



Sustainable healthy diets from the lens of behavioural science

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1
2 **Title:**

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27 **Summary**

28 Changes in the food system are key for attaining the Sustainable Development Goals. This viewpoint i)
29 contends that, alongside structural changes to the food production and distribution systems, the next
30 years are decisive to foster individual behaviour change for sustainable healthy diets , especially in high-
31 income countries, ii) provides a set of behaviour change techniques that can contribute to the design of
32 individual interventions aimed at that dietary change, iii) highlights the main weaknesses of previous
33 eating behaviour interventions and suggest how they may be overcome, notably by addressing potential
34 negative spillovers and trade-offs, and iv) provides an actionable definition of sustainable healthy diets
35 for designing behaviour change interventions. This viewpoint offers a relevant starting point for the
36 design of future interventions targeting individual behavioural change for sustainable healthy diets from
37 a multi-disciplinary perspective.

38

39 The way we produce and consume food carries high social and environmental costs. Despite producing
40 more than enough calories to feed the global population, distribution is highly unequal.¹ More than two
41 billion people are suffering some type of food insecurity, leading to undernutrition as well as overweight
42 and obesity.² More than one third of the food produced is lost or wasted.³ Three billion people cannot
43 afford a healthy diet, with unhealthy diets being the leading cause of morbidity and mortality
44 worldwide.² Additionally, there are countless cases of forced labor conditions and unfair salaries across
45 the food system.⁴ From a planetary health perspective, the food system is responsible of around one
46 third of all greenhouse gas (GHG) emissions worldwide.^{5,6} Its contribution to global warming is so
47 important that it has been postulated that even if the GHG emissions from all non-food-related sectors
48 were immediately stopped and net zero from now on, emissions from the food system solely would still
49 preclude reaching the Paris Agreement goal of limiting global warming to 1.5 degrees Celsius.⁷ Beyond
50 climate change, the food system currently uses about 70% of freshwater withdrawals and is a major
51 source of water eutrophication.^{8,9} Forty percent of the habitable land on Earth is used for growing our
52 food or to feed farmed animals.¹⁰ About 73% of the world's deforestation is related to the food
53 system,¹¹ being the leading cause of habitat degradation and biodiversity loss.¹² The consequences of
54 this environmental degradation is already noticeable (e.g., extreme weather events are further
55 compromising food security), affecting especially the most vulnerable areas.¹³ If the current food
56 production and consumption patterns continue as usual, the global impact on the environment of the
57 food system will increase among 50-90% by 2050 in comparison to 2010 values.¹⁴ Therefore, rapid,
58 effective and combined structural, technological and individual changes are needed to achieve a more
59 resilient, sustainable and fair food system within planetary boundaries.^{15,16} This viewpoint focus on the
60 specific role of individual behaviour changes towards sustainable healthy diets (i.e., those healthy diets
61 with low environmental impact, in which foods are obtained from fair and ethical sources)^{17,18}, from the
62 consumers perspective, and under the lens of a multi-disciplinary collaboration between behavioural,
63 socio-economic and climate scientists as well as nutritionists.

64

65 **Promoting individual eating behaviour change: why, for whom, and how?**

66 **Why.** The question of individual behaviour change versus systems change is a false dichotomy.^{16,19-21}
67 Lifestyles choices are enabled and constrained by the physical environment, political contexts and
68 infrastructures, but at the same time individual behaviours can spread into, and ultimately shape, social
69 and cultural norms in a bottom-up fashion, thus leading to political and structural changes.^{15,22,23} Being
70 generated in a top-down or bottom-up fashion, radical changes in current individuals' dietary patterns
71 towards healthy diets with low environmental impact are essential for achieving a food system that fits
72 in planetary boundaries, and contribute to end the global syndemic of malnutrition.^{16,24,25} Such healthy
73 diets with low environmental impact, beyond differences in preferences and traditions of each specific
74 culture, are characterized by being nutritionally-balanced patterns, mainly (if not totally) based on
75 whole plant-sourced foods.^{2,25} Shifting current dietary patterns towards such diets has the potential of
76 halving the pressure of the food system on climate change, and reducing by 6 to 22% other
77 environmental impacts, such as water and land use, or the application of fertilizers.¹⁶ At the individual
78 level, changing eating behaviour is one of the most effective climate change mitigation strategies that

79 someone can undertake, representing between 10 to 30% of an individual carbon footprint.²⁶⁻²⁹
80 Transitioning to healthy diets with low environmental impact would also have major impacts on human
81 health, avoiding about 11 million deaths per year and reducing premature mortality by almost 20%.^{25,30}
82 Additionally, if opting for foods from sustainable sources, not only considering environmental but also
83 the socioeconomic dimension of food (e.g., working conditions, economic fairness, gender equality,
84 etc.), consumers could significantly contribute to achieve a fairer food system, and the achievement of
85 many of the Sustainable Development Goals (i.e., goals adopted by the United Nations in 2015 as a
86 universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy
87 peace and prosperity).³¹

88 Encouragingly, early signs of this transition are already noticeable and should now be encouraged. For
89 instance, a report from the grey literature shows that almost 40% of people in the United States point
90 that environmental sustainability has an impact on their decision to buy certain foods and beverages,
91 and a similar percentage say that knowing that the workers who produce, distribute, or serve the food
92 are treated in a fair and equitable way is important.³² In Europe, another report from the grey literature,
93 conducted across 7 countries (i.e., Germany, Denmark, Switzerland, Austria, Portugal, France and
94 Belgium), shows that the number of Europeans deliberately consuming meat less frequently is growing
95 rapidly at 23%, with the primary motivator reported being health followed by sustainability.³³ This
96 highlights that relatively new interests towards sustainable healthy diets is ongoing in consumers. This
97 transition should now be strongly encouraged to help people changing their behaviours and ultimately
98 progressively create new food-related social norms.³⁴

99 **For whom.** To be fair and effective, most behaviour changes initiatives promoting sustainable healthy
100 diets should be first directed to the higher emitter groups, usually the individuals with the higher
101 incomes, between- and within-countries.^{15,35,36} Between countries, mathematical modelling studies
102 suggests that the general adoption of sustainable healthy diets in developed countries could be an
103 effective strategy in reducing GHG emissions by 70-90% and the use of resources by 5-50%, while
104 improving people's health.^{35,37} The general adoption of healthy diets in low-income countries, however,
105 would require an increased use of natural resources due to the need to address existing combinations of
106 often inefficient farming systems and widespread dietary insufficiency in terms of both quantity and
107 quality.³⁵ Further, eating behaviours in high-income countries can have social, economic and
108 environmental consequences in low-income countries, that can exacerbate food insecurity and
109 environmental degradation in those areas (e.g., the boom of quinoa demand from the Global North
110 countries has led to biodiversity loss in the producer countries, conflicts over land among peasants, and
111 a reduced accessibility to this staple food by low-income families).³⁸

112 Within high-income countries, individuals' dietary environmental impact is higher among men,^{39,40} and
113 among those with higher socioeconomic status and incomes.^{36,41} Food insecurity and hunger are even
114 experienced among people with the lowest incomes in high-income countries.⁴² Thus, individuals from
115 upper socioeconomic level in high income countries, frequently men, should be targeted first if we are
116 to achieve significant reductions in diet-related environmental impact and a fair food system as soon as
117 possible. Similar groups in rapidly industrialising countries, such as China, are also key targets for
118 behavioural scientists if we want to prevent emerging economies to follow the unsustainable pathways
119 of high-income countries.⁴³

120 **How:** Two main approaches have been applied so far for promoting eating behaviour change: *i)*
121 interventions inspired by behavioural economics using large- (e.g., taxing and subsidizing foods) and
122 micro-environmental (the so-called “nudges”) modifications to alter peoples’ behaviours with little
123 cognitive engagement (e.g.,^{44,45}), and, central to this viewpoint, *ii)* individual behavioural change
124 interventions targeting peoples’ knowledge, capability, attitudes and motivations in order to help
125 individuals reevaluate their behaviours and adopt relevant modifications (e.g.,^{46,47}). The combination of
126 both approaches is required to achieve scaled and long lasting change in eating behaviors.²⁰ Indeed,
127 although reshaping food environments can be effective to change eating behaviours,^{15,44,48} this set of
128 approaches is likely to be more powerful if combined with individual measures aimed at educating,
129 raising awareness and motivating individuals directly.²⁰ Individuals behaviour change interventions can
130 also contribute to the acceptability of political, structural and environmental modifications and to limit
131 potential forms of psychological reactance.⁴⁹

132 Behaviour change interventions targeting individuals are also effective in changing eating behaviours on
133 their own (increasing the consumption of certain food groups, such as fruits and vegetables,⁵⁰⁻⁵³ and
134 reducing the intake of others, such as meat^{47,54-56}). Those behavioural interventions are composed of
135 several “active ingredients”, usually reported and labelled in the literature under the term “behaviour
136 change techniques (BCT)”.^{57,58} These techniques describe the content of behavioural change
137 interventions by naming each specific individual component forming the intervention, such as
138 “providing information about the health consequences”, “goal setting”, or “self-monitoring”. One of the
139 challenges in designing individual behaviour change interventions is to use a good “cocktail” of BCTs. In
140 theory, BCTs can be selected with the aim to target specific modifiable factors, also called mechanisms
141 of actions, that can cause the targeted behaviour.⁵⁹ For example, if one assumed that eco-anxiety is
142 positively associated with the consumption of fruits and vegetables,⁶⁰ specific BCTs can be selected to
143 explicitly manipulate eco-anxiety and ultimately the consumption of fruits and vegetables. A second
144 option that can help identifying relevant BCTs is to empirically review the literature to identify which
145 techniques are associated with interventions’ efficacy. Following this second option, and as part of this
146 perspective, we performed a scoping review of systematic reviews and meta-analyses of eating
147 behaviour change interventions to identify key BCTs that can effectively contribute to the promotion of
148 successful eating behaviour changes. Key results from this scoping review are presented in the following
149 section (please, see additional methodological details and findings of this review at:
150 <https://osf.io/q8jmk/>.

151 **Effective behaviour changes techniques for achieving individual eating behaviour change**

152 In the last years, several systematic reviews or meta-analyses explicitly testing BCT effectiveness for
153 changing eating behaviours,^{50-53,61,62} or identifying eating interventional features associated with changes
154 in eating behaviours have been published (see a description of these individual studies at
155 <https://osf.io/q8jmk/>).^{47,54-56,63} Table 1 presents the behaviour change techniques identified according to
156 different food groups and defined according to the BCT taxonomy (v1).⁵⁷ Overall, we identified 16
157 techniques that were associated with eating behaviour change across the different reviews and meta-
158 analyses. Some BCTs, such as “goal setting” or “self-monitoring of the behaviour”, were positively
159 associated with interventions efficacy considering different food groups, such as increases in fruit and

160 vegetable intake,^{51,52} decreases in meat consumption,^{47,55} and change in overall diet, including fat and
161 energy intake.⁶³ On the other hand, other BCTs were associated with intervention efficacy for changing
162 some specific behaviours but not others. For instance, “information about emotional consequences”
163 (e.g., emphasising animal suffering) was positively associated with reductions in meat consumption,^{54,55}
164 but negatively with the promotion of fruits and vegetables in one systematic review and meta-analysis.⁵¹
165 Finally, some BCTs were only associated with one food group, such as “information about others’
166 approval” that can positively contribute to reduced meat consumption.⁵⁴

167 This meta-synthesis of the literature offers a list of BCTs that can positively contribute to successful
168 eating behaviour changes and, thus, can serve as a basis to design individual behaviour changes
169 interventions based on available empirical evidence. Although this question should be explored further,
170 it appears that depending if we want to promote or hinder the consumption of certain food groups,
171 different BCTs should be implemented. In other words, some BCTs could be more effective for targeting
172 a reduction in the consumption (e.g., reduce meat consumption) than for targeting an increment (e.g.,
173 promote fruits and vegetables intake).²⁵ It is also worth mentioning that different eating behaviours
174 probably don’t have the same behavioural plasticity or, in other words, are not equally easy to change
175 and sustain.⁶⁴ It is likely that some deeply established behaviours, such as meat consumption, are more
176 difficult to change and require greater emphasis when designing an intervention than other behaviours,
177 such as increased fruit and vegetable consumption.⁴⁶ Beyond the type of the BCTs to be applied, it
178 seems that using several BCTs in the same intervention would lead to more effective results,⁵³ up to a
179 certain threshold where the manipulation of too many interventional components can have detrimental
180 effect.⁶⁵ The most effective combination of BCTs and the order in which they have to be implemented is
181 something that requires further research.⁶⁶ Importantly also, the effectiveness of eating behaviour
182 interventions may depends on the characteristics and motivations of targeted individuals. The
183 assessment of intervention features that are most likely to successfully tackle eating behaviours in those
184 with less sustainable diets is definitely needed.

185

186 **Limitations of previous individual behaviour change interventions and perspectives**

187 Past eating behaviour interventions mainly focused on specific food groups, such as fruits and
188 vegetables intake, the reduction of meat consumption or reduced fat and energy intake, instead of
189 taking a global dietary approach. Focusing on single food groups comes with a particular limitation: the
190 lack of consideration of potential behavioural spillovers (also called rebound effects when expressed in
191 terms of energy). Spillovers occur when a change in one specific behaviour leads to secondary order
192 changes in other related behaviours.⁶⁷ In some cases these spillovers can be positive, when one
193 favourable change to one’s diet leads to another favourable behavioural change; but they can also be
194 negative, when one positive change comes with a secondary order, likely unplanned, change in another
195 behaviour, compromising the overall effect of the intervention. These negative spillovers may occur
196 *among food groups*, for instance when an increment in vegetable consumption “licenses” a subsequent
197 increase in added sugars, offsetting the health benefits of increased vegetable intake,⁶⁸ or when meat
198 reduction, such as pork or poultry, is compensated by an increase in cheese (one of the food products
199 with the higher environmental impact, not only by weight, but also by protein and energy content),
200 incrementing the dietary environmental impact.⁶⁹ Spillovers can also arise in behaviours unrelated to

201 food choices: within the *whole food domain* (e.g., the environmental benefits of adopting a low
202 environmental impact diet would be offset if followed by more food wasted);⁷⁰ between *high-*
203 *environmental impact behaviours* (e.g., when the money saved from reducing meat consumption is re-
204 directed to goods or services with high environmental impact, for instance, traveling by plane)⁷¹ or
205 *between health-related behaviours* (e.g., when the adoption of a healthier diet could license the lack of
206 practice of a regular physical activity).⁷²

207
208 Additionally, it is quite rare to find literature on eating behaviour change that simultaneously aims at
209 promoting diets that are both healthier and more sustainable. While the healthiness and environmental
210 impact of foods/diets usually go hand in hand, this is not always the case. For example, fish is a healthy
211 food, but -in some instances- its environmental impact is notorious.⁷³ Similarly, the promotion of healthy
212 diets may lead to health benefits, but at the expenses of a higher dietary environmental impact
213 depending on the foods added and removed.^{74,75} Even healthy foods with low environmental impact, if
214 obtained from unfair sources, could compromise the wellbeing and even food security of producers and
215 other stakeholders all along the food system.⁷⁶ All these dimensions should be considered together to
216 achieve the maximum co-benefits, avoiding unintended spillovers and trade-offs among domains.

217
218 We argue here that addressing spillovers and trade-offs is crucial when designing interventions to
219 promote sustainable healthy diets to ensure an overall positive impact of the intervention in terms of
220 human health, planetary health and social equity. Based on this, and considering the major dietary
221 changes required in high-income countries for the general adoption of sustainable healthy diets,²⁵ we
222 propose an actionable definition based on previous guiding principles,¹⁸ but explicitly tailored to
223 researchers, practitioners and policy-makers aimed at the promotion of sustainable healthy diets:

224
225 *When promoting sustainable healthy diets, the consumption of animal-sourced proteins, such as*
226 *meats, especially red and processed meat, and dairies should be reduced, and substituted by*
227 *plant-based proteins, i.e. legumes and nuts. At the same time, the consumption of whole grains*
228 *should be emphasized over the refined versions, unsaturated and unrefined oils (e.g., virgin olive*
229 *oil, canola oil) should be promoted over other dietary fats (e.g. butter, coconut oil), and the*
230 *consumption of water should be targeted as a main dietary beverage, over sweetened beverages*
231 *and alcoholic drinks. The consumption of fruits and vegetables should be incentivised, while the*
232 *intake of highly processed foods rich in sugars, salt and/or fats be decreased.*²⁵ *All these*
233 *behavioural changes should be monitored accounting for potential negative spillovers across food*
234 *groups, making sure that all required nutrients and energy are intake, neither in deficiency nor in*
235 *excess. Special attention should be paid also on spillovers across high-environmental impact and*
236 *health-related behaviours, and so potential trade-offs within the dimensions of dietary*
237 *sustainability: human healthiness, environmental impact and socio-economic wellbeing.*

238
239 Additionally, and as pointed out elsewhere,⁶⁴ future eating behaviour change interventions will also
240 have to overcome specific limitations of the previous interventions related to pro-environmental and/or
241 health behaviour change. This includes i) the adoption of study designs allowing for strong causal
242 inferences such as randomized control trials but also N-of-1 trials, offering higher possibilities of tailoring

243 and continuous optimization, at lower financial costs;⁷⁷ *ii)* longer period of monitoring, such as several
244 months, to capture accurate patterns of change in eating behaviours over time, and at the right
245 resolution (.e., changes happening from week to week);⁷⁸ and *iii)* the inclusion of citizen and directly
246 targeted users in the development process of such interventions to increase the chances for its
247 acceptability and feasibility, and gathering relevant information on peoples' needs.⁷⁹

248
249 Further, the development of reliable measurement tools and scoring procedures to both briefly screen
250 as well as continuously monitor individuals changes in sustainable diets, together with the
251 aforementioned spillovers, is definitely necessary. Traditional dietary indices have only focused on the
252 dietary healthiness and nutrient adequacy, leaving aside the environmental, socio-cultural and
253 economic dimensions of food; the scoring criteria of those few that considered all those dimensions at
254 once was not easily applicable by consumers, nutritional practitioners or behavioural researchers.^{80,81}
255 Some efforts have been done in the last years for the development of more practical scores for the
256 assessment of sustainable healthy diets, but they still lack consideration of the socio-cultural and
257 economic dimensions, and so other behaviours beyond diet.^{82,83} Their consideration is key to evaluating
258 the overall effect of the intervention on the sustainability as a whole. The utilisation of more objective
259 data collection, in parallel with self-reported behavioural outcomes, such as food photos, could also help
260 improving the evaluation of these interventions.⁸⁴

261
262 **Conclusions**
263 A social transformation toward a lifestyle in general, and diet in particular, that fits with the planetary
264 boundaries is urgent. Beyond structural changes, individual behavioural change is deeply needed in
265 order to accelerate such a transition, notably among high-income groups within- and between-
266 countries. The present viewpoint offers a starting point for the design of future individual interventions
267 for sustainable healthy diets based on available evidence in terms of effective behaviour change
268 techniques for promoting different eating behaviours. We also draw important new perspectives related
269 to the consideration of various spillovers and trade-offs when changing one's behaviour. Ultimately, this
270 viewpoint is also a call for more multidisciplinary collaborations between environmental, socio-
271 economic, nutrition and behavioural researchers to develop future relevant interventions promoting
272 sustainable healthy diet as a whole and in its full complexity.

273
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275 wrote the original draft; PB searched the literature and reviewed and edited the draft; VAS
276 conceptualized the study and reviewed and edited the draft; SJL reviewed and edited the draft; FEH
277 reviewed the draft. All authors have read the whole document and accept responsibility to submit for
278 publication.

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Table 1. Associations between behaviour change techniques (BCT) and eating behaviours outcomes

BCT		Definition	Eating behaviour change			
			Improve overall diet	Increase fruit and vegetable intake	Reduce meat consumption	Decrease SSB and increase water
1.1	Goal setting	Set or agree on a goal defined in terms of the behaviour to be achieved	+	+	+	
1.2	Problem solving	Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators	+	+		
1.4	Action planning	Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity)	+		+	
2.2	Feedback on behavior	Monitor and provide informative or evaluative feedback on performance of the behaviour		mixed		
2.3	Self-monitoring of behavior	Establish a method for the person to monitor and record the outcome(s) of their behaviour as part of a behaviour change strategy	+	+	+	
3.1	Social support (unspecified)	Advise on, arrange or provide social support (e.g. from friends, relatives, colleagues, 'buddies' or staff) or non-contingent praise or reward for performance of the behaviour		+		
4.1	Instruction on how to perform a behavior	Advise or agree on how to perform the behaviour			+	+

4.2	Information about antecedents	Provide information about antecedents (e.g. social and environmental situations and events, emotions, cognitions) that reliably predict performance of the behaviour	+				
5.1	Information about health consequences	Provide information (e.g. written, verbal, visual) about health consequences of performing the behaviour	+	-	+		
5.3	Information about social and environmental consequences	Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behaviour			+		
5.6	Information about emotional consequences	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behaviour		-	+		
6.1	Demonstration of the behavior	Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g. via film, pictures, for the person to aspire to or imitate			+	+	
6.2	Social comparison	Draw attention to others' performance to allow comparison with the person's own performance	+				
6.3	Information about others' approval	Provide information about what other people think about the behaviour. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do			+		
7.1	Prompt/cues	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour	+	mixed			
15.3	Focus on past success	Advise to think about or list previous successes in performing the behaviour	+				

Improvement in overall diet includes outcomes such as fruits and vegetables together with reduced fat intake and caloric intake. "+" indicates that interventions using the specific BCT are more effective at changing the behavioural outcomes compared to interventions that do not integrate the specific BCT; "mixed" indicates mixed findings about the effectiveness of that behaviour change technique on those outcomes (including positive and negative

effects); "-" indicates that interventions using the specific BCT are less effective at changing the behavioural outcomes compared to interventions that do not integrate the specific BCT.