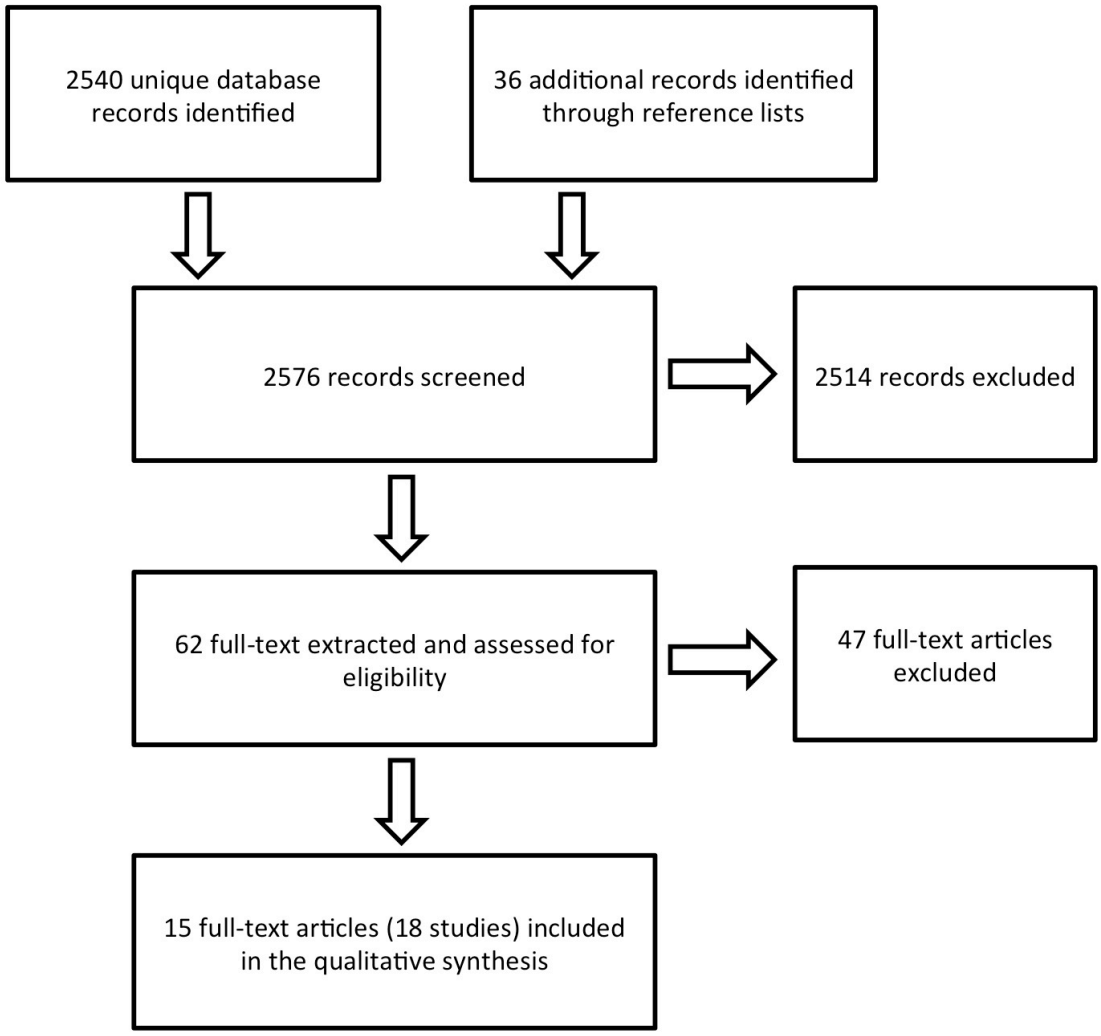

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Table 1. Characteristics of included studies (n=18) assessing the effect of positional changes in the microenvironment on food choice.

Author, Year	Type of study	Type of nudge	Setting	Country	Subjects	Subject age (years)	Subject weight status
Engell et. al., 1996	Experimental between subjects design	Distance/ Proximity	Field study: Army research centre dining hall	USA (Boston)	Employees of U.S. Army Natick Research Centre, N =36	39.5±13.2	Normal weight (181.6±30.7) pounds, 70.6±2.4 inches)
Maas et al.,2012 (Study 1)	Experimental between subjects design	Distance/ Proximity	Laboratory	The Netherlands (Utrecht)	77 females recruited on campus	17-38	Normal weight (BMI: 22.4 ±2.96 kg/m^2)
Maas et al.. 2012 (Study 2)	Experimental between subjects design	Distance/ Proximity	Laboratory	The Netherlands (Utrecht)	54 females recruited on campus	17-38	Normal weight (BMI: 20.89 ±2.16 kg/m^2)
Meiselman et. al., 1994 (Study 1)	Experiment (repeated measures possible)	Distance /Proximity	Field study: University cafeteria	England (Bournemouth)	Customers in University cafeteria; 43 students 334 meals	18 years, 4;19 years,15;20 years,12;21 years,7; over 21.5	N/A
Meiselmann et. al., 1994 (Study 2)	Experiment (repeated measures possible)	Distance/ Proximity	Field study: University cafeteria	England (Bournemouth)	Meals of customers in University cafeteria; 60 students (36 male) who consumed potato chips at baseline	between 18 and 62	N/A
Musher-Eizenman et. al., 2010	Correlation analysis	Distance/ Proximity	Field study: child day care	USA (Ohio)	46 children	6.3 ± 2.3, range: 3.4-11	8th to 98 percentile (M = 65th), 25% overweight (85th percentile and higher)
Privitera et.al.,2010	Between subjects experiment	Distance/ Proximity	Laboratory	USA (St. Bonaventure, NY)	96 (24 male) university students	Variation 1: 19.9 ± 1.1;Variation 2: 20.1 ± 16	BMI: 26.9 ± 3.8 kg/m2 and 26.4 ± 4 kg/m^2--> mean overweight
Privitera et.al., 2014	Between subjects experiment	Distance/ Proximity	Laboratory	USA (St. Bonaventure, NY)	56 university students (26 male)	19 ± 0.9	BMI: 26.0 ± 3.8 kg/m^2; 21 overweight, 15 obese
Wansink et. al., 2006	Within subjects experiment	Distance/ Proximity	Field study: Offices at University	USA (Illinois)	40 female University staff members	42.2 ± 11.3	N/A

Author, Year	Type of study	Type of nudge	Setting	Country	Subjects	Subject age (years)	Subject weight status
Keller and Bucher, 2014	Experimental between subjects design	Order/ Accessibility	Field study: University campus	Switzerland (Zurich)	120 students (60 male, age 24±3yr)	24±3	N/A
Levitz, 1976	Naturalistic observation, experiment (repeated measures possible)	Order/ Accessibility	Field study: Hospital cafeteria	N/A	Customers in hospital cafeteria. 3267 observations. Only choices of normal weight (n=2385) and obese (n=425) subjects were analysed.	N/A	Normal weight and overweight (classification by trained observers)
Levy et. al., 2012	Longitudinal study pre-/post design	Order/ Accessibility	Field study: Hospital cafeteria	USA (Boston)	4642 employees of a hospital cafeteria (71% females)	41	N/A
Meyers et. al., 1980	Experiment (repeated measures possible)	Order/ Accessibility	Field study: Hospital cafeteria	USA (Memphis)	Customers in hospital cafeteria. 4412 observations. Separate analysis for normal weight, over weight and obese subjects.	N/A (adults)	Normal weight and overweight, assessed by observer
Rozin et. al., 2013 (Study 3)	Experimental between subjects design	Order/ Accessibility	Field study: University cafeteria	USA (Pennsylvania, Philadelphia)	Customers of the University cafeteria. Mainly employees of the University of Pennsylvania	N/A	N/A
Thorndike et. al., 2012	Pre-/post intervention	Order/ Accessibility	Field study: Hospital cafeteria	USA (Boston)	Customers of hospital cafeteria	N/A	N/A
van Kleef et. al., 2012 (Study 1)	Two factor experimental design, between subjects	Order/ Accessibility	Laboratory	The Netherlands (Wageningen)	158 undergraduate students (55 male)	21.8 ± 6.7	N/A
van Kleef et. al., 2012 (Study 2)	Two factor experimental design, between subjects.	Order/ Accessibility	Hospital cafeteria	The Netherlands (Wageningen)	291 snack sales, Customers of hospital canteen	N/A	N/A
Wansink et. al., 2013	Between subjects experiment	Order/ Accessibility	Field study: conference venue	USA (Illinois)	124 health conference attendees	N/A	N/A

Table 2. Intervention description and findings of the included studies (n=18)

Author, Year	Description of intervention	Context (Setting and participants)	Magnitude of change in effort	Type of food involved	Data analysis method	Dependent Variables (unit)	Magnitude of the effect	Main Finding	Conclusions
Engell et. al., 1996	Water pitcher on table, vs. dispenser at 20ft or 40ft distance	Customers in Army research centre dining hall	Major; variation in proximity. Large increase in effort to obtain water at a dispenser across room or in another room	Water	ANOVA	Water consumption (gram)	Significant main effect of proximity on intake: $F_{(2,33)}$=8.4, p<.001, Post hoc tests: significant reduction for distant conditions compared to proximate condition, no difference between the two more distant conditions.	Major reduction of water intake if dispenser is further away (on table vs. 20 or 40 feet). No difference between 20ft and 40ft. No effect on other food intake	Effort to obtain water determined amount consumed
Maas et al.,2012 (Study 1)	Distance to snack bowl was varied at 20, 70 and 140 cm	Staff/students recruited to laboratory on University campus	Medium; 70 cm and 140 cm proximity variation required standing up	Candy: Chocolate M&M's (without peanuts) 1kg	Logistic regression, ANCOVA (control for chocolate liking)	Amount of snack consumed (gram) and risk of compensatory behaviour	Significant main effect of proximity on intake: $F_{(2,73)}$=7.59, p=.001 Post hoc tests: significant reduction for distant conditions compared to proximate condition, no difference between the two more distant conditions.	An increase in distance had a significant effect on the probability of snack consumption even for an increase from 20 to 70 cm. No effect for compensatory eating was found.	Distance affected intake, but salience did not.

Author, Year	Description of intervention	Context (Setting and participants)	Magnitude of change in effort	Type of food involved	Data analysis method	Dependent Variables (unit)	Magnitude of the effect	Main Finding	Conclusions
Maas et al.. 2012	Distance to snack bowl was varied at 20, 70 and 140 cm	Staff/students recruited to laboratory on University campus	Medium: 20, 70 and 140 cm. 70 and 140 cm required standing up	Candy: Chocolate M&M's (without peanuts) 1kg	ANOVA	Amount of snack consumed (gram), perception of salience and effort, likelihood of consumption	Significant main effect of proximity on intake: $F_{(2,51)}$=3.8, p=.029, Post hoc tests: significant reduction for distant conditions compared to proximate condition, no difference between the two more distant conditions.	An increase in distance had a significant effect on the probability of snack consumption even for an increase from 20 to 70 cm. Perceived effort increased in distant conditions but not salience	Sign. Effect of proximity on intake. Perceived effort was higher in the two distant conditions, but not perceived salience.
Meiselman et. al., 1994 (Study 1)	Move candy from cash point to distant snack bar.	Customers (students) of University cafeteria	Major; increase of distance (20 meters) and waiting at separate queue. Plus reduction in availability, (from four cash registers to one snack bar)	9 Food categories; Main dishes; pizza, alternatives, salads, sandwich, Desserts;, fruit, accessory foods, Candy; chocolate, chocolate containing bars and muesli bars	Binominal model (Chi-Square)	Candy selection with meals (selection rates)	Less candy selected in nudging condition: $\chi^2(1)=17.78$, $p<.001$. Trend towards more total desserts: $\chi^2(1)=2.21$, $p<.1$ (ns), no effect on other foods	Less candy was purchased during the intervention week. However, participants who chose candy in the first week chose more dessert fruit or accessory foods during the intervention week.	Major increase in effort to obtain an unhealthy food can reduce the consumption of the food. People may partially compensate unhealthy choices.

Author, Year	Description of intervention	Context (Setting and participants)	Magnitude of change in effort	Type of food involved	Data analysis method	Dependent Variables (unit)	Magnitude of the effect	Main Finding	Conclusions
Meiselman et. al., 1994 (Study 2)	Move potato chips from cash register to distant snack bar.	Customers (students) of University cafeteria	Major; increase of distance (20 meters) and waiting at separate queue. Plus reduction in availability, (from four cash registers to one snack bar)	11 Food categories; Main meal, pizzas, starch, vegetables, salads, bread, sandwiches, dessert, fruit, crisps, sweets/cakes, sauces, candy, drinks	Fleiss's formula and chi-square tests	Potato chips selection with meals (selection rates)	Less potato chips selected in nudging condition: $\chi^2(1)=77.27$, $p<.001$. More starch foods during intervention: $\chi^2(1)=6.20$, $p<.001$	Increased effort reduced potato chips selection, reduction was accompanied by increased starch selection	Varying effort can increase or decrease consumption. Foods are substituted with other foods (within same food group)
Musher-Eizenman et. al., 2010	Children were randomly placed at varying distances to healthy and unhealthy snacks	Children in day care	Major: children had to stand up and come up to the experimenter from varying distances and ask for more snack	Snacks: High energy dense animal crackers vs. carrot slices	Hierarchical regression	Consumption of crackers and carrot slices (number of pieces consumed)	Distance from serving bowl predicted intake Distance from crackers: $\beta=-.41$, $p<.05$ ($\Delta R^2=.17$), distance from carrots $\beta=-.38$, $p<.05$ ($\Delta R^2=.14$)	Distance from the serving bowl significantly predicted number of crackers and carrot slices consumed	Proximity influences consumption of healthy and unhealthy snacks in children

Author, Year	Description of intervention	Context (Setting and participants)	Magnitude of change in effort	Type of food involved	Data analysis method	Dependent Variables (unit)	Magnitude of the effect	Main Finding	Conclusions
Privitera et.al.,2012	Manipulation of proximity (near vs. far) and visibility (clear vs. opaque bowl) of healthy foods	Students recruited to laboratory on University campus	Medium: Serving bowl placed 2 metres away on counter or on table within arm's reach	Snacks (healthy): fruits and vegetables	ANOVA	Apple and carrot consumption (number of pieces consumed)	Significant effect of distance on intake: Apple: $F_{(1,44)}$=25.46, p<.001 Carrots: $F_{(1,44)}$=4.52, p<.04	Proximity increased intake of both, fruit and vegetable intake (Visibility only affected of fruit intake).	Proximate can increase consumption of healthy foods. The effect was stronger for apples compared to carrots. This might be because fruits are sweeter and more appealing than vegetables.
Privitera et.al., 2014	Effect of proximity was tested in a competitive food environment with healthy food and unhealthy food at different distances	Students recruited to laboratory on University campus	Medium: Two meters vs. arms reach	Snacks: Apple slices (healthy food) vs. buttered popcorn (high fat/unhealthy food)	ANCOVA: BMI as covariate	Apple and popcorn consumption (kcal and proportion)	Proximity influenced intake: Popcorn: $t_{(17)}$=4.96, p<.001 Apple: $t_{(16)}$=5.16, p<.001 Significant interaction of proximity and food type $F_{(2,52)}$= 16.46, p<.001, R^2=.38	The food that was placed closer to the participants was consumed most, regardless of preference	Making a low calorie food more proximate than a high calorie food, will reduce total energy intake, even if a high calorie and more preferred food is also available but less proximate
Wansink et. al., 2006	Manipulation of proximity (near vs. far) and visibility (clear vs. opaque bowl) of candy	Female staff within their offices at University	Medium: two meters vs. arms reach	Candy (individually wrapped chocolates)	ANOVA, (post hoc t-tests)	Chocolate consumption (number of pieces)	1.8 chocolates more consumed if they were proximate. Effect size unclear.	More candy consumed if it is more proximate	Proximity increases consumption. People overestimate consumption of less proximate foods.

Author, Year	Description of intervention	Context (Setting and participants)	Magnitude of change in effort	Type of food involved	Data analysis method	Dependent Variables (unit)	Magnitude of the effect	Main Finding	Conclusions
Keller and Bucher, 2014	Manipu-lation of snack bar order on tray; healthy bar at the side vs. in the middle of an assortment	Students recruited on campus at University	Minor or none: only positions of foods within reach were altered.	Snacks: Healthy apple cereal bar v.s. unhealthy cereal bars (chocolate cereal bars)	Chi Square	Cereal bar choice (selection rates)	Significant influence of position on selection: $\chi^2(2)=14.95$, $p<.001$	The healthy bar was selected more often, when it was placed in the middle	Changing the position of snacks can nudge healthier choices
Levitz, 1976	Order of desserts with varying energy content in within shelves; front vs. rear position.	Customers in hospital cafeteria	Minor: change within display	Three types of dessert; High calorie: cakes and pies, 350 kcal/serving low calorie: fruit, gelatine, 75 kcal/serving moderate: custard, pudding	Chi Square	Dessert sales, (selection rates)	Normal weight subjects: low energy dessert more available: $\chi^2=4.13$, $p<.05$ high energy dessert more available: $\chi^2=3.96$, $p<.05$ obese subjects: low energy dessert more available: $\chi^2=17.67$, $p<.05$ high energy dessert more available: ns	Normal-weight individuals consistently selected the most available choice Obese people chose more low energy dessert if it was made more salient. No change for obese if high energy dessert was more salient.	Both, obese and normal weight individuals are responsive changes in food positioning.

Author, Year	Description of intervention	Context (Setting and participants)	Magnitude of change in effort	Type of food involved	Data analysis method	Dependent Variables (unit)	Magnitude of the effect	Main Finding	Conclusions
Levy et. al., 2012	2-phase intervention 1st phase: labelling of healthy and unhealthy food. 2nd phase: placement variation of various foods.	Customers in hospital cafeteria	Minor: for sandwiches and chips: only positions of foods within shelves were altered. Eye level vs. below eye level position. Medium for bottled water: bottled water available at several locations in nudging condition.	Beverages, sandwiches, chips	Linear regression (demo-graphics as controls)	Sales of healthy and unhealthy foods (percent change)	Decrease of red item purchases by 4.1% during the Phase-2 choice architecture intervention.	Repositioning red (unhealthy) beverages reduced sales in addition to the colour coding intervention.	Choice architecture intervention improved food and beverage choices among employees from all racial and socioeconomic backgrounds on top of the labelling intervention
Meyers et. al., 1980	Manipulatio n of order of desserts with varying energy content within shelves; front vs. rear position.	Customers in hospital cafeteria	Minor: change within display	Desserts: Two types; high calorie: cakes and pies low calorie: fresh fruit and gelatine	Multiple contingency analysis (chi-square)	Dessert sales, (selection rates)	Likelihood to choose a dessert in front was increased. $\chi^2(2)= 22.3$, $p<.001$ (significant interaction between dessert array and dessert choice)	Subjects were more likely to choose the dessert in front. No difference between overweight and normal weight subjects.	All subjects were more likely to select the dessert in front

Author, Year	Description of intervention	Context (Setting and participants)	Magnitude of change in effort	Type of food involved	Data analysis method	Dependent Variables (unit)	Magnitude of the effect	Main Finding	Conclusions
Rozin et. al., 2013 (Study 3)	Manipulation of salad order at self-service salad bar: less accessible middle position vs. more accessible edge position.	Customers in hospital cafeteria	Minor: change within display	8 ingredients at a salad bar: chicken, egg, tuna, salmon, tomatoes, carrots, mushrooms cucumbers	Multiple t-tests	Sales (weight) from pay-by weight salad bar	Average sales of each ingredient was reduced by 8.9% in the middle position compared to the edge position ($t(7)$= -4.13, p<.01, Z-score = 0.30	Sales of each of the eight ingredients diminished when displayed in the less accessible middle row	Food positions at self-serving pay-by-weight salad bar had a significant influence on sales.
Thorndike et. al., 2012	See Levy et al.,2012	Customers in hospital cafeteria	Medium and minor; See Levy et al.,2012	Beverages, sandwiches, chips	Logistic regression	Sales of healthy and unhealthy foods, selection rates	Decrease of unhealthy beverage purchase by 11.4% increase of healthy beverage purchase by 4% increased sales of bottled water by 25% ,p>.001	small but significant increases in sales by reordering sandwiches and chips on shelves	Choice architecture intervention improved food and beverage choices.
van Kleef et. al., 2012 (Study 1)	Manipu-lation of snack position (healthy foods on top vs. at bottom)	Undergraduate students recruited to laboratory on University campus	Minor; only positions of foods on screen were altered	Snacks: an assortment of 16 (out of 24) healthy and unhealthy snacks; fresh and dried fruit and vegetables, savoury and salty snacks, and sweet biscuits and chocolates.	Logistic regression and ANOVA	Snack choice on screen	No significant differences were observed in the 'healthy snacks at the top' conditions (30.38% choose healthy) compared to the bottom conditions (27.85%; (1, n=158) = 1.29, p=.34).	No significant effect of shelf position on snack choice	Field study showed a trend that consumption of healthy foods was affected, but that consumption of unhealthy foods was not altered

Author, Year	Description of intervention	Context (Setting and participants)	Magnitude of change in effort	Type of food involved	Data analysis method	Dependent Variables (unit)	Magnitude of the effect	Main Finding	Conclusions
van Kleef et. al., 2012 (Study 2)	Manipu-lation of shelf position (healthy foods on top vs. at bottom)	Customers in hospital cafeteria	Medium; positions of foods within a shelf were altered, reaching some foods required bending down	Snacks: an assortment of 16 healthy and unhealthy snacks: fresh and dried fruit and vegetables, savoury and salty snacks, and sweet biscuits and chocolates.	ANOVA	Snack sales	No significant effect of shelf arrangement on total snack sales ($F_{(1,6)=}$3.84, p=0.1. Separate analysis for healthy and unhealthy snacks revealed that no effect on unhealthy items but a trend towards higher sales of healthy items when healthy foods were placed on top ($F_{(1,6)}$=5.03,p=.07	no significant effect of shelf position for unhealthy foods, but a trend to higher sales for healthy foods, if they were placed more prominent	No effect of repositioning on choice.
Wansink et. al., 2013	Food order inverted at breakfast buffet: healthiest to least healthy vs. least healthy to healthiest food	Conference participants at conference venue	Medium; order of foods on buffet was altered	7 item buffet: cheesy eggs, potatoes, bacon, cinnamon roll, low fat granola, low-fat yoghurt and fruit	Chi Square, Maxwell tests	Breakfast item selection (selection rates)	Significant effect of order on choice: $\chi^2(6)=25.1$, $p<.001$, Stuart-Maxwell test = 171.2 ($p<.001$, $df=6$)	Order significantly influences what people select	First foods in line were consumed most often

Table S1. Quality scoring according to the review Evidence Analysis Manual of the Academy of Nutrition and Dietetics (©2012) of the included publications (n=15)

	Engell et. al., 1996	Maas et al.,2012 (Study 1)	Maas et al.. 2012 (Study 2)	Meiselman et. al., 1994 (Study 1)	Meiselman et. al., 1994 (Study 2)	Musher-Eizenman et. al., 2010	Privitera et.al.,2012	Privitera et.al., 2014	Wansink et. al., 2006
Overall study quality	Ø	Ø	Ø	Ø	Ø	**(-)**	Ø	Ø	Ø
VALIDITY QUESTIONS									
1. Was the research question clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the selection of study subjects/patients free from bias?*	**Unclear**	**Unclear**	**Unclear**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Unclear**
3. Were study groups comparable?*	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Unclear**	**Unclear**	**Unclear**	**Unclear**
4. Was method of handling withdrawals described?	No	Yes	Yes	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
5. Was blinding used to prevent introduction of bias?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
6. Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were intervening factors described?*	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Unclear**	**Yes**	**Yes**	**Yes**
7. Were outcomes clearly defined and the measurements valid and reliable?*	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Unclear**	**Yes**	**Yes**	**Yes**
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	Unclear	Yes	Yes	Unclear	Unclear	Unclear	Yes	Yes	Yes
9. Are conclusions supported by results with biases and limitations taken into consideration?	No	Yes	Yes	No	No	Yes	No	Yes	Yes
10. Is bias due to study's funding or sponsorship unlikely?	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Yes	Unclear	Unclear

	Keller and Bucher, 2014	Levitz, 1976	Levy et. al., 2012	Meyers et. al., 1980	Rozin et. al., 2013 (Study 3)	Thorndike et. al., 2012	van Kleef et. al., 2012 (Study 1)	van Kleef et. al., 2012 (Study 2)	Wansink et. al., 2013
Overall study quality	Ø	**(-)**	Ø	**(-)**	Ø	Ø	**(+)**	Ø	Ø
VALIDITY QUESTIONS									
1. Was the research question clearly stated?	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the selection of study subjects/patients free from bias?*	**No**	**Unclear**	**No**	**Unclear**	**N/A**	**N/A**	**Yes**	**Yes**	**N/A**
3. Were study groups comparable?*	**Yes**	**Unclear**	**N/A**	**Unclear**	**N/A**	**N/A**	**Yes**	**N/A**	**Unclear**
4. Was method of handling withdrawals described?	Unclear	No	N/A	Unclear	N/A	N/A	Unclear	Unclear	N/A
5. Was blinding used to prevent introduction of bias?	Yes	Yes	N/A	Unclear	N/A	N/A	Yes	Yes	Yes
6. Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were intervening factors described?*	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7. Were outcomes clearly defined and the measurements valid and reliable?*	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	Unclear	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9. Are conclusions supported by results with biases and limitations taken into consideration?	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes
10. Is bias due to study's funding or sponsorship unlikely?	Unclear	Unclear	Yes	Yes	Unclear	Yes	Yes	Yes	Yes

Notes. Legend study quality scores: (+) positive, (-) negative, Ø neutral. N/A – Not applicable.
* For human studies to be graded as positive, questions 2, 3, 6 and 7 needed to be graded as *"Yes"* plus one additional criteria