

Towards healthier diets and more sustainable food systems: Developing and evaluating behavioural interventions to reduce meat consumption

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Abstract

Producing meat generally leads to greater greenhouse gas emissions, deforestation, water use and pollution, and biodiversity loss compared to producing plant-based foods. While there are many supply-side measures that can help to mitigate livestock's environmental impact, substantively reducing meat consumption is required to ensure that food systems can sustainably feed the growing global population and would result in some benefits for human health too. Behavioural interventions to encourage changes in eating habits could help to reduce meat intake, but few such interventions have been implemented and rigorously tested. The aim of this thesis is to contribute towards addressing this evidence gap by generating empirical evidence on the effectiveness of behavioural interventions to reduce meat consumption through (i) systematically reviewing and synthesising the evidence on the effectiveness of interventions targeting conscious behavioural determinants or restructuring physical micro-environments; (ii) the development of a novel behavioural intervention (Replacing Meat with Alternative Plant-based Products, RE-MAP) to reduce meat consumption through the provision of meat substitutes, infographics, success stories, and recipes; (iii) a randomised trial evaluating the impact of RE-MAP on meat consumption, wider dietary changes, markers of health risk, markers of environmental degradation, and psychosocial factors related to meat and meat substitutes consumption; and (iv) qualitative interviews exploring the mechanisms through which the intervention might have delivered impact and recipients' experiences of the intervention. The results of my DPhil suggest that some behavioural interventions targeting conscious determinants of human behaviour and restructuring physical micro-environments can help to reduce meat consumption. Providing meat substitutes for four consecutive weeks along with supporting informational material is an acceptable strategy to help people eat less meat and emerged as one of the most effective interventions to reduce meat consumption tested to date. Specifically, RE-MAP led to a 63 g/d reduction in meat consumption at the end of the intervention and a 39 g/d reduction four weeks after the intervention completion. Based on these findings, future research should investigate how to translate the active components of the RE-MAP intervention into a scalable policy option.

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Statement of contribution

I declare that this thesis is entirely my own work, completed under the supervision of Professor Susan Jebb, Professor Paul Aveyard, Dr Nerys Astbury, and Dr Brian Cook at the Nuffield Department of Primary Care Health Sciences, University of Oxford. I led all aspects of the work presented in this thesis, including the design, conduct, and analysis of all studies, as well as the writing of chapters and related journal articles. Emma Garnett and Claudia Dorsel contributed to the systematic reviews presented in Chapter 2 by duplicating the screening and data extraction of the reviews. Cristina Stewart contributed to the Randomised Controlled Trial (RCT) of the RE-MAP intervention presented in Chapter 3 by assisting with the analysis of food diaries. All tables and figures contained within this thesis are my own creation or are appropriately referenced. I hereby declare that no part of this thesis has been submitted for any other degree at this or any other University. Parts of this thesis have been previously published as peer reviewed journal articles. Wordcount: 46,428.

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Chapter 1: Meat, health, and the environment

1. Chapter summary

This chapter sets the scene for the rest of my thesis by outlining the environmental impact of producing meat and the potential public health benefits of eating less red and processed meat in high income countries. Producing meat generally leads to greater greenhouse gas emissions, deforestation, water use and pollution, and biodiversity loss compared to producing plant-based foods, regardless of whether comparisons are conducted per unit of produce, protein, or energy. While there are many supply-side measures that can help to mitigate livestock's environmental impact, substantively reducing meat consumption is also required to ensure food systems can sustainably feed the growing global population. Reducing meat consumption in high income countries is also likely to result in direct benefits to human health, as a growing body of epidemiological research suggests that consuming red and processed meat is associated with an increased risk of colorectal cancer and various cardiometabolic conditions. While meat consumption has started to decline in many high income countries, the pace and scale of these reductions are not sufficient to ensure the sustainability of food systems and interventions are needed to accelerate and magnify this dietary transition. Behavioural interventions to encourage changes in eating habits could help to reduce meat intake, but only few such interventions have been implemented and rigorously tested. The aim of this thesis is to contribute towards addressing this evidence gap by generating empirical evidence on the effectiveness of behavioural interventions to reduce meat consumption.

2. The environmental impact of global food systems

Since the mid-1950s human activities have become a dominating driver of environmental change contributing to an unprecedented pace and scale of environmental degradation. Food production represents one of the most important anthropogenic sources of environmental harm.(1–6) Current food systems account for 26% of anthropogenic GHG emissions (13.7 Gt CO_2-eq per year), 32% of terrestrial acidification (92.4 Mt SO2eq per year), 70% of freshwater withdrawals (28,350 km3 per year), and 78% of freshwater eutrophication (65.3 Mt PO43-eq per year).(4,7–10) Food systems also cover 37% of ice- and desert-free land and the continued expansion of agriculture into natural ecosystems negatively affects the natural biodiversity.(4)

By mid-21st century the environmental pressures of food systems are expected to further increase, primarily due to increasing affluence and population growth: global income is expected to triple from US$68 trillion in 2010 to US$180–290 trillion in 2050 and the global population is expected to rise from 6.9 billion in 2010 to 8.5–10 billion in 2050.(11) In the absence of effective mitigation strategies, these demographic transitions are estimated to increase GHG emissions from food systems by 87%, demand for cropland by 67%, blue water usage by 65%, and phosphorus and nitrogen application by more than 50%.(11) Based on these projections, food systems will soon exceed the planetary boundaries that define a safe operating space for humanity. For example, by 2050 it is estimated that food systems will exceed the planetary boundaries for GHG emissions by 110%, those for cropland usage by 70%, and those for blue water usage by 50%.(11)

Achieving international environmental goals, such as limiting global warming to 2°C above pre-industrial levels, therefore requires radical transitions to more environmentally sustainable food systems.(1,12) Exclusively focussing on increasing the sustainability of other human activities (e.g. decarbonising the global energy system) will not suffice to ensure a sustainable global development.(1,12)

3. Livestock production and the natural environment

When considering options to increase the sustainability of food systems it is important to recognise that producing different foods may result in different levels of environmental degradation.(2,6) Comparing the environmental impact of different foods is challenging due to the widespread heterogeneity in production processes, inconsistencies in the methodological approach of different environmental analyses, and suboptimal data quality.(2,5,13–15) However, a growing body of empirical research suggests that there is a consistent 'hierarchy' in the level of environmental degradation associated with producing different foods,(1,16,17) with meat generally resulting in much greater levels of environmental degradation compared to producing plant-based foods regardless of whether analyses are conducted per produce weight, per unit of energy, or per unit of protein.(1,13,16–19)

3.1 Livestock's impact on global warming

The strongest evidence for livestock's disproportionate impact on the environment relates to GHG emissions. Due to low feed-conversion rates, ruminants' enteric fermentation, and manure-related emissions, livestock makes up for 14.5% of global anthropogenic GHG emissions and for up to 78% of agricultural emissions.(1,11,20–26) Ruminants account for the majority of these emissions: beef production is responsible for 25% of GHG emissions from food systems, while only providing 1% of energy.(20) To date, the most comprehensive study on the environmental impact of food, estimates that on average producing 1kg of beef leads to 99.5kg of CO_2-eq, 1kg of pork leads to 12.3kg of CO_2-eq, and 1kg of poultry leads to 9.9kg of CO_2-eq. These emissions are 3 to 249 times greater than those generated by producing 1kg of protein-rich plant-based foods, such as tofu (3.2kg of CO_2-eq), pulses (1.4kg of CO_2-eq), or nuts (0.4kg of CO_2-eq).(24) Results are similar when analyses are conducted per 100g of protein: Producing 100g of protein from beef leads to 50kg of CO_2-eq, 100g of protein from pork leads to 7.6kg of CO_2-eq, and 100g of protein from poultry leads to 5.7kg of CO_2-eq, while much lower emissions result from producing 100g of protein from tofu (2kg of

CO_2-eq), pulses (0.6kg of CO_2-eq), and nuts (0.3kg of CO_2-eq).(24,27) These data are consistent with studies comparing GHG emissions of wider dietary patterns, which generally find vegetarian and vegan diets to be linked with the lowest levels of emissions.(1,2,13,14,28–30)

Some studies have attempted to compare livestock's emissions to those of other human activities, such as transport.(31) Since different human activities result in different *types* of GHGs, these comparisons require converting all emissions onto a common scale. For this purpose, most such studies used a metric known as CO_2-eq , which involves converting all non- CO_2 GHG emissions to the amount of CO_2 that would have led to the equivalent level of global warming over the first 100 years from the time of emission.(5) For livestock, 44% of emissions are CH_4 (making up for 44% of yearly anthropogenic CH_4 emissions), 29% are N_2O (making up for 53% of yearly anthropogenic N_2O emissions), and only 27% are CO_2 (making up for 5% of yearly anthropogenic CO_2 emissions).(21,32,33) Because the average warming from CH_4 and N_2O over the first 100 years from emission is much greater than that of CO_2, some analyses claimed that livestock accounts for more GHG emissions in CO_2-eq than the transport sector.(5,31)

These direct comparisons can be problematic because different GHGs affect the environment in different ways: N_2O and CH_4 are relatively short-lived gases and their contribution to global warming dissipates quickly after their emission. Conversely, CO_2 continues to contribute to global warming for millennia after its emission.(5,33–36) Assuming livestock's current levels of N_2O and CH_4 emissions remain constant, these emissions would cease to contribute to further global warming within 10 to 100 years, which is when the warming of new emissions would only replace that of past emissions.(5) Conversely, since CO_2 continues to warm the atmosphere for millennia, new CO_2 emissions cumulatively add to the warming of past emissions. Directly comparing the emissions from livestock to those of other human activities by coercing different GHGs onto a single CO_2-eq scale may therefore lead to misleading results, usually overestimating the relative warming impact of livestock.(5,33–36)

However, in absolute terms, there is no doubt that livestock significantly contributes to global warming: Based on current meat production levels, every hundred years of CO_2 emissions from livestock would lead to a 0.1°C increment in global temperatures and current emission rates of N_2O and CH_4 account for a temperature rise of 0.44°C (but will result in no further warming once the climate system has reached equilibrium).(5,35)

3.2 Livestock's impact on land use change and water use and pollution

While many analyses to date have focussed on livestock's contribution to global warming, meat production also detrimentally affects numerous other aspects of the natural environment, including land use change, water use and pollution, and biodiversity loss.(1,5,11,24,37–40) Producing 1kg of meat requires on average 181.4m^2, which is 18 times higher[a] than the land needed to produce the same amount of protein-rich plant-based foods, such as tofu, pulses, and nuts.(24) As a consequence, livestock accounts for approximately 83% of the world's farmland, while only providing 37% of protein and 18% of energy for human consumption.(24) Agricultural expansion for livestock also represents the greatest driver of anthropogenic deforestation and each year 18 million acres of forest are lost to livestock production.(20) Livestock's expansion into natural ecosystems is therefore considered one of the most important drivers of biodiversity loss, with an estimated 30% of global biodiversity loss resulting from animal husbandry.(5,7,24,41–44)

Livestock also uses more freshwater than any other anthropogenic activity and leads to high levels of water use and pollution.(5,45–48) Producing 1kg of meat results in the withdrawal of approximately 1428L, which is more than four times greater than the freshwater withdrawals required to produce the same amount of pulses and tofu, although producing some other protein-rich plant-based foods (e.g. nuts) require large amounts of water.(24) Additionally, animal waste, pesticides, ammonia, faecal microbes, antibiotics, and hormones from livestock leach and pollute waterways, contributing

[a] Average land need of tofu, pulses, and nuts vs average land need of beef, lamb and mutton, pork, and poultry

to the eutrophication of surface waters, the acidification of oceans, and the rise in antimicrobial resistance.(20,21,49)

3.3 Options to mitigate the environmental impact of livestock

Taken together, the evidence suggests that producing meat significantly contributes to global warming, deforestation, water use and pollution, and biodiversity loss. Numerous strategies have been proposed to mitigate livestock's detrimental impact on the natural environment.(50–53) These strategies generally focussed on technical supply-side measures, including:

- **Intensifying the production of meat** to reduce the land requirements and land use change associated with livestock (15,50,54–56)
- **Reducing methane emissions from enteric fermentation** through changes to animal feed, genetic selection of animals, and animal vaccination (26,33,57–61)
- **Reducing emissions from manure** by decreasing the temperature at which manure is stored or increasing the rate of manure removal to outside storage facilities (26,62–66)
- **Reducing emissions from feed production** by avoiding the application of nitrogen to promote animal feed growth during wet seasons and before major rainfall events (26,67,68)
- **Increasing animal's production efficiency** by breeding animals with improved feed conversion rates, requiring less energy to produce the same amount of meat (26,33,69)
- **Reducing food waste,** since approximately 33% of global food supply – i.e. 1.3 billion ton of food per year - is wasted and leads to 'wasted' depletion of natural resources (70)

Another important strategy to mitigate livestock's environmental impact is to reduce meat consumption, though this option has received less attention and has sometimes been dismissed as unfeasible.(21,71–75) Reducing meat consumption has been recommended by various committees as it could lead to an 80% reduction in the food system's GHG emissions, while improving production methods is estimated to only reduce GHG emissions by 10%.(1,76,77) This is because

producing meat generally results in greater environmental degradation than producing plant-based foods, regardless of the production method employed: even producing the lowest-impact animal-sourced foods usually leads to greater GHG emissions, eutrophying and acidifying emissions, and land use than producing plant-based foods.(4,5) Promoting dietary changes could therefore deliver environmental benefits on a scale that cannot be feasibly achieved through supply-side measures.(4)

An increasing body of evidence therefore suggests that no matter the level of intensification and technological advancement, reducing meat consumption will be necessary to sustainably feed the growing global population.(11,34,72,73,78–80) For example, a recent analysis suggested that only implementing supply-side measures would not suffice to keep food systems within planetary boundaries that define a safe operating space for humanity and that radical reductions in meat consumption are also required.(11) More specifically, the analysis suggested that food system can only stay within planetary boundaries if global diets did not exceed 97 g/w of red meat and 169 g/w of poultry.(11) This is well below current consumption levels in the UK, where adults aged 19-64 report consuming 756 g/w of total meat and 434 g/w of red and processed meat.(81) Significant reductions in meat consumption are therefore required to develop sustainable food systems.

4. Health co-benefits of reducing meat consumption

Focussing on reducing meat consumption is also likely to benefits human health.(5,6,82–89) Meat consumption is an important dietary source of many macro and micronutrients, including protein, iron, zinc, and vitamin B12.(81,90,91) However, it is possible to obtain a sufficient intake of these nutrients without meat by consuming a wide variety of other foods.(5) For example, while the prevalence of anaemia in the UK is slightly higher among vegetarians (i.e. 3.9% among men, 12.8% among pre-menopausal women, 5.8% among post-menopausal women) than regular meat eaters (i.e. 2.9% among men, 8.7% among pre-menopausal women, 3.4% among post-menopausal women), the great majority of vegetarians and vegans are not anaemic and there are only very small differences in

the prevalence of anaemia between regular meat eaters and those eating meat occasionally (i.e. ≤3 portions per week).(92) Similarly, modelling studies have found that nutritional recommendations for adult women aged 19–50 years can be met while reducing GHG emissions by eating diets featuring only 27 g/d of red and processed meat (i.e. 56% less than the 62 g/d consumed in the UK) and 26 g/d of poultry (i.e. 62% less than the 69 g/d consumed in the UK).(89,93) While it should not be assumed that environmentally sustainable diets are automatically healthier, recent analyses suggest that foods with lower environmental footprints are generally healthier and that red and processed meat is associated with negative environmental as well as health outcomes (Fig. 1.1).(6,89,94)

Fig. 1.1: Association between a food group's impact on mortality and on the environment

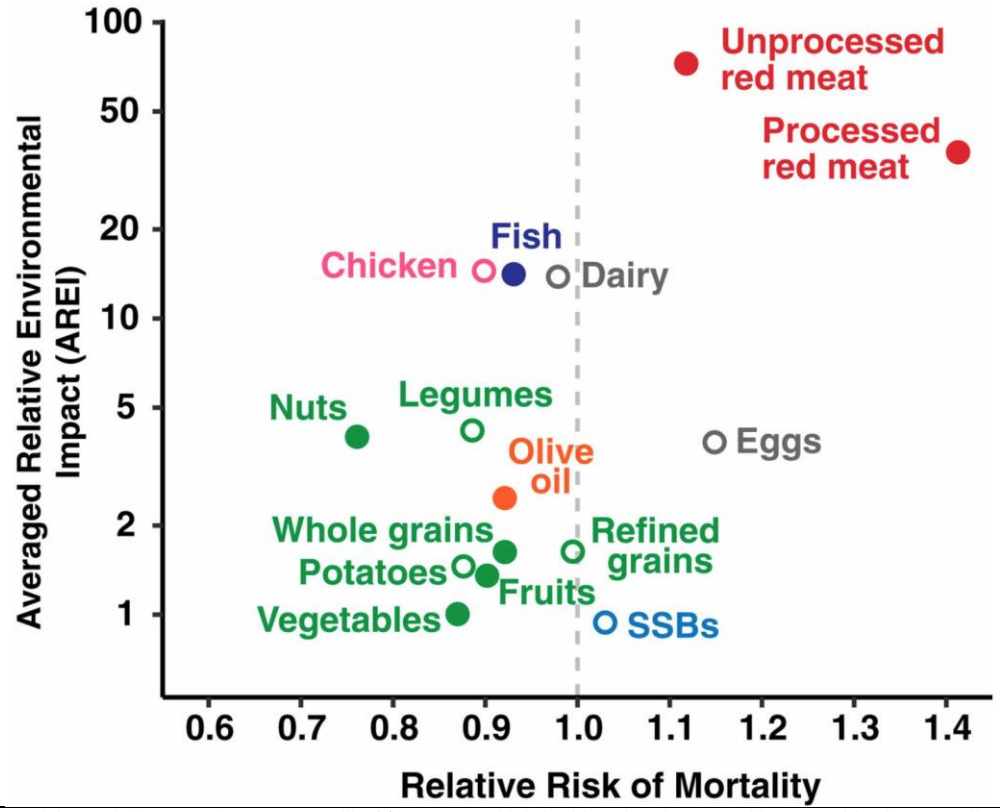


Figure and legend from Clark MA, Springmann M, Hill J, Tilman D. Multiple health and environmental impacts of foods. Proceedings of the National Academy of Sciences. 2019. Legend from original paper: Association between a food group's impact on mortality and its AREI. The *y* axis is plotted on a log scale and is the AREI of producing a serving of each food group across 5 environmental outcomes relative to the impact of producing a serving of vegetables (not including starchy roots and tubers). The *x* axis is the relative risk of mortality, where a relative risk >1 indicates that consuming an additional daily serving of a food group is associated with increased mortality risk, and a relative risk <1 indicates that this consumption is associated with lowered mortality risk. Labels and points are colored with green = minimally processed plant-based foods; dark blue = fish; gray = dairy and eggs; pink = chicken; red = unprocessed red meat (beef, lamb, goat, and pork) and processed red meat; light blue = sugar-sweetened beverages; and orange = olive oil. Food groups associated with a significant change in risk of mortality (at $P < 0.05$) are denoted by solid circles. Food groups not associated with a significant change in mortality risk are denoted by open circles. Serving sizes for the food groups are: whole grains (30 g dry weight); refined grains (30 g dry weight); fruits (100 g); vegetables (100 g); nuts (28 g); legumes (50 g dry weight); potatoes (150 g); fish (100 g); dairy (200 g); eggs (50 g); chicken (100 g); unprocessed red meat (100 g); processed red meat (50 g); SSBs (225 g); and olive oil (10 g). Data used to create the plot are available in Dataset S1. The association between total mortality and olive oil was estimated by weighting disease-specific contributions (e.g., CHD, stroke, and diabetes) to mortality by disease-specific relative risk.

An increasing body of epidemiological evidence suggests that eating red and processed meat is linked with greater risks of developing some non-communicable conditions, including cancer, cardiovascular disease, and type-2-diabetes.(5) In countries where it is possible to eat a nutritious diet without meat, reducing red and processed meat intake would therefore help to promote human health.(1,5,6) Taken together this evidence suggests that, if appropriately implemented, substantive reductions in meat consumption can help to promote population health without negatively affecting the intake of important macro and micronutrients.(95)

4.1 Meat consumption and cancer

The strongest evidence on the health consequences of red[b] and processed meat consumption pertains to colorectal cancer. In 2015, the World Health Organization's International Agency for Research on Cancer (IARC) classified processed meat as carcinogenic and red meat as probably carcinogenic to humans.(96) This classification was based on a growing number of large longitudinal studies finding evidence of an association between red and processed meat consumption and colorectal cancer incidence.(97–99) Many meta-analyses of large prospective cohort studies further reinforced IARC's statement by consistently finding statistically significant associations between meat intake and cancer, particularly colorectal cancer.(87,100–111)

To date, the most influential meta-analysis examining this association included 21 prospective cohort studies and found that the relative risk of developing colorectal cancer increases by 18% (95%CI = 10% to 28%) for every 50g/d of processed meat, by 17% (95%CI = 5% to 31%) for every 100g/d of unprocessed red meat consumed, and by 14% (95%CI = 4% to 24%) for every 100g/d of red and processed meat consumed.(103) Assuming causality, with a baseline lifetime risk of developing colorectal cancer of 5%, this analysis suggests that:

[b] Here, red meat refers to meat from ruminants and pork. However the definition of 'red meat' can differ by discipline: In environmental sciences, 'red meat' typically refers to meat from ruminant animals only, while in epidemiology and health sciences red meat typically includes pork too.

- For every 100 people eating an additional 50g/d of processed meat there would be 0.9 (95%CI = 0.5 to 1.4) additional cases of colorectal cancer;
- For every 100 people eating an additional 100g/d of unprocessed red meat there would be 0.85 (95%CI = 0.25 to 1.55) additional cases of colorectal cancer; and
- For every 100 people eating an additional 100g/d of red and processed meat there would be 0.7 (95%CI = 0.2 to 1.2) additional cases of colorectal cancer.(5,103)

Applying these effect sizes to current levels of red and processed meat intake in the UK (62 g/d in adults aged 19 to 64), suggests that meat intake might lead to a 9.1% (95%CI = 2.6% to 15.6%) relative risk increase of developing colorectal cancer in the UK.(81,103) While at the individual level these effects may seem small, their impact adds up to a meaningful health burden at the population level. Globally, IARC estimates that 34,000 cancer deaths per year are attributable to diets high in processed meat and an additional 50,000 cancer deaths could be attributable to diets high in unprocessed red meat.(5,96)

A more recent meta-analysis of longitudinal studies confirmed the positive relationship between processed meat intake and colorectal cancer incidence but found smaller effect sizes compared to those reported previously. Based on 15 longitudinal studies comprising 1,616,707 participants followed up for 5 to 16 year, this analysis estimated that reducing processed meat intake by 150g/w was linked with 1.4 fewer cases of colorectal cancer per 1000 people (RR and 95% CI = 0.93, 0.89–0.95).(104) No evidence of an association was found for a 300g/w reduction in unprocessed red meat intake and colorectal cancer incidence (RR and 95% CI = 1.00, 0.92–1.09, 5 studies, 322502 participants, 3-15 years follow up), although reductions in unprocessed red meat were associated with lower lifetime risks of overall cancer mortality (RR and 95% CI = 0.93, 0.91–0.94, 7 studies, 875291 participants, 5-28 years follow up).(104) Taken together, the evidence above points towards a

consistent association between processed meat (and to a lesser degree unprocessed red meat) and increases in colorectal cancer risk.

4.2 Meat consumption and cardiometabolic conditions

An increasing body of research also identified associations between red and processed meat consumption and cardiometabolic conditions.(86,88,100,112–115) Vernooij et al. conducted a systematic review to compare the risk of cardiovascular conditions among people following high meat diets and people following low meat diets. This research found that diets low in red and processed meat were associated with small reductions in:

- Cardiovascular mortality (RR and 95% CI= 0.86, 0.79–0.94, 25 studies, 858554 participants, 4-26 years follow up),
- Non-fatal stroke (RR and 95% CI = 0.86, 0.81–0.92, 2 studies, 38937 participants, 6 to 12 years follow up), and
- Type-2-diabetes (RR and 95% CI = 0.76, 0.68–0.86, 14 studies, 378788 participants, 2-34 years follow up).

However, no evidence of an association was found for total or fatal stroke, myocardial infarction, and total cardiovascular disease.(100) Another study comparing cardiovascular outcomes among people following different dietary patterns found that vegetarians had 22% (RR and 95% CI 0.78, 0.70 to 0.87, total cases=496, person-years=276938) lower rates of ischaemic heart disease than meat eaters, corresponding to 10 (95%CI = 6.7 to 13.1) fewer cases of ischaemic heart disease per 1000 people over 10 years.(116) Conversely, vegetarians had 20% higher rates of stroke than meat eaters (RR and 95% CI 1.20, 1.02 to 1.40, total cases=258, person-years=278383), corresponding to 3 (95%CI = 0.8 to 5.4) more cases of stroke per 1000 people over 10 years.

This effect was primarily driven by vegetarians' higher risk of haemorrhagic stroke (RR compared to meat eaters and 95% CI = 1.43, 1.08 to 1.90, total cases=89, person-years=278383), while no evidence of an association was found for ischaemic stroke (RR and 95% CI = 1.12, 0.9 to 1.41, total cases=117, person-years=278383).(116) The association between plant-based diets and higher risk of haemorrhagic stroke may be due to lower circulating levels of vitamin B12, vitamin D, essential amino acids, long chain n-3 polyunsaturated fatty acids, or LDL-cholesterol among vegetarians.(116–119)

The studies reported so far compare cardiometabolic outcomes between people following different dietary patterns (e.g. low and high in meat, vegetarians vs meat eaters). This methodological approach may produce limited insights since it does not capture the quantity of red and processed meat consumed and because extreme categories of meat intake may not accurately capture effects sizes observed at more typical consumption levels.(112,120)

A recent dose-response meta-analysis overcomes these limitations by investigating the associations between different levels of meat intake and cardiometabolic conditions.(112) This analysis included 55 cohorts and 4.2 million participants who consumed various amounts of meat and who were followed up for 2 to 28 years. In this study, a 300 g/w lower intake of unprocessed red meat was associated with small reductions in the relative risk of type-2 diabetes (RR and 95% CI= 0.9, 0.88–0.92, 6 studies, 293869 participants, 5-28 years follow up), cardiovascular mortality (RR and 95% CI= 0.9, 0.88–0.91, 7 studies, 874896 participants, 9-28 years follow up), myocardial infarction (RR and 95% CI= 0.93, 0.87–0.99, 1 study, 55171 participants, 13.6 median years follow up), and stroke (RR and 95% CI= 0.94, 0.9–0.98, 6 studies, 254742 participants, 12-26 years follow up), but not overall cardiovascular disease.(112)

Similarly, a 150 g/w lower intake of processed meat was associated with small reductions in the relative risk of type-2 diabetes (RR and 95% CI = 0.78, 0.72–0.84, 14 studies, 669530 participants, 5-28 years follow up), cardiovascular mortality (RR and 95% CI = 0.9, 0.84–0.97, 7 studies, 1240634

participants, 9-28 years follow up), myocardial infarction (RR and 95% CI = 0.94, 0.91–0.98, 1 study, 55171 participants, 13.6 years follow up), and stroke (RR and 95% CI = 0.94, 0.9–0.98, 6 studies, 254742 participants, 12-26 years follow up), but not overall cardiovascular disease.(112) Despite some heterogeneity in the findings, the existing empirical evidence therefore suggests that a lower intake of red and processed meat is generally associated with lower rates of various cardiometabolic conditions.

4.3 Meat and health: a causal effect or mere correlation?

While there is substantive evidence on the association between meat and various non-communicable health conditions, establishing whether these associations are causal or purely correlational is far more challenging.(121,122) Conducting randomised controlled trials where people are assigned to different levels of red and processed meat intake over several years would provide strong empirical evidence on the causal health impact of eating meat.(123–125) However, these trials are simply not feasible and – perhaps even more importantly – not ethical, given the existing consistent evidence on the associations between red and processed meat intake and various health conditions.(5,126–129) As such, there is currently no robust trial investigating the health effects of meat consumption.(123)

Prospective cohort studies – such as those described above - currently represent the best available empirical method to estimate the health impact of eating meat. These studies assess meat consumption levels among thousands of participants before prospectively following up their health over many years.(5,125,130–132) The results of these studies should be interpreted with caution since people consuming different levels of meat may differ on many other dimensions potentially impacting their health, including demographic characteristics, socioeconomic status, or other health behaviours.(122,133,134) Meta-analyses aggregating the results of several cohort studies can help to reduce the impact of unsystematic error (such as random imprecision in the measurement of meat) but will not overcome the impact of systematic bias (such as systematic underreporting of meat intake) or residual confounding factors.

To complement the evidence from cohort studies, one of the most insightful ways to establish whether meat causally leads to disease is to explore the plausibility of biological mechanisms underpinning these associations.(96,121,134,135) While research on these mechanisms is still in its infancy, numerous mechanisms have been proposed.(96,121,134) For example, there are various compounds in meat products that are considered to be carcinogenic. These include haem iron, nitrites, and nitrates all of which can promote the formation of carcinogenic N-nitroso compounds in human's gastrointestinal tract.(121,136–144) Additionally, cooking meat at high temperatures may lead to the formation of heterocyclic amines, many of which are genotoxic.(121,136,145–147) Meat is also rich in saturated fatty acids and sodium, which are well established risk factors for cardiovascular conditions.(123,148–152) In the UK, meat products contribute to 24% of saturated fatty acid intake and to 27% of sodium intake in adults aged 19-64 years, and represent a plausible pathway through which meat may cause cardiovascular conditions.(81) Finally, some compounds in meat (including haem iron, nitrates and nitrites) may reduce the production of insulin by the pancreas, impairing insulin sensitivity, leading to rises in blood glucose, and consequently increasing the risk of developing type-2-diabetes.(121,153–155)

The putative mechanisms linking meat consumption and adverse health outcomes described above are independent of body weight. However, there is also some evidence to suggest that meat intake is associated with excess weight gain, which is in turn an important determinant of many adverse health consequences, including some cancers, cardiovascular conditions, and type-2-diabetes.(156–161) For example, recent analyses show that eating or switching to low meat diets is associated with lower weight gain after adjusting for numerous confounders and that the association between meat intake and type-2-diabetes is attenuated after adjusting for body mass index.(162,163)

Given the consistency and strength of the association between meat and various health conditions, the dose-response nature of these associations, and the availability of plausible biological mechanisms, it is likely that meat consumption is – at least in part - causally involved in the aetiology

of colorectal cancer and some cardiometabolic conditions. Additionally, human health may also benefit from reductions in meat production through indirect pathways, including the mitigation of global warming, the decrease in antimicrobial resistance, and the reduced contact with animal pathogens.(164–168)

5. Reducing meat consumption: a challenge for behavioural sciences

Based on the best available empirical evidence, reducing meat consumption is necessary to develop sustainable food systems and is likely to result in small but significant co-benefits to human health. However, achieving these reductions represents a significant behavioural challenge. While many high income countries have recently started to transition towards more plant-based diets, in absolute terms the market for plant-based meat alternatives still pales compared to the meat industry and the proportion of vegetarian and vegans in the UK still makes up less than 4% of the total population.(73,93,169–171) The current scale and pace of the transitions towards plant-based diets in high income countries is therefore not sufficient to achieve international environmental targets and to keep food systems within safe planetary boundaries.(11,169)

There is a need for interventions and policies to promote an acceleration in the reduction of meat consumption and a wider uptake of plant-based diets.(20,169) This dietary transition could be promoted through numerous policy options with varying levels of restrictiveness: from legislation and regulation, to economic and fiscal measures, all the way down to behavioural interventions, such as information provision or nudges that encourage the selection of plant-based foods without restricting choice.(170,172) While, in general, more restrictive interventions achieve greater effects, this thesis focusses on less restrictive behavioural interventions (henceforth: behavioural interventions) because they are generally perceived as more acceptable among the general public and might therefore represent a more feasible policy option for the immediate future.(173–175)

However, even within the realm of such interventions, there has been a remarkable lack of action to encourage reductions in meat consumption.(73,176,177) Numerous reasons may be contributing to this inaction, including concerns about the ethics and acceptability of influencing personal food choices, misaligned economic incentives, and fear of a consumer backlash.(34,71) Research suggests that there is a widespread lack of awareness about the environmental impact of meat production and that people perceive their individual dietary choices to only play a minimal role in the global environmental degradation.(178,179) Additionally, people eat meat for several reasons including experiencing hedonic pleasure, ensuring intake of necessary nutrients, expressing one's cultural and traditional heritage, affirming one's personal identity, consciously or unconsciously following social pressures, or as a marker of social status or masculinity.(178,180–183) Reducing meat consumption is therefore likely to be a very challenging behavioural target and interventions aiming to promote this dietary change are likely to be met with resistance.(178)

An influential report by Chatham House also highlighted the uncertainty around the effectiveness of interventions as a key barrier preventing governments and other stakeholders from implementing interventions to reduce meat consumption.(71,73) Against this backdrop, the overarching aim of this thesis is to contribute towards expanding the empirical evidence base on the effectiveness of behavioural interventions to reduce meat consumption. To achieve this objective, I will:

- Systematically review the existing empirical evidence on the effectiveness of behavioural interventions to reduce meat consumption (Chapter 2);

- Develop a novel behavioural intervention to help meat eaters reduce their consumption of meat (Chapter 3);

- Evaluate the effectiveness of my intervention in a randomised controlled trial to quantify its impact on meat consumption and other dietary, psychosocial, health, and environmental outcomes (Chapter 4);

- Conduct qualitative research to explore recipients' experiences of my intervention and investigate the mechanisms through which recipients perceived the intervention to deliver impact (Chapter 5)

Finally, in Chapter 6, I will summarise the learnings from my doctoral research and discuss my findings as well as opportunities for future research in the context of the wider landscape of public policy and academic research on meat consumption. I hope this research will contribute towards promoting healthier diets and more sustainable food systems.

Chapter 2: Systematic reviews of behavioural interventions to reduce the demand for meat

1. Chapter summary

Reducing meat consumption can help to reduce the risk of non-communicable diseases and protect the natural environment but not much is known about the effectiveness of interventions to change this eating behaviour. In this chapter, I outline the results of two systematic reviews I conducted: The first evaluates interventions targeting conscious determinants of human behaviour to reduce meat demand and the second evaluates interventions restructuring physical micro-environments. I identified 24 papers reporting on 59 interventions targeting conscious determinants of human behaviour. Based on the limited available evidence, self-monitoring interventions and individual lifestyle counselling interventions were linked with reduced meat consumption. Providing information about the health or environmental consequences of eating meat was linked with reduced intentions to select meat in virtual environments, but there was no evidence that it influenced actual behaviour. Education about the animal welfare consequences of eating meat was linked with reduced intentions to consume meat, while interventions implicitly highlighting animal suffering were not. Education on multiple consequences of eating meat led to mixed results and tailored education was not found to reduce actual or intended meat consumption. I identified 22 interventions restructuring physical micro-environments in the second review. Based on the limited evidence, interventions reducing the portion size of meat servings, providing free meat substitutes, or altering the sensory properties (e.g. visual presentation) of meat or meat alternatives at point-of-purchase were linked with reduced meat demand. There was less promising or inconclusive evidence for interventions repositioning or manipulating the description of meat and meat alternatives at point-of-purchase, pricing intervention, and interventions restructuring several aspects of micro-environments. The two systematic reviews have been previously published in peer reviewed journals:

- Bianchi F, Dorsel C, Garnett E, Aveyard P, Jebb SA. Interventions targeting conscious determinants of human behaviour to reduce the demand for meat: a systematic review with

qualitative comparative analysis. International Journal of Behavioral Nutrition and Physical Activity. 2018 Dec;15(1):1-25. (184)

- Bianchi F, Garnett E, Dorsel C, Aveyard P, Jebb SA. Restructuring physical micro-environments to reduce the demand for meat: a systematic review and qualitative comparative analysis. The Lancet Planetary Health. 2018 Sep 1;2(9):e384-97. (185)

2. Introduction

In this section, I will outline the theoretical rationale for conducting two systematic reviews evaluating the effectiveness of different behavioural interventions to reduce the demand for meat. As mentioned in Chapter 1, red and processed meat consumption is associated with an increased risk of developing some non-communicable chronic conditions (96,103,186–191) and livestock negatively affects the natural environment. (192–197) While the potential health and environmental benefits of reducing meat consumption are well established, concerns about a consumer backlash and the poor understanding of how to promote this behaviour change have contributed to a general state of inaction. (198–200)

Interventions targeting conscious determinants of human behaviour, such as those providing information to change people's knowledge and values, are generally perceived to be affordable and acceptable approaches to promote health behaviours and might help to overcome this state of inaction. (173,201) Furthermore, interventions targeting conscious determinants of human behaviour might, over time, enhance the public's support for more structural interventions aiming at reducing the demand for meat, such as fiscal measures and regulation. (198,199,202) It is therefore unsurprising that, to date, initiatives aiming to promote environmentally sustainable lifestyles have primarily focussed on providing information about the effect of human activities on the environment. (202)

Nevertheless, dual process models of human behaviour suggest that habitual actions, such as people's consumption of meat, are not the exclusive results of a rational and conscious evaluations of what we know to be the pros- and the cons- of performing a behaviour. Instead these behaviours are often the result of automatic reactions to the physical environments in which people live (202–208): After learning about the greenhouse gas emissions caused by livestock, one might consciously intend to eat less meat but fail to behave accordingly when dining at a canteen that lacks appealing meat-free alternatives or shopping in a supermarket that offers discounts for larger portions of meat products.

Following the same logic, these micro-environments can be designed purposefully to shape habitual behaviours, and there is growing interest in how this approach can be used to help people eat less meat.(41,202) Interventions targeting conscious determinants of human behaviour and those restructuring physical micro-environments therefore have different strengths and limitations and could both be part of a wider portfolio of measures designed to promote lower meat intakes. I have therefore decided to conduct two systematic reviews respectively evaluating the effectiveness of these two intervention approaches. Against this backdrop, this chapter aims to answer two research questions:

- Based on the evidence from experimental studies, are interventions targeting conscious determinants of human behaviours effective at reducing the selection, purchase, or consumption of meat?
- Based on the evidence from experimental studies, are interventions restructuring physical micro-environments effective at reducing the selection, purchase, or consumption of meat?

3. Methods

I prospectively published the protocol outlining the full methodology for both systematic reviews. (209,210) Below, I will outline the methods underlying the:

- search strategy,
- eligibility assessment,
- data extraction,
- studies quality assessment,
- narrative synthesis, and
- qualitative comparative analysis.

3.1 Search strategy

To maximise efficiency, I conducted the study searches jointly for both systematic reviews on the 31st of August 2017. I searched six electronic databases with terms relating to target products (e.g. meat), processes of change (e.g. reduction), the behaviours of interest (e.g. consumption), and a filter to identify intervention studies, including pilot and feasibility studies (Table 2.1).

The databases searched included CAB Abstracts (1973 to 2017 Week 33), Embase (1974 to 2017 August 30), Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) (1946-present), PsycINFO (1967 to August Week 3 2017), Science Citation Index, Social Science Citation Index, Conference Proceedings Citation Index – Science (1945-present), Dissertations Theses: Global full-text.

Table 2.1: Search strategy

Block	Keywords (MEDLINE)	Hits (MEDLINE)
1	((meat* or beef or veal or lamb or pork or poultry or chicken or turkey or venison or offal* or sausage* or ham or pastrami or bacon or salami or nugget* or burger* or hamburger* or black pudding* or haggis or plant-based or vegetable-based or vegetar* or vegan* or flexitarian* or ((green or environment* or sustainab*) adj2 (eat or eating or diet*))) adj7 (chang* or increas* or decreas* or improv* or reduc* or low or moderat* or shift* or eliminat* or replac* or substitut* or alternat* or cut* or more or less or free or sustainab* or promot* or encourag* or enhance* or support* or motivat* or achiev*) adj7 (consum* or intak* or eat* or purchas* or choos* or select* or prefer* or demand* or buy* or avoid* or choice* or nudg* or cook* or prepar* or cater* or behav* or inten* or attitud* or social* norm*)).ti,ab.	6781
2	((meat* or beef or veal or lamb or pork or poultry or chicken or turkey or venison or offal* or sausage* or ham or pastrami or bacon or salami or nugget* or burger* or hamburger* or black pudding* or haggis or plant-based or vegetable-based or vegetar* or vegan* or flexitarian* or ((green or environment* or sustainab*) adj2 (eat or eating or diet*))) adj7 (consum* or intak* or eat* or purchas* or choos* or select* or prefer* or demand* or buy* or avoid* or choice* or nudg* or cook* or prepar* or cater* or behav* or inten* or attitud* or social* norm*) adj7 (chang* or increas* or decreas* or improv* or reduc* or low or moderat* or shift* or eliminat* or replac* or substitut* or alternat* or cut* or more or less or free or sustainab* or promot* or encourag* or enhance* or support* or motivat* or achiev*)).ti,ab.	7008
3	((chang* or increas* or decreas* or improv* or reduc* or low or moderat* or shift* or eliminat* or replac* or substitut* or alternat* or cut* or more or less or free or sustainab* or promot* or encourag* or enhance* or support* or motivat* or achiev*) adj7 (consum* or intak* or eat* or purchas* or choos* or select* or prefer* or demand* or buy* or avoid* or choice* or nudg* or cook* or prepar* or cater* or behav* or inten* or attitud* or social* norm*) adj7 (meat* or beef or veal or lamb or pork or poultry or chicken or turkey or venison or offal* or sausage* or ham or pastrami or bacon or salami or nugget* or burger* or hamburger* or black pudding* or haggis or plant-based or vegetable-based or vegetar* or vegan* or flexitarian* or ((green or environment* or sustainab*) adj2 (eat or eating or diet*))) adj7 (consum* or intak* or eat* or purchas* or choos* or select* or prefer* or demand* or buy* or avoid* or choice* or nudg* or cook* or prepar* or cater* or behav* or inten* or attitud* or social* norm*)).ti,ab.	6734
4	1 or 2 or 3	7722
5	((randomized controlled trial or controlled clinical trial).pt. or randomized.ab. or placebo.ab. or drug therapy.fs. or randomly.ab. or trial.ab. or groups.ab.) not (exp animals/ not humans.sh.)	3647928
6	(((feasability or pilot or demonstration or multicentre* or multicentre* or multi-centre* or multi-center* or preliminary or follow-up or major) adj2 (stud* or project?)) or intervention or preintervention or postintervention or pre-post or (pre adj5 post) or quasiexperiment* or quasi-experiment* or quasirandom* or quasi-random or (before adj10 (after or during)) or ("time series" adj2 interrupt*) or ("time points" adj3 (over or multiple or day? or week? or month?))).mp. not (exp animals/ not humans.sh.)	1591076
7	5 or 6	4672088
8	4 and 7	1845

I also searched publicly accessible online resources, contacted experts in the field, and conducted iterative backward and forward reference searches for all papers that I considered eligible for inclusion in either of the two reviews.

3.2 Study eligibility criteria

All papers identified through the aforementioned searches were independently assessed against pre-specified eligibility criteria. For the first review, I included any experimental intervention study, including pilot and feasibility studies, that evaluated the effectiveness of interventions targeting conscious determinants of human behaviour to reduce the demand for meat, defined as the actual or intended consumption, purchase, or selection of meat in real or virtual environments. I considered studies to be eligible if they reported objective or self-reported measures of meat demand. The comparators I considered eligible were, in order of preference, no or minimal intervention controls, pre-intervention baseline, or other eligible interventions. I excluded interventions promoting general dietary patterns (e.g., Mediterranean diet), qualitative studies, and non-experimental studies. There were no exclusion criteria pertaining to the publication status, publication year, language, length of follow-up, or population, except for people diagnosed with clinical conditions for which it is required to consume specific amounts of meat.

For the second review, I used the same eligibility criteria as for the first review, except that the eligible interventions were those restructuring physical micro-environments to reduce the demand for meat. Interventions not explicitly aiming to reduce meat demand were eligible in this second review if they altered physical micro-environments in ways that could reduce the selection of meat or encourage the uptake of meat alternatives in discrete choice situations, where the selection of meat-free options implied the rejection of meat (Table 2.2).

Table 2.2: Inclusion and exclusion criteria

	Inclusion	Exclusion
Population	All are eligible except those listed in the exclusion criteria.	People diagnosed with clinical condition(s) for which it is required to consume specific amounts of meat.
Intervention for review 1	Interventions targeting conscious determinants of human behaviour to reduce the demand for meat, including information provision, motivational interviewing, and interventions aiding self-regulatory processes.	Dietary interventions aiming to promote a general dietary pattern (e.g. interventions promoting the Mediterranean dietary pattern) and interventions restructuring elements of the physical microenvironment (e.g. pricing, positioning, or portion size).
Intervention for review 2	Interventions restructuring one or more elements of physical micro-environments (e.g. availability, portion size, position, label, sensory properties, or price) to reduce the demand for meat with or without additional educational, motivational, or training components.	Dietary interventions aiming to promote a general dietary pattern (e.g. interventions promoting the Mediterranean dietary pattern) and interventions not featuring any component of environmental restructuring (e.g. purely educational interventions).
Comparison	In order of preference (1) no- or minimal-intervention controls, (2) pre-intervention baseline, or (3) other eligible intervention(s).	Interventions not fulfilling the eligibility criteria.
Outcome	Objective or self-reported measures of demand for meat, defined as actual or intended consumption, purchase, or selection of meat in real or virtual environments. I extracted data pertaining to the follow-up closest to the intervention completion and to the longest available follow-up, with the former representing our primary outcome.	Studies not reporting meat demand as an outcome
Study design	Any experimental intervention study, including pilot and feasibility studies regardless of publication status, publication year, language, or length of follow-up.	Qualitative and non-experimental studies.

The eligibility assessment was conducted on COVIDENCE by myself and another member of the research team in two rounds: first at the title and abstract level and then at the full paper level. Disagreements about the eligibility of studies were resolved through discussion or escalation to a more senior member of the research team.

3.3 Data extraction

Myself and another member of the research team independently reviewed all eligible studies and extracted data on (i) title, authors, and publication year; (ii) funding sources and conflicts of interest; (iii) countries and settings of the study; (iv) study design; (v) recruitment methods; (vi) participants' inclusion/exclusion criteria; (vii) sample characteristics, where available (including baseline values of the primary and secondary outcomes, sex, age, socioeconomic status, ethnicity, health status, and household characteristics); (viii) unit of allocation; (ix) type of meat or meat products that were targeted by the intervention; (x) intervention characteristics (narrative description, intervention aim, theoretical basis, TiDIER checklist, and the behaviour change techniques employed); (xi) characteristics of the comparator group; (xii) statistical analyses, including imputation techniques employed for missing data and covariates included in the models; (xii) eligible outcomes for the shortest and longest available follow up; (xiv) attrition; (xv) method of outcome measurement; (xvi) and results, where possible with numerical outcomes.

For all eligible outcomes, I extracted data pertaining to the follow-up closest to the intervention completion and to the longest available follow-up, with the former representing the primary outcome. The primary outcome extracted was participants' demand for meat, defined as the actual or intended consumption, purchase, or selection of meat. Meat purchases were in turn defined as the selection of meat involving a real or virtual monetary transaction, while meat selection did not involve any form of monetary transaction.

Where available, I extracted data pertaining to secondary outcomes that were not key for the selection of papers. These outcomes included attitudes, subjective social norms, and perceived behavioural control of eating, purchasing, or selecting meat, as well as body weight, blood pressure, blood glucose, and blood lipids. These outcomes were selected based on my general familiarity with the literature, as many studies evaluating the impact of interventions on psychosocial outcomes focused on the

variables of the Theory of Planned Behaviour and many studies reporting on the impact of interventions on health focussed on cardiometabolic biomarkers.

When an outcome was assessed in multiple ways, I only extracted data for the most granular measure (e.g. food diary > self-reported score of consumption change) referring to the longest time-span (e.g. consumption over a month > consumption over a week). When the necessary data was not available in the main paper, I referred to the study protocols and/or contacted study authors. Discrepancies in the data extracted by myself and the other member of the research team were resolved through discussion or escalation to a more senior member of the research team.

3.4 Quality assessment

The methodological quality of the included studies was assessed using the Effective Public Health Practice Project's Quality Assessment Tool for Quantitative Studies (EPHPP's QATQS). I selected this tool because it can be applied to studies employing various designs and because it allows to generate a single overall quality score to evaluate the methodological quality of all studies included. The overall score of the EPHPP's QATQS can be 'weak', 'moderate', or 'strong' and is generated by combining the study's quality score on six methodological dimensions, including:

- selection bias,
- study design,
- confounders,
- blinding,
- data collection method, and
- withdrawals and dropouts.

The methodological quality assessment was conducted independently by myself and another member of the research team. Discrepancies in this assessment were resolved through discussion or escalation to a more senior member of the research team.

3.5 Narrative data synthesis

Given the high heterogeneity of interventions and study designs included in both reviews, I elected to narratively synthesise the included studies. For the review evaluating interventions targeting conscious determinants of human behaviour to reduce meat demand, my narrative synthesis grouped the interventions in five categories: (i) individual lifestyle counselling, (ii) goal-setting and self-monitoring interventions, (iii) non-tailored education about the consequences of meat consumption, (iv) tailored education about the consequences of meat consumption, and (v) interventions implicitly highlighting animal suffering.

For the review evaluating interventions restructuring physical micro-environments to reduce meat demand, my narrative synthesis grouped interventions in seven categories: (i) reductions in the portions of meat servings, (ii) provision of meat alternatives, (iii) alteration of the sensory properties of meat or meat alternatives, such as changing the visual presentation or hedonic value of these products at point-of-purchase, (iv) repositioning meat products to reduce their prominence at point-of-purchase, (v) manipulating the description or label of meat or meat alternatives, (vi) changes in the price of meat, and (vii) interventions altering multiple elements of physical micro-environments.

3.6 Qualitative comparative analysis

Many of the interventions included in my systematic reviews featured multiple components. A narrative synthesis can only provide a high-level overview of what 'types' of interventions are likely to be effective. However, I wanted to provide more granular insights into what *configurations of intervention characteristics* are likely to be associated, or not associated, with statistically significant reductions in the demand for meat.

To achieve this objective, I augmented my narrative synthesis with an exploratory qualitative comparative analysis (QCA). At the high level QCA requires to break down the interventions into pre-specified components, and then to use a bespoke software to identify what combinations of these

intervention components are linked with a specific outcome (here: a significant reduction in meat demand) and what combinations are not. Implementing QCA in systematic reviews is a very novel methodological approach and involves mainly four steps:(211)

- **Step 1: Describing interventions through a dichotomous system:** The first step involves specifying the characteristics that will be used to describe the interventions included in the review. For example, one might decide to describe interventions according to whether they included (i) '*information about the consequences of a behaviour*', (ii) '*in-person professional support*', and (iii) *'peer support'*. It is possible to add criteria pertaining to the evaluation of the intervention too. For example, one might decide to include an item that describes whether interventions were assessed based on (iv*) 'actual behaviour change'* (as opposed to stated intentions). Every intervention included in the systematic review is then described in terms of these characteristics using a dichotomous system (yes/no), which indicates whether the intervention presents the feature in question. The result is a simple table describing intervention configurations (illustrative example in Fig. 2.1).

Fig. 2.1: Example of table describing intervention configurations in QCA

	information about the consequences of a behaviour	in-person professional support	peer support	Outcome is actual behaviour change
Intervention A	**1**	**0**	**0**	**0**
Intervention B	**1**	**0**	**1**	**1**
Intervention C	**1**	**0**	**1**	**1**
Intervention D	**1**	**0**	**0**	**0**
Intervention E	**1**	**0**	**1**	**1**
Intervention F	**1**	**1**	**1**	**1**
0 = feature is not present, 1 = feature is present				

Interventions can then be grouped into those with the same configurations. In the illustrative example above, Interventions A and D have the same configuration, as do interventions B, C, and E, while intervention F is the only one with its unique configuration.

For my QCA of interventions targeting conscious determinants of human behaviour I used the aforementioned binary coding system to describe interventions based on whether they provided information about the (i) health, (ii) environmental, (iii) animal welfare, (iv) socio-

economic, (v) and multiple consequences of meat consumption, and whether it (vi) provided tailored information, (vii) employed self-monitoring strategies, (viii) employed goal-setting strategies, (ix) implicitly highlighted animal suffering, (x) implemented individual lifestyle counselling sessions, (xi) targeted people with, or at increased risk of ill-health, (xii) provided information on 'how to' eat less meat, and whether (xiii) the outcome was actual behaviour as opposed to intentions or behaviour in virtual environments.

For my QCA of interventions restructuring physical micro-environments I used the same coding system to describe interventions based on whether they (i) reduced portions of meat servings, (ii) provided free meat alternatives, (iii) altered the sensory properties of meat or meat alternatives, (iv) repositioned meat products to reduce their prominence at point-of-purchase, (v) manipulated the description or label of meat or meat alternatives, (vi) changed the price of meat, (vii) altered multiple elements of physical micro-environments, (viii) featured additional educational and/or training components, and (ix) whether the outcome was actual as opposed to virtual or intended consumption, purchase, or selection of meat.

Step 2: Defining the outcome: The second step of QCA involves developing a binary system to describe whether the interventions led to the desired outcome or not (e.g. if the intervention was linked with a statistically significant change in the outcome). During this step, the table describing the intervention configurations is augmented with an additional column describing the presence or absence of this outcome (illustrative example in Fig. 2.2).

Fig. 2.2: Example of table describing intervention configurations in QCA

	information about the consequences of a behaviour	in-person professional support	peer support	Outcome is actual behaviour change	**Effective (at $p<0.05$)?**
Intervention A	1	0	0	0	**0**
Intervention B	1	0	1	1	**1**
Intervention C	1	0	1	1	**1**
Intervention D	1	0	0	0	**0**
Intervention E	1	0	1	1	**1**
Intervention F	1	1	1	1	**1**
0 = feature is not present, 1 = feature is present					

To define 'intervention effectiveness' in my QCAs, I focussed on whether the interventions were linked with statistically significant reductions in the demand for meat at the follow-up closest to the intervention completion, which was the primary outcome in my reviews. Where studies reported results for multiple eligible outcomes, I only considered the outcome closest to 'actual behaviour' (actual behaviour > behaviour in virtual environments > intention) in my QCA. A criterion p-value of <0.05 was used to define statistical significance.

Step 3: Defining threshold criteria for the effectiveness of intervention configurations: The third step involves defining threshold criteria for when to consider a configuration of intervention characteristics 'effective'. Specifically, one must select a minimum number of interventions with the same intervention configuration and the lowest proportion of these interventions that needs to be linked with the pre-specified outcome. Given the small number of studies included in my reviews, I decided to consider an intervention configuration to be linked with reductions in meat demand if at least 75% of more than one intervention with the same configuration were linked with significant reductions in meat demand. The same criteria applied to identify configurations of interventions consistently linked with no evidence of effectiveness.

In practical terms, the methodology described above meant that (i) if only one intervention had a specific configuration, then no statement was made about this configuration through QCA; (ii) if two to three interventions had the same configuration, then they were described as associated with effectiveness (or lack of evidence of effectiveness) if 100% of these interventions led to the same outcome (significant reductions in meat demand or no significant reductions in meat demand), else no statement was made about this configuration through QCA; (iii) if four or more interventions had the same configuration, then this configuration was described as associated with effectiveness (or lack of evidence of effectiveness) if at least 75% of these interventions led to the same outcome

(significant reductions in meat demand or no significant reductions in meat demand), else no statement was made about this configuration through QCA .

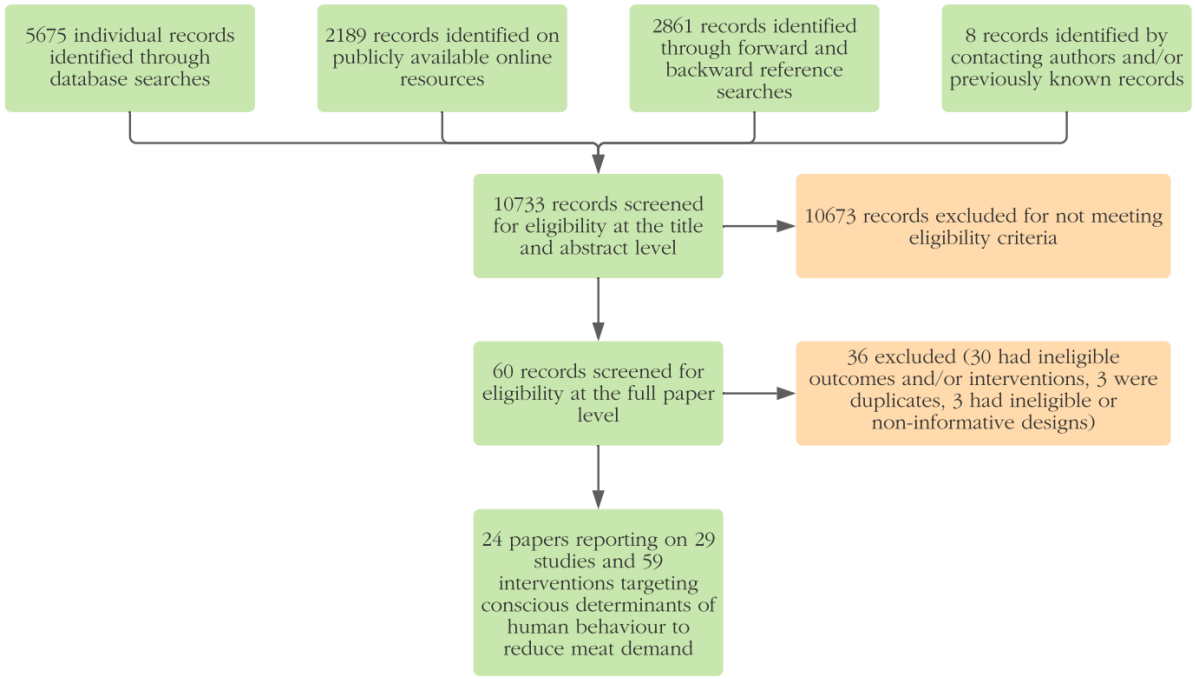
In both QCA analyses, I only included comparisons between interventions and no-intervention control conditions or between pre-intervention and post-intervention assessments, while comparisons between multiple interventions were excluded.

4. Results: interventions targeting conscious determinants of human behaviour

4.1 Study selection

I screened 10,733 titles/abstracts, assessed the full-text of 60 papers, and included 24 papers reporting on 29 studies and 59 interventions targeting conscious determinants of human behaviour to reduce meat demand (Fig. 2.3).

Fig. 2.3: Study selection process for the first review



4.2 Study characteristics

The majority of papers (54%) were published or written between 2015 and 2017. This review includes 25,477 observations (i.e. individuals or individual meal purchases) at the follow-up closest to the intervention completion and 305 observations at the longest follow-up for the four studies reporting on multiple end-points. Where reported, mean age ranged from 19 to 74 years (median=36), the proportion of female participants ranged from 49% to 100% (median=61%), the proportion of white participants ranged from 58% to 83% (median=75%), and participants' education and/or household income were high in most studies.

Forty-five percent of studies only included individuals who ate meat. Studies recruited individuals (N=26) or food providers (N=3) through active recruitment (N=15), advertisement (N=8), or through online panels (N=6). Studies were conducted in Europe (N=12), the USA (N=9), China (N=2), New Zealand (N=2), and Brazil (N=1), and were implemented in various settings, including experimental settings (N=18), canteens or food services (N=3), healthcare settings (N=2), or delivered interventions to free-living individuals (N=6).

Fourteen studies employed a randomised controlled trial (RCT), 5 employed a non-randomised controlled trial (CT), 1 study employed a crossover design (CO), 7 employed a pre-post design, and 2 studies retrospectively evaluated the intervention effectiveness. Retention at the shortest follow-up ranged from 59% to 100% (median=95%). The overall methodological quality was 'strong' for 6 studies, 'medium' for 10 studies, and 'weak' for 13 studies. Table 2.3 summarises the characteristics of all studies included in this review.

I included 37 interventions providing non-tailored information about meat consumption and health (N=11), the environment (N=8), animal welfare (N=2), socio-economic issues (N=2), or a combination thereof (N=14). Ten interventions provided tailored education, four implicitly highlighted animal suffering, six delivered individual lifestyle counselling, and two delivered self-monitoring interventions. Of all interventions included, two targeted food suppliers while the rest targeted consumers. Fifteen studies reported on participants' actual meat consumption, 6 on meat purchase or selection, and 15 on intended consumption.

Fifteen studies additionally reported on other pre-specified secondary psychosocial outcomes or biomarkers of health risk. Table 2.4 summarises each intervention and its impact on, or association with participants' demand for meat at the shortest follow-up. The results for the longest follow-up and for other secondary psychosocial outcomes are summarized in tables 2.7 and 2.8.

Table 2.3: Study-level characteristics for report evaluating interventions targeting conscious determinants of human behaviour

Reference and country	Eligibility criteria	Recruitment strategy	Attrition and sample size (a, b)	Availability	*EPHPP QATQS* score (c)
Randomised Controlled Trials (RCT)					
Arndt, 2016, study 1, USA (212)	Exclusion: Individuals who seldom or never ate meat, did not eat meat weekly, consumed no meat containing meal in the past 3 days, ate no serving of meat on an average day, less than 10% of what they ate on an average day is meat, believed that eating meat is bad, disliked eating meat, identified as vegetarians or vegans.	Individual recruitment through Amazon Mechanical Turk.	T1: 0% (179 to 179)	Unpublished, available online	Low
Arndt, 2016, study 2, USA (212)	See Arndt 2016, study 1.	See Arndt 2016, study 1.	T1: 0% (296 to 296)	Unpublished, available online	Low
Carfora et al., 2017, Italy (213)	Exclusion: Individuals following specific diets (such as vegan, vegetarian, protein, slimming and/or fattening diets).	E-mails were sent to a convenience sample of Italian undergraduates.	T1: 9.68% (124 to112)	Peer reviewed publication	Medium
Carfora et al., 2017, Italy (214)	Participants had to have a mobile phone supporting SMS. Exclusion: Individuals following specific diets or who participated to the other study by Carfora.	See Carfora et al., 2017 above.	T1: 4.2% (238 to 228)	Peer reviewed publication	Medium
Emmons et al., 2005, USA (215)	Participants had to be between 40 and 75 years, have an adenomatous colon polyp removed within 4 weeks of recruitment, have no personal history of CRC, be competent in English, be capable of informed consent, and be reachable by phone.	Eligible individuals were sent a letter describing the study and were later contacted by phone unless they opted out.	T1: 12.59% (1247 to 1090)	Peer reviewed publication	Strong
Emmons et al., 2005, USA (216)	Participants had to be 18 to 75 years old, have a visit scheduled with a participating healthcare provider, be competent in English or Spanish, and come from an eligible working-class neighbourhood. Exclusion: Individuals who had cancer at enrolment, or who were employed by the participating health centres or at a worksite participating in the companion study (Emmons et al., 2005 (a)).	See Emmons et al., 2005 above.	T1: 12% (2219 to 1954)	Peer reviewed publication	Medium
Fehrenbach, 2013, USA (217)	Exclusion: Individuals who were vegan, vegetarian, or pescetarian, self-reported insufficient attention to the message, previously completed part or all of the survey, had incomplete data, received the wrong intervention, and international or non-undergraduate students.	Individuals were sampled from communication classes at a large university in Arizona in exchange for extra credits.	T1: 10.1% (208 to 187)	Unpublished, not available online	Low

Fehrenbach, 2015, USA (218)	Participants had to be U.S. resident, 25-44 years of age and consume meat 7+ times/week. Exclusion: Individuals who took the survey on mobile devices, failed an attention filter, or completed the survey too quickly or without viewing the video.	Individual recruitment from a national panel using Qualtrics.	T1: 1.61% (373 to 367) T2: 58.98% (373 to 153)	Unpublished, available online	Low
Graham et al., 2017, New Zealand (219)	Participants had to reside in New Zealand and pass an attention filter.	Individual recruitment through convenience and snowball techniques on a university campus, and advertisement outside the university campus.	T1: 0%	Peer reviewed publication	Medium
Klöckner et al., 2017, study 1, Netherlands (220)	Participants had to be adult Norwegians.	Individuals were randomly selected from the population registry and sent an invitation letter.	T1: 17.1% (1047 to 868)	Peer reviewed publication	Low
Klöckner et al., 2017, study 2, Netherlands (220)	Participants had to be adults.	Individuals were recruited from the professional online panel TNS Gallup.	T1: 8.63% (3895 to 3559)	Peer reviewed publication	Medium
Tian et al., 2016, study 1, France and China (221)	Exclusion: Individuals who identified as vegetarians.	Individuals were recruited using social media and internal university advertisement.	T1: 41.47% (885 to 518)	Peer reviewed publication	Low
Tian et al., 2016, study 2, France and China (221)	See Tian et al., 2016, study 1.	See Tian et al., 2016, study 1.	T1: 14.52% (606 to 518)	Peer reviewed publication	Low
Vibhuti, 2016, USA (222)	Participants had to be adults and reside in the US.	Individual recruitment through Amazon Mechanical Turk.	T1: 0,97% (412 to 408)	Unpublished, available online	Low
Non-randomised Controlled Trials (CT)					
Allen et al., 2012, Australia (223)	N/A	The survey was sent to a random sample of individuals drawn from the telephone directory.	T1: 1.82% (220 to 216) T2: 55.91% (220 to 97)	Peer reviewed publication	Low
Berndsen et al., 2005, study 1, Netherlands (224)	Participants had to be meat eaters.	Individual recruitment through internal university advertisement	T1: 0% (141 to 141) T2: 0%	Peer reviewed publication	Low

			(141 to 141)		
Berndsen et al., 2005, study 2, Netherlands (224)	See Berndsen et al., 2005, study 1.	See Berndsen et al., 2005, study 1.	T1: 0% (92 to 92) T2: 0% (92 to 92)	Peer reviewed publication	Low
Bertolotti et al., 2016, Italy (225)	Participants had to be over 60 years old, had to volunteer to participate, and complete sufficient sections of the questionnaire.	Active recruitment of individuals from socio-recreational centres for the elderly in Milan, Italy.	T1: 19.17% (120 to 97)	Peer reviewed publication	Strong
Schiavon et al., 2015, Brazil (226)	All patients admitted for surgical treatment of suspected malignant breast tumors in the Maternidade Carmela Dutra Hospital. Exclusion: Individuals who had a history of cancer or a surgical procedure in the previous year; were pregnant or breastfeeding at the time of diagnosis; had positive results for HIV; had neoadjuvant cancer treatment, or a neurological disease.	Active recruitment of all aforementioned patients.	T1: 9.71% (103 to 93)	Peer reviewed publication	Strong
Crossover design (CO)					
Scrimgeour, 2012, New Zealand (227)	N/A	Individuals were recruited using the University Psychology and Geography mailing lists and snowballing techniques	T1: 18.66% (434 to 353)	Unpublished, available online	Medium
Single group pre-post design					
Cordts et al., 2014, Germany (228)	Participants had to be meat eaters.	Individual recruitment through a professional panel provider with the aim of obtaining a representative sample of the German population.	T1: 5.76% (590 to 556)	Peer reviewed publication	Strong
Godfrey, 2014, Canada (204)	N/A	Food stations were recruited from the University Dining Centre at the University of Calgary.	T1: N/A (16,786 meal purchases)	Unpublished, available online	Medium
Grimmet et al., 2016, UK (229)	Participants had to be over 18 years, have completed treatment for non-metastatic CRC within the last 6 months, be competent in	Consultants in 3 London hospitals referred patients to the researchers and research-nurses recruited	T1: 20.69% (29 to 23)	Peer reviewed publication	Medium

	English, have adequate mobility and no contraindications for unsupervised physical activity.	participants from 5 London hospitals.			
Hawkes et al., 2009, Australia (230)	Participants had to be 20-80 years old, approximately 6 months post-CRC diagnosis; competent in English; and have no hearing, speech, or cognitive disabilities preventing them from completing telephone interviews.	Invitation and consent packages were sent to individuals who had undergone treatment in 3 the practices of three practitioners in Brisbane.	T1: 0% (20 to 20)	Peer reviewed publication	Strong
Hawkes et al., 2012, Australia (231)	Participants had to be able to understand and give informed consent in English; have no current or previous diagnosis of CRC or medical conditions limiting adherence to an unsupervised lifestyle program; own a phone; and have one or more poor health behaviour(s) among: not achieving ≥150 minutes of physical activity/week; eating >4 servings of red meat/week or <2 serves of fruit/day, or <5 servings of vegetables/day; consuming >2 drinks/day; or if they had a BMI ≥25. Participants had to have a first degree relative with CRC.	Social media, printed material, radio and online advertisement.	T1: 0% (22 to 22)	Peer reviewed publication	Medium
Loy et al., 2016, Germany (232)	Participants had to be non-vegetarians and proficient in German.	Individuals were recruited through internal university advertisement.	T1: 3,33% (60 to 58) T2: 8.33% (60 to 55)	Peer reviewed publication	Medium
Marette et al., 2016, France (233)	Participants had to eat ground beef, at least occasionally.	Individuals were recruited via phone to randomly select a sample representative of the age groups and socio-economic status of the population in Dijon, France.	T1: 3,23% (124 to 120)	Report, available online	Strong
Retrospective intervention evaluation					
Leidig, 2012, study 1, USA (234)	All healthcare accounts of Sodexo's food service in the USA were eligible.	The survey was distributed to the managers of all USA healthcare accounts.	T1: N/A (119 account managers)	Report, available online	Low
Leidig, 2012, study 2, USA (234)	All corporate and governmental accounts of Sodexo's food service in the USA were eligible.	The survey was distributed to the managers of all USA corporate and government accounts.	T1: N/A (126 account managers)	Report, available online	Low

T1 and T2 respectively refer to the shortest and longest available post-intervention follow-up. This information refers to the data underlying the analyses of meat

demand. The EPHPP QATQS rating is based on: (1) study design, (2) selection bias, (3) confounders, (4) blinding, (5) data collection method, (6) withdrawal and dropouts. Studies with 2+ weak ratings in the aforementioned dimensions are assigned a 'low' overall rating, studies with 1 weak rating are assigned a 'medium' overall rating, and studies with no weak ratings are assigned a 'strong' overall rating.

4.3 Interventions' impact on the demand for meat

4.3.1 Individual lifestyle counselling

Six studies (N=2 RCT, N=1 CT, N=3 pre-post) evaluated the effectiveness of six lifestyle counselling interventions to reduce red and/or processed meat consumption. (215,216,226,229–231) All found evidence that lifestyle counselling led to (215,216) or was associated with reduced meat consumption. (226,229–231) However, two studies measuring red and processed meat separately, only found significant reductions in the consumption of the latter.(230,231) Lifestyle counselling interventions were delivered individually by a trained health professional through multiple face-to-face and/or phone sessions and lasted from 6 weeks to 1 year.(230,231)

All counselling interventions additionally comprised written supporting material, with two interventions tailoring this material to individuals.(215,216) Lifestyle counselling promoted behavioural changes other than meat consumption, including one or more of fruit and vegetable consumption, multivitamin supplement usage, smoking cessation, physical activity, weight loss, and reduction in alcohol consumption. Most counselling interventions (N=5) targeted individuals affected by, or at increased risk of chronic diseases,(215,226,229–231) and only one such intervention targeted healthy working-class individuals.(216)

4.3.2 Self-monitoring interventions

Evidence from two RCTs suggested that two self-monitoring interventions reduced red (214) and processed meat consumption(213) during the intervention period and increased intentions to not exceed recommended levels of consumption over the week following the intervention. Both interventions lasted one week and comprised daily text-messages encouraging participants to self-monitor their red or processed meat consumption with the goal of not exceeding pre-specified recommendations. The intervention focussing on processed meat additionally encouraged participants to think about 'the regret they could experience' if they exceeded recommendations. (213)

4.3.3 Education on meat consumption and health

Five studies (N=2 RCT, N=1 CT, N=1 CO, N=1 Pre-post) evaluated seven interventions providing written information (217,224,227,228) or informational videos (218) about the health consequences of eating meat. Of these, five interventions led to, (217,218) or were associated with intended reductions in meat consumption directly post-intervention. (227,228) Among these studies, one RCT found this effect to be sustained one week after the intervention. (218)

Conversely, neither a cognitively framed nor an affectively framed message about the health consequences of eating meat were associated with intended reductions in meat consumption directly post-intervention and/or three weeks later. (224) Two studies (N=1 RCT, N=1 CT) assessed the impact of two health focussed educational interventions on actual meat consumption but neither found evidence of an effect. (218,224)

Finally, one controlled trial including elderly people compared the effect of four interventions on the selection of meat in a virtual environment and found that messages on health more effectively reduced the selection of meat when framed factually (i.e. describing the causal link between meat consumption and its consequences) rather than pre-factually (i.e. outlining hypothetical consequences of hypothetical meat consumption).(225) Conversely, messages on well-being more effectively reduced intended meat consumption when framed pre-factually rather than factually.(225)

4.3.4 Education on meat consumption and the natural environment

Six studies (N=3 RCT, N=1 CO, N=2 Pre-post) evaluated eight interventions providing written information about the environmental consequences of meat consumption. (204,217,219,222,227,228) Six interventions led to (217,219,222) or were associated with increased intentions to eat less meat (227,228) or with fewer meat products being selected in a simulated food choice experiment. (222) These interventions provided information in the form of paragraphs, (219,227) brief articles,

(222,228) or websites, (217) and two interventions also outlined practical strategies to aid reductions in meat intake. (217,227) Conversely, the only pre-post study assessing the impact on actual meat purchases found no evidence that two informational posters on livestock's water footprint reduced meat purchases in a university canteen. (204)

4.3.5 Education on meat consumption and animal welfare

Two studies (N=1 crossover, N=1 pre-post) evaluated two interventions providing written information about the animal welfare implications of consuming meat. (227,228) Both were associated with significant reductions in intended meat consumption, and showed more promise than comparable messages on health or the environment. There was no study assessing the impact of such interventions on actual consumption, purchase, or selection of meat.

4.3.6 Education on meat consumption and social issues

Two studies (N=1 CT, N=1 pre-post) evaluated two interventions focussing on the social consequences or antecedents of eating meat. (223,228) Providing information about the association between pursuing high meat diets and holding social dominance values was not associated with reductions in intended consumption directly post-intervention or with actual meat consumption three weeks later. (223) Conversely, reading an article on the adverse social consequences of high meat diets was associated with increased intentions to eat less meat, though it offered less promise than similar articles on health, the environment, or animal welfare. (228)

4.3.7 Education on multiple consequences of meat consumption

Nine studies (N=4 RCT, N=1 CT, N=2 Pre-post, N=2 retrospective evaluations) assessed fourteen interventions providing written information about multiple consequences of meat consumption. (212,220,224,232–234) These interventions provided printed or online information about two or more of health, environmental, animal welfare, social, personal appearance, and economic

consequences of eating meat. The impact on actual meat consumption was evaluated in seven interventions: two were associated with lower meat intakes directly and four weeks post-intervention in pre-post studies, (232) four were not found to effectively reduce meat intakes in RCTs, (220) and there was insufficient data to make inferences about the effectiveness of the last intervention. (224)

There was no evidence that any of five interventions reduced intended consumption directly post-intervention (212) or three weeks later, (224) while a pre-post study suggested that providing information about the health and environmental consequences of meat consumption was associated with reduced meat selection in a virtual food choice experiment. (233)Actual food purchases were measured following two interventions providing the Meatless Monday toolkit to the US government/corporate accounts or the US healthcare accounts of a large food service company. Only the latter intervention was associated with significant declines in meat purchases. (234)

In summary, only four of fourteen interventions providing written information about multiple consequences of eating meat were associated with significant reductions in meat consumption, purchases or selection, though none of these interventions was assessed in a RCT.

4.3.8 Tailored education

Four RCTs evaluated ten tailored educational interventions, none of which was found to effectively reduce actual (220) or intended meat consumption. (212) Specifically, providing information that was matched to participants' stage of change (235) for eating less beef was not found to reduce beef consumption in two RCTs, and there was no robust evidence that this tailored intervention outperformed its stage-mismatched equivalent. (220)

Two RCTs found no evidence that messages tailored to participants' most valued consequence of meat consumption, and/or to participants' self-schema (being responsible, or adventurous, or

compassionate, or logical), and/or to participants' personal levels of meat intakes reduced their intended meat consumption. (212)

4.3.9 Interventions implicitly highlighting animal suffering

Two RCTs found no evidence that any of four interventions implicitly highlighting animal suffering reduced intended meat consumption (221). All such interventions employed a combination of visual and written material leading recipients to reflect upon the animal suffering involved in the production of meat. (221) For example, participants were shown a picture of a cow accompanied by the statement that the cow will be send to a slaughterhouse, and were asked to think about what would happen to the animal. None of the aforementioned studies assessed actual meat consumption or purchases.

Table 2.4: Impact of interventions targeting conscious determinants of human behaviour on the primary outcomes

Paper	Sample characteristics and comparison (a)	Intervention	Outcome	Results (b)	Direction of outcome
Individual lifestyle counselling					
Emmons et al., 2005, (216).	Sample size: IG: N=1088, CG: N= 1131 Age: M=49 Female: 66% Comparison: IG vs CG, RCT	The intervention targeted consumption of red meat, fruit and vegetable, multivitamin, and physical activity. It comprised endorsement and tailored prescription to prompt behavior change by participants' clinician, 1 x 20' in-person and 4 x 10' telephone counseling sessions with a health advisor, and tailored supporting material including information on barriers to change. The intervention focused on social determinants of behavior. CG: Usual care.	The proportion of participants reporting consuming ≤3 servings/w of red meat over the past 4 weeks was assessed at the baseline and 8 months later with a semi-quantitative Food Frequency Questionnaire (FFQ).	In the IG the proportion of participants consuming ≤3 servings/w rose by 11.8%, while in the CG it decreased by 0.2%. The changes over time between the two conditions were significantly different (p<0.001).	Desired direction
Emmons et al. (a), 2005, (215).	Sample size: IG: N= 591, CG: N= 656 Age: Median: within 60-75 Female: 42% Comparison: IG vs CG, RCT	IG: The intervention targeted consumption of red meat, fruit and vegetable, alcohol, multivitamin, physical activity, and smoking. It comprised 1 motivational and goal-setting telephone session and 4 telephone counselling sessions delivered at monthly intervals by health advisors, and tailored supporting materials. CG: Usual care, gastroenterologist endorsement of the study's behavioural targets, and CRC prevention leaflet.	The proportion of participants reporting consuming on average ≤3 portions/w of red meat was assessed at the baseline and 8 months later with a semi-quantitative FFQ.	Compared to the CG (12%) more participants in the IG reduced their meat intakes to <3 portions/w (18%, p=0.002).	Desired direction
Schiavon et al., 2015, (226).	Sample size: IG: N= 18, CG: N=75 Age: M=51 Female: 100% Comparison: IG vs CG, CT	IG: The 12 month intervention targeted consumption of red and processed meat and fruit and vegetables. It provided information bi-weekly phone calls, bimonthly 24-hour dietary recalls followed by researchers' feedback, and supporting material. CG: Basic healthy lifestyle guidelines at the baseline and follow-up.	Red and processed meat consumption (in g/d) was assessed with an FFQ for Brazilian diets, directly post-intervention.	There was a significant difference in red and processed meat consumption between the groups in unadjusted analyses (B(exp)=0.5, p<0.05) and in analyses adjusting for post-intervention energy intake and baseline red and processed meat consumption	Desired direction

				(B(exp)=0.6, p<0.05). This effect was not detected when also adjusting for baseline saturated and monounsaturated fat, and carbonyl protein and reduced glutathione (B(exp)=0.6, p>0.05).	
Grimmet et al., 2016, (229).	Sample size: N=29 Age: M=65 Female: 62% Comparison: Pre-post	IG: The 12 week intervention targeted consumption of red and processed meat, fruit and vegetables, and physical activity. It comprised 2 weekly telephone calls from the researcher and supporting materials including recipes. The intervention focused on goal setting, review of goals, self-monitoring, and feedback on performance.	Consumption of red (in g/w) and processed meat (in portions/w) was assessed with an FFQ before and directly post-intervention.	Red and processed meat consumption decreased from pre- to post-intervention (mean reduction for red meat: 147.4, p=0.013; mean reduction for processed meat: 0.83, p=0.002).	Desired direction
Hawkes et al., 2009, (230).	Sample size: N=20 Age: Median: 66 Female: 50% Comparison: Pre-post	IG: The 6 week intervention targeted consumption of red and processed meat, fruit and vegetable, alcohol, weight management, physical activity, and smoking. It comprised 6 weekly 45' telephone counselling sessions from a trained health coach, and supporting material. The intervention included lifestyle support, health risks information, behaviour change strategies, self-efficacy, and outcome expectations.	Consumption of red and processed meat (in servings/w) was assessed via phone, before and directly post-intervention.	There was a significant decrease in the intake of processed meat servings/w from baseline (Median=1) to post intervention (Median=0, p=0.01). The proportion of participants eating ≤3-4 servings/w of red meat did not change from pre- (85%) to post-intervention (85%, p=1).	Desired direction (processed meat) No association (red meat)
Hawkes et al., 2012, (231).	Sample size: N=22 Age: M=47 Female: 82% Comparison: Pre-post	IG: The 6 week intervention targeted consumption of red and processed meat, fruit and vegetable, alcohol, weight management, physical activity, and smoking. It comprised 6 x 1-hour telephone-coaching sessions with a trained health coach, focussing on motivation, expectations, values, mindfulness, action planning, goal-setting, and self-monitoring, and supporting material.	Consumption of red and processed meat (in servings/w) was assessed via phone before and directly post-intervention.	Processed meat consumption declined from pre- to post-intervention (mean change, 95%CI=-1.2, -1.8 to -0.5, p<0.01). Red meat consumption did not change from pre- to post-intervention (mean change, 95%CI= 0.02, -0.6 to 0.6, p=0.93).	Desired direction (processed meat) Undesired direction (red meat)

Self-monitoring and goal setting interventions					
Carfora et al., 2017, (213),	Sample size: IG: N=57, CG: N=55 Age: M= 19 Female: 56% Comparison: IG vs CG, RCT	IG: Daily text messages for a week, encouraging participants to self-monitor their consumption of processed meat and to 'think about the regret they could experience' if they were to exceed the recommended levels of processed meat consumption (50g/d). CG: No intervention.	Consumption of processed meat (in servings) was assessed using a 7-day food diary during the week preceding and the week concomitant to the intervention. Intention to eat ≤50g of processed meat over the upcoming week was assessed with three items on a scale from 1 (strongly disagree) to 7 (strongly agree) before and directly post-intervention.	During the intervention the IG ate significantly fewer servings of processed meat (M=1.74) than the CG (M=3.29, p<0.001, d=0.7). At post- intervention, the IG reported higher intentions to eat ≤1 serving of processed meat in the upcoming week (M=4.47) compared to the CG (M=3.60, p<0.008, d=0.51).	Desired direction
Carfora et al., 2017(a), (214).	Sample size: IG: N=116, CG: N=112 Age: M=19 Female: 72% Comparison: IG vs CG, RCT	IG: Daily text messages for a week, encouraging participants to self-monitor their consumption of red meat to not exceed a recommended maximum of two medium servings per week. CG: No intervention.	Consumption of red meat (in servings) was assessed using a 7-day food diary during the week preceding and the week concomitant to the intervention. Intention to eat <2 portions of red meat over the upcoming week was assessed with three items on a scale from 1 (strongly disagree) to 7 (strongly agree) before and directly post-intervention.	During the intervention the IG ate significantly fewer servings of red meat (M=1.62) than the CG (M= 3.03, p<0.001, d=0.74). At post- intervention, the IG reported higher intentions to eat <2 servings of red meat over the upcoming week (M=4.80) compared to the CG (M=4.07, p<0.01, d=0.41).	Desired direction

Non-tailored information about meat consumption and health					
Fehren-bach, 2013, (217).	Sample size: N=187 (total study) Age: Median: within 18-25 (total study) Female: 57% (total study) Comparison: IG vs CG, RCT	IG: A webpage on the health impact of eating meat, recommending practical strategies to eat less meat. CG: A webpage about the Rolling Stones.	Intention to reduce meat consumption was measured directly post-intervention, with three items on a scale from 1 (strongly disagree) to 5 (strongly agree).	Post-intervention intention to eat less meat was higher in the IG (M=3.90) than in the CG (M=2.69, p<0.001).	Desired direction
Fehren-bach, 2015,(218).	Sample size: IG: N=124, CG: N=124 Age: 57 (total study) Female: 57 (total study) Comparison: IG vs CG, RCT	IG: A 4' video about the health impact of eating meat, highlighting participants' susceptibility to these outcomes. CG: No intervention.	At the baseline and one week post-intervention, participants reported how many meat-containing meals they ate in the past 7 days. Intention to eat less meat in the upcoming 7 days was assessed with three 5-points scales, directly post-intervention.	Meat intakes did not differ between the IG (M=-3.16) and the CG (M=-1.92) or any other study groups (p=0.31, d=0.29). Intention to eat less meat was higher in the IG (M= 3.46) than in the CG (M= 2.57, p<0.001).	Desired direction
Fehren-bach, 2015, (218).	Sample size: IG: N=124, CG: N=124 Age: 57 (total study) Female: 57 (total study) Comparison: IG vs CG, RCT	IG: A 7' video about the negative health outcomes of eating meat, highlighting participants' susceptibility to these outcomes, the health benefits of low meat diets, and strategies to eat less meat. CG: No intervention.	At the baseline and one week post-intervention, participants reported how many meat-containing meals they ate in the past 7 days. Intention to eat less meat in the upcoming 7 days was measured with three 5-points scales, directly post-intervention.	Meat intakes did not differ between the IG (M=-2.11) and the CG (M=-1.92), or any other study groups (p=0.31, d=0.29). Intention to eat less meat was higher in the IG (M=3.69) than in the CG (M= 2.57, p<0.001).	Desired direction
Berndsen et al., 2005,	Sample size: IG: N=50, CG: N=38 Age: M=20 (total study)	IG: Cognitively framed paragraph on the health consequences of eating meat. CG: No intervention.	Three weeks post-intervention, participants reported	Self-reported change in meat consumption did not differ between the IG (M= 2.78) and	Undesired direction

study 1, (224).	Female: 59% (total study) Comparison: IG vs. CG, CT		whether they ate less meat in the past 3 weeks. Directly post-intervention, participants reported if they intended to eat less meat over the upcoming 3 weeks. The scales ranged from 1 (fully disagree) to 9 (fully agree).	CG (M=3.16, p>0.05). Intention to eat less meat did not differ between the IG (M=2.38) and the CG (M=3.08, p>0.05).	
Scrim-geour, 2012, (227).	Sample size: N=363 Age: M=28 Female: 68% Comparison: Pre-post, Crossover	IG: Information paragraph on the health impact of eating less meat.	Whether participants intended to eat less, the same, or more meat in the future was assessed pre- and post-intervention.	Compared to the baseline (M≈2.18), participants' intention to eat less meat was higher after the intervention (M≈2.26, p<0.001, d=0.59). (c)	Desired direction
Cordts et al., 2014, (228).	Sample size: N=136 Age: Median: within 40-59 (total study) Female: 45% Comparison: Pre-post	IG: Article on the health impact of eating meat.	The number of participants intending to eat less meat was assessed pre- and post-intervention by asking whether they would eat less, the same, or more meat in the future.	The percentage of participants intending to reduce meat consumption increased from pre- (13.1%, N=137) to post-intervention (23.5%, N=136, p<0.001).	Desired direction
Berndsen et al., 2005, study 1, (224).	Sample size: IG1: N=53, IG2: N=50 Age: M=20 (total study) Female: 59% (for total study) Comparison: IG1 vs. IG2, CT	IG1: Affectively framed paragraph on the health impact of eating less meat. IG2: Cognitively framed paragraph on the health impact of eating less meat.	Three weeks post-intervention, participants reported whether they ate less meat in the past 3 weeks. Directly post-intervention, participants reported if they intended to eat less meat over the upcoming 3 weeks. The scales ranged from 1(fully disagree) to 9(fully agree).	Self-reported change in meat consumption did not differ between IG1 (M=3.75) and IG2 (M=2.78, p=0.07). Directly post-intervention, IG1 (M=3.48) had higher intentions to eat less meat over the upcoming 3 weeks than IG2 (M=2.38, p<0.05). (d)	N/A

Bertolotti et al. 2016, (225).	Sample size: IG1: N=25, IG2: N=23, IG3: N=24, IG4: N=25 Age: M=74 (total study) Female: 73% (total study) Comparison: IG1 vs. IG2, IG3 vs. IG4, IG1 vs IG4, CT	IG1: Factually framed paragraph on the health impact of eating less meat. IG2: Pre-factually framed paragraph on the health impact of eating less meat. IG3: Factually framed paragraph on the well-being impact of eating less meat. IG4: Pre-factually framed paragraph on the well-being impact of eating less meat.	Selection of meat dishes was assessed in a simulated food choice task directly post-intervention. Intention to eat red and processed meat in the upcoming month was assessed on a scale from 1 ("much less than before") to 7 ("much more than before") at post-intervention.	At post-intervention, IG1 chose fewer meat dishes than IG2 (p=0.015) but had not significantly lower intentions to eat red or processed meat (p>0.07). IG4 did not choose fewer meat dishes than IG3 (p=0.089) but had lower intention to eat red (p=0.046) and processed meat (p=0.035). Intention to eat red and processed meat did not differ significantly between IG1 and IG4 (p>0.28). There was no main effect of content (health vs well-being) or frame (pre-factual vs factual) on any outcome.	N/A
Information about meat and the environment					
Fehren-bach, 2013, (217).	Sample size: N=187 (total study) Age: Median: within 18-25 (total study) Female: 57% (total study) Comparison: IG vs CG, RCT	IG: A webpage on the environmental impact of eating meat, recommending practical strategies to eat less meat. CG: Control web-site on the Rolling Stones.	Intention to reduce meat consumption was measured directly post-intervention, with three items on a scale from 1 (strongly disagree) to 5 (strongly agree).	Intention to eat less meat was higher in the IG (M=3.71) than in the CG (M=2.69, p<0.001).	Desired direction
Graham, 2017, (219).	Sample size: IG: N=264, CG: N=317 Age: Median: within 21-30 (total study) Female: 69% (total study) Comparison: IG vs CG, RCT	IG: A self-transcendent framed paragraph on the livestock related GHG emissions in NZ and the mitigation potential of reduced consumption.	Intention to eat meat in the upcoming month was assessed with three items on a scale from 1 (low intention) to 7 (high intention), directly post-intervention.	Intention to eat meat was lower in the IG (M=3.9) than in the CG (M=4.2, p<0.05).	Desired direction
Graham, 2017, (219).	Sample size: IG: N=267, CG: N=317 Age: Median: within 21–30 (total	IG: A self-enhancement framed paragraph on the livestock related GHG emissions in NZ and the mitigation potential of reduced	Intention to eat meat in the upcoming month was assessed	Intention to eat meat was lower in the IG (M=4.0) than in the CG (M=4.2, p<0.05).	Desired direction

	study) Female: 69% (total study) Comparison: IG vs CG, RCT	consumption.	with three items on a scale from 1 (low intention) to 7 (high intention), directly post-intervention.		
Vibhuti, 2016, (222).	Sample size: IG: N=183, CG: N=225 Age: M=36 Female: 54% Comparison: IG vs CG, RCT	IG: An essay on the environmental impact of the meat consumption and production. CG: No intervention.	Directly post-intervention participants completed six virtual food choices, selecting between a meat-based food and a comparable meat-free alternative.	The proportion of selected meat and meat-free products differed significantly between the CG (meat≈61%) and the IG (meat≈55%, p=0.003, V=0.06).	Desired direction
Scrim-geour, 2012, (227).	Sample size: N=363 Age: M=28 Female: 68% Comparison: Pre-post, Crossover	IG: Information paragraph on the environmental impact of eating meat and strategies to reduce consumption.	Whether participants intended to eat less, the same, or more meat in the future was assessed pre- and post-intervention.	Intention to eat less meat was higher at post-intervention (M≈2.27) than at the baseline (M≈2.18, p<0.001, d=0.27).	Desired direction
Cordts et al., 2014, (228).	Sample size: N=128 Age: Median: within 40-59 (total study) Female: 45% Comparison: Pre-post	IG: An article on the environmental impact of eating meat.	The number of participants intending to eat less meat was assessed pre- and post-intervention by asking whether they would eat less, the same, or more meat in the future.	The percentage of participants intending to eat less meat increased from pre- (13.4%, N=127) to post- intervention (18.8%, N=128, p<0.001).	Desired direction
Godfrey, 2014, (204).	Sample size: N= 6758 purchases during the intervention period, N=4426 purchases during the control period. Comparison: Pre-post	IG: A poster on the water footprint of meals containing vegetables (300 L/meal), pork, chicken or fish (590 L/meal), and beef (1350 L/meal) was displayed over 2 weeks in a university canteen.	Meat purchases were assessed using production reports of the dining centres indicating how many servings of each main course were made daily.	There was no difference in the proportion of meat dishes purchased in the control period (87.19%) and in the intervention period (87.82%, p>0.05).	Undesired direction
Godfrey, 2014, (204).	Sample size: N= 1176 purchases during the intervention period, N=4426 purchases during the	IG: A poster on the water footprint of meals containing vegetables (300 L/meal), pork, chicken or fish (590 L/meal), and beef (1350	Meat purchases were assessed using production reports of	There was no difference in proportion of meat dishes purchased in the control period	Undesired direction

	control period. Comparison: Pre-post	L/meal) and mentioning the daily water-friendly option was displayed for 4 days in a university canteen.	the dining centres indicating how many servings of each main course were made daily.	(87.19%) and in the intervention period (91.58%, p>0.05).	
Information on meat and animal welfare					
Scrim-geour, 2012, (227).	Sample size: N=363 Age: M=28 Female: 68% Comparison: Pre-post, Crossover	IG: Information paragraph on the animal welfare implications of eating meat and strategies to eat less.	Whether participants intended to eat less, the same, or more meat in the future was assessed pre- and post-intervention.	Intention to eat less meat was higher at post-intervention (M≈2.3) than at the baseline (M≈2.18, p<0.001, d=0.65).	Desired direction
Cordts et al., 2014, (228).	Sample size: N=150 Age: Median: within 40-59 (total study) Female: 55% Comparison: Pre-post	IG: An article on the animal welfare implications of eating meat.	The number of participants intending to eat less meat was assessed pre- and post-intervention by asking whether they would eat less, the same, or more meat in the future.	The percentage of participants intending to eat less meat increased from pre- (15.6%, N=147) to post- intervention (28%, N=150, p<0.001).	Desired direction
Information about the socio-political consequences of meat consumption					
Allen et al., 2002, (223).	Sample Size: IG: N=103, CG: N=113 Age: Median within: 45-65 Female: 59% Comparison: IG vs CG, CT	IG: Participants were informed that people higher in social dominance orientation (SDO) eat more meat and fewer vegetables, while people lower in social dominance do the opposite. CG: No intervention.	Intended consumption of red and white meat servings in the upcoming 3 days was assessed with a single item directly at post-intervention. Three weeks post-interventions participants reported their consumption of meat servings over the past 7 days.	Intended meat consumption did not differ between IG (High SDO= 1.45, Low SDO=1.45) and CG (High SDO= 1.56, Low SDO=1.37). Actual meat consumption remained unchanged in both groups from pre- (IG=2.88, CG=2.66) to post-intervention (IG= 2.87, CG=2.61, p>0.05).	Desired direction (High SDO) Undesired direction (Low SDO)

Cordts et al., 2014, (228).	Sample size: N=149 Age: Median within: 40-59 (total study) Female: 48% Comparison: Pre-post	IG: An article on the social consequences of eating meat.	The number of participants intending to eat less meat was assessed pre- and post-intervention by asking whether they would eat less, the same, or more meat in the future.	The percentage of participants intending to eat less meat increased from pre- (9%, N=145) to post-intervention (12.1%, N=149, p<0.001).	Desired direction
Information about multiple consequences of eating meat					
Arndt, 2016, study 1, (212).	Sample size: IG: N=29, CG: N=40 Age: M=37 (total study) Female: 64% (total study) Comparison: IG vs CG, RCT	IG: Paragraph on the impact of meat consumption of an average American on health, and personal finances, and animal welfare, and the environment, and personal appearance. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=2.21) and CG (M=2.63), or among any other study groups (p=0.19).	Desired direction
Arndt, 2016, study 2, (212).	Sample size: IG: N=37, CG: N=40 Age: 37 (total study) Female: 62% (total study) Comparison: IG vs CG, RCT	IG: Paragraph on the impact of meat consumption on health, and personal finances, and animal welfare, and the environment, also stating that eating less meat can help fulfil one's altruistic duty. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=2.24) and CG (M=2.75), or among any other study groups (p=0.45).	Desired direction
Arndt, 2016, study 2, (212).	Sample size: IG: N=38, CG: N=40 Age: 37 (total study) Female: 62% (total study) Comparison: IG vs CG, RCT	IG: Paragraph on the impact of meat consumption on health, and personal finances, and animal welfare, and the environment, also stating that eating less meat could help fulfil one's personal (egoistic) objectives. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=1.92) and CG (M=2.75), or among any other study groups (p=0.45).	Desired direction
Arndt, 2016, study 2, (212).	Sample size: IG: N=30, CG: N=40 Age: 37 (total study) Female: 62% (total study) Comparison: IG vs CG, RCT	IG: Paragraph on the impact of meat consumption on health, and personal finances, and animal welfare, and the environment. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=2.57) and CG (M=2.75), or among any other study groups (p=0.45).	Desired direction
Klöckner et al., 2017,	Sample size: IG: N= 246, CG: N=235 Age: M=40 (total study)	IG: Access to one of three subsections of a web-page (selected at random) outlining (a) why to eat less beef, or (b) how to eat less	Change in beef consumption from pre- to 8 weeks post-	Adjusted for baseline consumption, there was no difference in the changes in	Undesired direction

study 1, (220).	Female: 49% (total study) Comparison: IG vs CG, RCT	beef, or (c) how to master challenges associated with eating less beef. The webpages included health, and environmental, and social reasons for eating less beef, practical strategies, statements triggering personal values, links to scientific sources, and videos of people's stories. CG: No intervention.	intervention, was measured with a retrospective food diary.	beef consumption between the IG (M=54.42) and the CG (M=-37.09, simple contrast: p=0.3).	
Klöckner et al., 2017, study 1, (220).	Sample size: IG: N= 273, CG: N=235 Age: M=40(for total study) Female: 49% (for total study) Comparison: IG vs CG, RCT	IG: Access to a web-page outlining (a) why to eat less beef, and (b) how to eat less beef, and (c) how to master challenges associated with eating less beef. The webpages included health, and environmental, and social reasons for eating less beef, practical strategies, statements triggering personal values, links to scientific sources, and videos of people's stories. CG: No intervention.	Change in beef consumption from pre- to 8 weeks post-intervention, was measured with a retrospective food diary.	Adjusted for baseline consumption, there was no difference in the changes in beef consumption between the IG (M=38.17) and the CG (M=-37.09, simple contrast: p=0.79).	Undesired direction
Klöckner et al., 2017, study 2, (220).	Sample size: IG: N= 975, CG: N=970 Age: M= 43 (for total study) Female: 47% (for total study) Comparison: IG vs CG, RCT	IG: Access to one of three subsections of a web-page (selected at random) outlining (a) why to eat less beef, or (b) how to eat less beef, or (c) how to master challenges associated with eating less beef. The webpages included health, environmental, and social reasons for eating less beef, practical strategies, statements triggering personal values, links to scientific sources, and videos of people's stories. CG: No intervention.	Change in beef consumption from pre- to 8 weeks post-intervention, was measured with a retrospective food diary.	Adjusted for baseline consumption, there was no difference in the changes in beef consumption between the IG (M=28.5) and the CG (M=-66.38, simple contrast: p=0.79).	Undesired direction
Klöckner et al., 2017, study 2, (220).	Sample size: IG: N= 974, CG: N=970 Age: M= 43 (for total study) Female: 47% (for total study) Comparison: IG vs CG, RCT	IG: Access to a web-page outlining (a) why to eat less beef, and (b) how to eat less beef, and (c) how to master challenges associated with eating less beef. The webpages included health, environmental, and social reasons for eating less beef, practical strategies, statements triggering personal values, links to scientific sources, and videos of people's stories. CG: No intervention.	Change in beef consumption from pre- to 8 weeks post-intervention, was measured with a retrospective food diary.	Adjusted for baseline consumption, there was a significant difference in the changes in beef consumption between the IG (M=13) and the CG (M=-66.38, simple contrast: p<0.001) but these changes went in the undesired direction.	Undesired direction

Berndsen et al., 2005, study 2, (224).	Sample size: IG: N=45, CG: N=47 Age: M=20.6 Female: 58% Comparison: IG vs. CG, CT	IG: Paragraph on animal welfare, and health, and environmental impact of eating meat. CG: No intervention control.	Three weeks post-intervention, participants reported whether they ate less meat in the past 3 weeks. Directly post-intervention, participants reported if they intended to eat less meat over the upcoming 3 weeks. The scales ranged from 1(fully disagree) to 9 (fully agree).	There was no significant main effect of condition (p<0.10). Interaction and post-hoc tests were not reported.	N/A
Loy et al., 2016, (232).	Sample size: IG: N=28 Age: M=22 Female: 82% Comparison: Pre-post	IG: A paragraph on the environmental, and ethical, and health, and socio-economic consequences of eating meat and written instructions for mental contrasting and intention implementation.	Meat consumption in g/d was assessed with a 7-day diary the week pre- and the week directly post-intervention.	Meat consumption decreased significantly from pre- to post-intervention (average reduction: 45.2 g/d, p<0.001, d=1.09).	Desired direction
Loy et al., 2016, (232).	Sample size: IG: N=30 Age: M=23 Female: 75% Comparison: Pre-post	IG: A paragraph on the environmental, and ethical, and health, and socio-economic consequences of eating meat.	Meat consumption in g/d was assessed with a 7-day diary the week pre- and the week directly post-intervention.	Meat consumption decreased significantly from pre- to post-intervention (average reduction: 26.4 g/day, p=0.001, d=0.63).	Desired direction
Marette et al., 2016, (233).	Sample size: 124 (recruited) Age: Median: within 40-49 Female: 54% Comparison: Pre-post	IG: Four paragraphs outlining the health and environmental impact of red meat consumption and the respective benefits of alternative soy-based products.	Before and directly post-intervention, participants conducted a virtual food choice task in which they selected 5 items from either beef or soy burgers.	The selection of beef items declined from pre- (M=3.52) to post-intervention (M=2.69, p<0.01).	Desired direction
Leidig, 2012, study 1, (234).	Sample size: IG: N=119 Comparison: Retrospective evaluation	IG: The Meatless Monday campaign toolkit was sent to all healthcare accounts in the US and it was posted on Sodexo's intranet. The toolkit included information about various benefits of eating less meat, and practical suggestions for implementing a Meatless	Three months post-intervention, the general managers of Sodexo's healthcare accounts retrospectively	Three months post-intervention 8% of accounts reported increases, 35% reported declines, and the rest reported no changes in meat sales. Using the scale's mid-	Desired direction

		Monday campaign.	assessed the change in meat purchases on a single scale with 5% increments ranging from 1 (10%+ decrease) to 7 (10%+ increase), with a score of 4 indicating no changes.	points as the average changes in sales, an overall decline was observed M=-0.75%, $p<0.001$).	
Leidig, 2012, study 2, (234).	Sample size: IG: N=126 Comparison: Retrospective evaluation	IG: The Meatless Monday campaign toolkit was posted on Sodexo's intranet for the corporate and governmental accounts to retrieve. The toolkit included information about various benefits of eating less meat, and practical suggestions for implementing a Meatless Monday campaign.	Three months post-intervention, the general managers of Sodexo's healthcare accounts retrospectively assessed the change in meat purchases on a single scale with 5% increments ranging from 1 (10%+ decrease) to 7 (10%+ increase), with a score of 4 indicating no changes.	Three months post-intervention 14% of accounts reported increases, 20% reported declines, and the rest reported no changes in meat sales. There was no overall reduction in sales, when using the scale's mid-points as average changes (M=-0.33%, $p=0.23$).	Desired direction
Tailored information provision					
Arndt, 2016, study 1, (212).	Sample size: IG: N=37, CG: N=40 Age: M=37 (total study) Female: 64% (total study) Comparison: IG vs CG, RCT	IG: Tailored paragraph on how strongly a participant's personal levels of meat consumption affect their health, or personal finances, or animal welfare, or environment, or personal appearance depending on which consequence participants valued. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=1.70) and the CG (M=2.63), or among any other study groups ($p=0.19$).	Desired direction
Arndt, 2016, study 1, (212).	Sample size: IG: N=37, CG: N=40 Age: M=37 (total study) Female: 64% (total study) Comparison: IG vs CG, RCT	IG: Tailored paragraph on how strongly a participant's personal levels of meat consumption affect their health, and personal finances, and animal welfare, and the environment, and personal appearance. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=2.57) and the CG (M=2.63), or among any other study groups ($p=0.19$).	Desired direction

Arndt, 2016, study 1, (212).	Sample size: IG: N=36, CG: N=40 Age: M=37 (total study) Female: 64% (total study) Comparison: IG vs CG, RCT	IG: Tailored paragraph on the consequences of an average American's meat consumption on health, or personal finances, or animal welfare, or the environment, or personal appearance, depending on which consequence participants valued. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=2.69) and the CG (M=2.63), or among any other study groups (p=0.19).	Undesired direction
Arndt, 2016, study 2, (212).	Sample size: IG: N=42, CG: N=40 Age: 37 (total study) Female: 62% (total study) Comparison: IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, or personal finances, or animal welfare, or the environment, depending on which consequence participants valued. The message stated that eating less meat is congruent with being responsible, or adventurous, or logical, or compassionate depending on participants' self-schema. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=2.73) and the CG (M=2.75), or among any other study groups (p=0.45).	Desired direction
Arndt, 2016, study 2, (212).	Sample size: IG: N=30, CG: N=40 Age: 37 (total study) Female: 62% (total study) Comparison: IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, and personal finances, and animal welfare, and the environment. The message stated that eating less meat is congruent with being responsible, or adventurous, or logical, or compassionate depending on participants' self-schema. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=2.13) and the CG (M=2.75), or among any other study groups (p=0.45).	Desired direction
Arndt, 2016, study 2, (212).	Sample size: IG: N=33, CG: N=40 Age: 37 (total study) Female: 62% (total study) Comparison: IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, or personal finances, or animal welfare, or the environment, depending on which consequence participants valued. The message stated that eating less meat can help fulfil one's altruistic duty. CG: No intervention.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=1.97) and the CG (M=2.75), or among any other study groups (p=0.45).	Desired direction
Arndt, 2016, study 2, (212).	Sample size: IG: N=29, CG: N=40 Age: 37 (total study) Female: 62% (total study) Comparison: IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, or personal finances, or animal welfare, or the environment, depending on which consequence participants valued. The	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=1.55) and the CG (M=2.75), or among any other study groups (p=0.45).	Desired direction

		message stated that eating less meat can help fulfil one's personal (egoistic) objectives. CG: No intervention.			
Arndt, 2016, study 2, (212).	Sample size: IG: N=29, CG: N=40 Age: 37 (total study) Female: 62% (total study) Comparison: IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, or personal finances, or animal welfare, or the environment, depending on which consequence participants valued.	Intended average daily meat consumption (in servings) was assessed with a single open question directly post-intervention.	Adjusted for baseline meat intake, intended meat consumption did not differ between IG (M=2.86) and the CG (M=2.75), or among any other study groups (p=0.45).	Undesired direction
Klöckner et al., 2017, study 1, (220).	Participants had to be adults Sample size: IG: N= 275, CG: N=235 Age: M=40 (total study) Female: 49% (total study) Comparison: IG vs CG, RCT	IG: Depending on participants stage of change for eating less beef, they were given access to the 'stage matched' subsections of a web-page about: (a) why to eat less beef, or (b) how to eat less beef, or (c) how to master challenges associated with eating less beef. The webpages included health, environmental, and social reasons for eating less beef, practical strategies, statements triggering personal values, links to scientific sources, and videos of people's stories. CG: No intervention.	Change in beef consumption from pre- to 8 weeks post-intervention, was measured with a retrospective food diary.	Adjusted for baseline consumption, there was no difference in the changes in beef consumption between the IG (M=81.12) and the CG (M=-37.09, simple contrast: p=0.37).	Undesired direction
Klöckner et al., 2017, study 2, (220).	Sample size: IG: N= 976, CG: N=970 Age: M=43 (for total study) Female: 47% (for total study) Comparison: IG vs CG, RCT	IG: See Klöckner et al. (2017) tailored intervention above. CG: No intervention.	Change in beef consumption from pre- to 8 weeks post-intervention, was measured with a retrospective food diary.	Adjusted for baseline consumption, there was no difference in the changes in beef consumption between the IG (M=23.79) and the CG (M=-66.38, simple contrast: p=0.65).	Undesired direction
Implicitly highlighting animal suffering					
Tian, 2016, study 1, (221).	Sample size: IG: N=105, CG: N=166 Age: M=23 (total study) Female: 79% (total study) Comparison: IG vs CG, RCT	IG: Participants viewed a diagram displaying the meat products from various parts of a cow's image and were asked to write a paragraph describing the figure. (e) CG: No intervention.	Intention to eat beef was measured with 2 items ranging from 1 (low intention to eat beef) to 7 (high intention to eat beef), directly post-intervention	Intended beef consumption did not differ between CG and IG (Mean difference=-0.16, 95%CI=-0.6 to 0.27, p=0.77).	Undesired direction

Tian, 2016, study 1, (221).	Sample size: IG: N=123, CG: N=166 Age: M=23 (total study) Female: 79% (total study) Comparison: IG vs CG, RCT	IG: Participants viewed a picture of a cow with a statement that the cow will be sent to another pasture the next day and were asked to write what would happen to the cow. CG: No intervention.	Intention to eat beef was measured with 2 items ranging from 1 (low intention to eat beef) to 7 (high intention to eat beef), directly post-intervention	Intended beef consumption did not differ between CG and IG (mean difference=0.11, 95%CI=-0.31 to 0.52, p=0.91).	Desired direction
Tian, 2016, study 1, (221).	Sample size: IG: N=124, CG: N=166 Age: M=23 (total study) Female: 79% (total study) Comparison: IG vs CG, RCT	IG: Participants viewed a picture of a cow with a statement that the cow will be sent to the abattoir the next day and were asked to write what would happen to the cow. CG: No intervention.	Intention to eat beef was measured with 2 items ranging from 1 (low intention to eat beef) to 7 (high intention to eat beef), directly post-intervention	Intended beef consumption did not differ between CG and IG (mean difference= 0.32, 95%CI= -0.09 to 0.73, p=0.19).	Desired direction
Tian 2016, study 2, (221).	Sample size: IG: N= 129, CG: N=120 Age: M= 32 (total study) Female: 67% (total study) Comparison: IG vs CG, RCT	IG: Participants were given a description of a beef dish together with an image of a cow to highlight its animal origin. CG: No intervention.	Intention to eat beef was measured with 2 items ranging from 1 (low intention to eat beef) to 7 (high intention to eat beef), directly post-intervention	Intended beef consumption did not differ between CG and IG (Mean difference: -0.05, 95%CI= -0.47 to 0.37, p=0.99).	Undesired direction

M=Mean, SD=Standard deviation, SE=Standard error, IG=Intervention group, CG=Control group, CI=Confidence interval, OR=Odds ratio.

4.4 Qualitative comparative analysis

Fifty-five comparisons were included in the QCA of interventions targeting conscious determinants of human behaviour to reduce the demand for meat. Four configurations of intervention characteristics were consistently associated with reductions in actual or intended meat consumption in real or virtual environments in more than one evaluation (Table 2.5), while six configurations were consistently not found to be associated with these outcomes (Table 2.6).

QCA supported the findings of my narrative synthesis suggesting that the approaches that were consistently associated with reductions in actual meat consumption were self-monitoring and lifestyle counselling interventions. Non-tailored information provision about the detrimental health or environmental consequences of eating meat was consistently associated with reductions in intended consumption or purchases/selection of meat in virtual environments but was not found to be associated with changes in actual behaviour.

Conversely, tailored and non-tailored interventions elaborating on several consequences of eating less meat and interventions implicitly highlighting animal suffering were not found to be associated with actual or intended consumption, purchase, or selection of meat in real or virtual environment.

Table 2.5: Configuration of intervention components associated with significant reductions in meat demand for interventions targeting conscious determinants of human behaviour

Non-tailored environmental information Raw coverage: 25%, Internal consistency: 100%	
Outcome:	(1) Reduction in intended consumption or purchase/selection of meat in virtual environments
In the presence of:	(2) Non-tailored (3) information about environmental issues (4) targeting healthy individuals
In the absence of:	Information about (5) health, (6) socio-economic, (7) animal welfare issues, (8) multiple consequences of eating meat, and (9) implicitly highlighting animal suffering, (10) self-monitoring, (11) goal-setting, and (12) lifestyle counselling
Regardless of:	(13) Provision of practical strategies to eat less meat
Non-tailored health information with practical strategies to eat less meat Raw coverage: 8%, Internal consistency: 100%	
Outcome:	(1) Reduction in intended consumption or purchase/selection of meat in virtual environments
In the presence of:	(2) Non-tailored (3) information about health issues (4) with practical strategies to eat less meat (5) targeting healthy individuals
In the absence of:	Information about (6) environmental, (7) socio-economic, (8) animal welfare issues, (9) multiple consequences of eating meat, and (10) implicitly highlighting animal suffering, (11) self-monitoring, (12) goal-setting, and (13) lifestyle counselling
Self-monitoring and goal-setting interventions Raw coverage: 8%, Internal consistency: 100%	
Outcome:	(1) Reduction in actual meat consumption, purchase, or selection
In the presence of:	(2) Non-tailored (3) self-monitoring and (4) goal-setting interventions (5) targeting healthy individuals
In the absence of:	Information about (6) health (7) environmental, (8) socio-economic, (9) animal welfare issues, (10) multiple consequences of eating meat, and (11) implicitly highlighting animal suffering, (12) practical strategies to eat less meat, and (13) lifestyle counselling
Lifestyle-counselling for people with, or at increased risk of ill-health Raw coverage: 17%, Internal consistency: 100%	
Outcome:	(1) Reduction in actual meat consumption, purchase, or selection
In the presence of:	(2) Tailored (3) lifestyle counselling (4) targeting people with ill health or at increased risk thereof, and including (5) information on health, (6) self-monitoring, (7) goal-setting, and (8) practical strategies to eat less meat
In the absence of:	Information about (9) environmental, (10) animal welfare, (11) socio-economic issues, (12) multiple consequences of eating meat, and (13) implicitly highlighting animal suffering

Configuration of intervention components associated with significant reductions in meat demand. The overall solution coverage was 58%, i.e. 58% of all interventions associated with significant reductions in meat demand are covered by one of the intervention configurations above. The overall solution consistency was 100%, i.e. 100% of all interventions covered by the configurations above are associated with significant reductions in meat demand. Raw coverage refers to the percentage of all interventions associated with significant reductions in meat demand that are covered by a specific intervention configuration. Internal consistency refers to the percentage of the interventions within a given configuration that are associated with reductions in meat demand.

Table 2.6: Configuration of intervention components not found to be associated with significant reductions in meat demand for interventions targeting conscious determinants of human behaviour

Tailored information provision Raw coverage: 26%, Internal consistency: 100%	
Outcome:	(1) Reduction in intended consumption or purchase/selection of meat in virtual environments
In the presence of:	(2) Tailored information about (3) one or more of (4) environmental, (5) health, (6) animal welfare, or (7) socio-economic issues, (8) targeting healthy individuals
In the absence of:	(9) Implicitly highlighting animal suffering, (10) self-monitoring, (11) goal-setting, (12) practical strategies to eat less meat, and (13) lifestyle counselling
Information about multiple issues Raw coverage: 19%, Internal consistency: 100%	
Outcome:	(1) Reduction in intended consumption or purchase/selection of meat in virtual environments
In the presence of:	Information about (2) two or more of (3) health, (4) environmental, (5) animal welfare, and (6) socio-economic issues (7) targeting healthy individuals
In the absence of:	(8) Practical strategies to eat less meat, (9) implicitly highlighting animal suffering, (10) self-monitoring, (11) goal-setting, and (12) lifestyle counselling
Regardless of:	(13) Tailoring
Information about multiple issues and practical strategies Raw coverage: 19%, Internal consistency: 100%	
Outcome:	(1) Reduction in actual meat consumption, purchase, or selection
In the presence of:	Information about (2) two or more of (3) health, (4) environmental, and (5) socio-economic issues (6) targeting healthy individuals, and (7) practical strategies to eat less meat
In the absence of:	Information about (8) animal welfare, (9) implicitly highlighting animal suffering, (10) self-monitoring, (11) goal-setting, and (12) lifestyle counselling
Regardless of:	(13) Tailoring
Interventions implicitly highlighting animal suffering Raw coverage: 13%, Internal consistency: 100%	
Outcome:	(1) Reduction in intended consumption or purchase/selection of meat in virtual environments
In the presence of:	(2) Non-tailored interventions (3) implicitly highlighting animal suffering, (4) among healthy individuals
In the absence of:	Information about (5) environmental, (6) health, (7) socio-economic, (8) animal welfare issues, (9) multiple consequences of eating meat, as well as (10) self-monitoring, (11) goal-setting, (12) practical strategies to eat less meat, and (13) lifestyle counselling.
Non-tailored education on the environment, when actual behaviour is the outcome Raw coverage: 6%, Internal consistency: 100%	
Outcome:	(1) Reduction in actual consumption, purchase, or selection of meat
In the presence of:	(2) Non-tailored (3) information about environmental issues (4) targeting healthy individuals

In the absence of:	Information about (5) health, (6) socio-economic, (7) animal welfare, (8) or multiple issues, as well as (9) implicitly highlighting animal suffering, (10) self-monitoring, (11) goal-setting, (12) practical strategies to eat less meat, and (13) lifestyle counselling.
Non-tailored education on health, when actual behaviour is the outcome Raw coverage: 6%, Internal consistency: 100%	
Outcome:	(1) Reduction in actual consumption, purchase, or selection of meat
In the presence of:	(2) Non-tailored (3) information about health issues (4) targeting healthy individuals
In the absence of:	Information about (5) environmental, (6) socio-economic, (7) animal welfare, (8) or multiple issues, as well as (9) implicitly highlighting animal suffering, (10) self-monitoring, (11) goal-setting, (12) practical strategies to eat less meat, and (13) lifestyle counselling.

Configuration of intervention components not found to be associated with significant reductions in meat demand. The overall solution coverage was 83%, i.e. 83% of all interventions that were not found to be associated with significant reductions in meat demand are covered by the intervention configuration above. The overall solution consistency was 100%, i.e. all interventions covered by the configuration above were not found to be associated with significant reductions in meat demand. Raw coverage refers to the percentage of all interventions not found to be associated with significant reductions in meat demand that are covered by the intervention configuration above. As there is only one such intervention this number is identical to the solution coverage. Internal consistency refers to the percentage of interventions within the configuration above that are not found to be associated with reductions in meat demand.

4.5 Secondary psychosocial outcomes

Self-monitoring interventions led to more favourable instrumental attitudes (beliefs about the impact of eating meat) but not affective attitudes (feeling about the hedonic aspects of eating meat) towards eating less meat. (213,214) One self-monitoring intervention additionally enhanced perceived behavioural control, (214) while there was no evidence that either influenced subjective social norms (213,214) of eating less meat. In all five interventions evaluating the impact of providing information about the health consequences of eating meat and measuring attitudes, there was evidence that the intervention led to or was associated with more favourable attitudes towards eating less meat. (217,218,224,227) Two out of four interventions providing information on the environmental impact of meat consumption led to, or were associated with, more favourable attitudes towards eating less meat. (217,219,227) One non-tailored educational intervention focussing on animal welfare (227) and another focussing on the social antecedents of meat consumption were associated with less favourable attitudes towards meat consumption. (223) Conversely, none of the eight tailored educational interventions or five non-tailored interventions focussing on multiple consequences of meat consumption were found to influence attitudes. (212,224)

4.6 Secondary biological outcomes

The only biomarker of health on which studies reported was weight. Of four studies (N=1 CT, N=3 pre-post) evaluating the impact of lifestyle counselling interventions on weight (226,229–231) only one intervention, which explicitly focussed on weight management, was associated with a significant reduction in BMI in a pre-post comparison. (231)

Table 2.7: Impact of interventions targeting conscious determinants of human behaviour at the longest available follow up

Paper	Sample characteristics and comparison	Intervention	Outcome	Results
Information about the health consequences of eating meat				
Fehrenbach, 2015, USA (218)	Sample size: IG: N= 59, CG: N=48 Comparison: IG vs CG, RCT	IG: A 4' video about the health impact of eating meat, highlighting participants' susceptibility to these outcomes. CG: No intervention.	Intention to eat less meat in the upcoming 6 months was measured with three 5-points scales, one week post-intervention.	Intention to eat less meat was higher in the IG (M=3.54) than in the CG (M=2.78, p<0.001).
Fehrenbach, 2015, USA (218)	Sample size: IG: N=46, CG: N=48 Comparison: IG vs CG, RCT	IG: A 7' video about the negative health outcomes of eating meat, highlighting participants' susceptibility to these outcomes, the health benefits of low meat diets, and strategies to eat less meat. CG: No intervention.	Intention to eat less meat in the upcoming 6 months was measured with three 5-points scales, one week post-intervention.	Intention to eat less meat was higher in the IG (M=3.71) than in the CG (M=2.78, p<0.001).
Berndsen et al., 2005, Netherlands (Study 1) (224)	Sample size: IG: N=50, CG: N=38 Comparison: IG vs CG, CT	IG: Cognitively framed paragraph on the health consequences of meat consumption. CG: No intervention control.	Three weeks post-intervention, participants reported whether they intended to reduce their meat consumption in the future from 1 (fully disagree) to 9 (fully agree).	Intention to eat less meat did not differ between the IG (M=7.50) and the CG (M=7.21, p>0.05).
Berndsen et al., 2005, Netherlands (Study 1) (224)	Sample size: IG: N=53, CG: 38 Comparison: IG vs CG,C T	IG1: Affectively framed paragraph on the health consequences of meat consumption. CG: No intervention control.	Three weeks post-intervention, participants reported whether they intended to reduce their meat consumption in the future from 1 (fully disagree) to 9 (fully agree).	Three weeks post-intervention, intention to eat less meat did not differ between the IG (M=7) and the CG (M=7.21, p>0.05).
Information about multiple consequences of eating meat				
Berndsen et al., 2005, Netherlands (Study 2) (224)	Sample size: IG: N=45, CG: N=47 Comparison: IG vs. CG, CT	IG: Paragraph on animal welfare, health, and environmental consequences of eating meat. CG: No intervention control.	Three weeks post-intervention, participants reported whether they intended to reduce meat consumption in the future on a scale from 1 (fully disagree) to 9 (fully agree).	Intention to eat less meat did not differ between the IG (M=7.20) and the CG (M=7.40, p>0.05)
Loy et al., 2016, Germany (232)	Sample size: IG: N=27 Comparison: Pre-post	IG: Paragraph on the environmental, ethical, health, and socio-political consequences of meat consumption including written instructions for mental contrasting and intention implementation.	Meat consumption (in g/d) was assessed using a 7-day diary the week pre- and the fourth week post-intervention	Meat consumption decreased significantly from pre- to post-intervention (average reduction: M=50.3 g/d, p<0.001, d=1.18).

Loy et al., 2016, Germany (232)	Sample size: IG: N=28 Comparison: Pre-post	IG: Paragraph on the environmental, ethical, health, and socio-political consequences of meat consumption.	Participants' consumption of meat in g/day way assessed using a 7-day diary was assessed the week pre-and the fourth week post-intervention	Meat consumption decreased significantly from pre- to post-intervention (average reduction: M=27.0g/d, p=0.001, d=0.63)

M=Mean, SD=Standard deviation, SE=Standard error, IG=Intervention group, CG=Control group, CI=Confidence interval, OR=Odds ratio.

Table 2.8: Impact of interventions targeting conscious determinants of human behaviour on secondary psychosocial outcomes

Paper	Comparison	Intervention	Outcome	Results
Information about the health consequences of eating meat				
Fehrenbach, 2013, USA (217)	IG vs CG, RCT	IG: A webpage on the health impact of eating meat, recommending practical strategies to eat less meat. CG: A webpage about the Rolling Stones.	Attitudes towards cutting out meat once a week were measured directly at post-intervention on four scales from 1 (negative) to 5 (positive).	Attitudes towards cutting out meat once per week were more positive in the IG (M=3.85) than in the CG (M=3.22, p<0.001).
Fehrenbach, 2015, USA (218)	IG vs CG, RCT	IG: A 4' video about the health impact of eating meat, highlighting participants' susceptibility to these outcomes. CG: No intervention.	Attitudes towards eating less meat were measured using seven 5-point scales, with higher values indicating more positive attitudes. Attitudes were measured directly post-intervention, and a week post-intervention.	Compared to the CG (M=3.16,) attitudes towards eating less meat were more positive in the IG directly post-intervention (M=3.84, p<0.001) and one week post-intervention (CG: M=3.10, IG: M=3.68, p<0.001).
Fehrenbach, 2015, USA (218)	IG vs CG, RCT	IG: A 7' video about the negative health outcomes of eating meat, highlighting participants' susceptibility to these outcomes, the health benefits of low meat diets, and strategies to eat less meat. CG: No intervention.	Attitudes towards eating less meat were measured using seven 5-point scales, with higher values indicating more positive attitudes. Attitudes were measured directly post-intervention, and a week post-intervention.	Compared to the CG (M=3.16) attitudes towards eating less meat were more positive in the IG directly post-intervention (M=3.90, p>0.001) and one week post-intervention (CG: M=3.10, IG: M=3.78, p<0.001).
Scrimgeour, 2012, New Zealand (227)	Pre-post, CO	IG: Information paragraph on the health impact of eating less meat.	Attitudes towards eating meat were measured on 5 scales from 1 (negative) to 5 (positive) at the baseline and directly post-intervention.	Attitudes towards eating meat were more positive at the baseline (M≈3.72) than at post-intervention (M≈3.47, p<0.001, d=0.59).
Berndsen et al., 2005, Netherlands (Study 1) (224)	Pre-post	IG: Cognitively framed paragraph on the health impact of eating meat.	Attitudes towards meat were measured with six scales from 1 (negative) to 9 (positive) three weeks post-intervention.	Attitudes towards eating meat were more positive at the baseline (M=6.71) than at post-intervention (M=6.15). No p-value was reported.
Berndsen et al., 2005, Netherlands (Study 1) (224)	Pre-post	IG: Affectively framed paragraph on the health impact of eating meat.	Attitudes towards meat were measured with six scales from 1 (negative) to 9 (positive) three weeks post-intervention.	Attitudes towards meat became significantly less positive from pre- (M= 6.59) to post-intervention (M=5.31, p<0.001).

Information about the environmental consequences of eating meat				
Fehrenbach, 2013, Germany (217)	IG vs CG, RCT	IG: A webpage on the environmental impact of eating meat, recommending practical strategies to eat less meat. CG: Control web-site on the Rolling Stones.	Attitudes towards cutting out meat once a week were measured directly at post-intervention on four scales from 1 (negative) to 5 (positive).	Attitudes towards cutting out meat once per week were more positive in the IG (M=3.68) than in the CG (M=3.22, p<0.01).
Graham, 2017, New Zealand (219)	IG vs CG, RCT	IG: A self-transcendent framed paragraph on the livestock related GHG emissions in NZ and the mitigation potential of reduced consumption.	Attitudes towards eating meat weekly were assessed directly post-intervention on six 7-points scales, with higher value indicating more positive attitudes towards having meat.	Attitudes towards eating meat weekly did not differ between the CG (M=4.2) and the IG (M=4.2), or any other study group (p>0.05).
Graham, 2017, New Zealand (219)	IG vs CG, RCT	IG: A self-enhancement framed paragraph on the livestock related GHG emissions in NZ and the mitigation potential of reduced consumption.	Attitudes towards eating meat weekly were assessed directly post-intervention on six 7-points scales, with higher value indicating more positive attitudes towards having meat.	Attitudes towards eating meat weekly did not differ between the CG (M=4.2) and the IG (M=4.2), or any other study group (p>0.05).
Scrimgeour, 2012, New Zealand (227)	Pre-post, CO	IG: Information paragraph on the environmental impact of eating meat and strategies to reduce consumption.	Attitudes towards eating meat, measured on 5 scales from 1 (negative) to 5 (positive), at the baseline and directly post-intervention.	Attitudes towards eating meat were more positive at the baseline (M≈3.72) than at post intervention (M≈3.48, p<0.001, d=0.62)
Information on meat consumption and animal welfare				
Scrimgeour, 2012, New Zealand (227)	Pre-post, CO	IG: Information paragraph on the animal welfare implications of eating meat and strategies to eat less.	Attitudes towards eating meat, measured on 5 scales from 1 (negative) to 5 (positive) at the baseline and directly post-intervention.	Attitudes towards eating meat were more positive at the baseline (M≈3.72) than at post-intervention (M≈3.4, p<0.001, d=0.65)
Information about the socio-political antecedents and consequences of meat consumption				
Allen et al., 2002, Australia (223)	IG vs CG, CT	IG: Participants were informed that people higher in social dominance eat more meat and less vegetable, while people lower in social dominance do the opposite. CG: No intervention.	Attitudes towards red and white meat were assessed directly post-intervention on a scale from 1 ('bad') to 7 ('good').	Participants with low social dominance orientation (SDO) in the IG had significantly less positive attitudes towards meat (M=4.58) than the CG (M=5.26, p<0.01). This effect did not emerge for participants with high SDO.
Information about multiple consequences of eating meat				
Arndt (study 1), 2016, USA (212)	IG vs CG, RCT	IG: Paragraph on the impact of meat consumption of an average American on health, and personal finances, and animal	Attitudes towards eating meat were assessed directly post-intervention with a scale from 1	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.38) and CG

		welfare, and the environment, and personal appearance. CG: No intervention.	("eating meat is bad") to 7 ("eating meat is good").	(M=5.80), or among any other study groups (p=0.27).
Arndt (study 2), 2016, USA (212)	IG vs CG, RCT	IG: Paragraph on the impact of meat consumption on health, and personal finances, and animal welfare, and the environment, also stating that eating less meat can help fulfil one's altruistic duty. CG: No intervention.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=4.97) and CG (M=5.90), or among any other study groups (p=0.16).
Arndt (study 2), 2016, USA (212)	IG vs CG, RCT	IG: Paragraph on the impact of meat consumption on health, and personal finances, and animal welfare, and the environment, also stating that eating less meat could help fulfil one's personal (egoistic) objectives. CG: No intervention.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.16) and CG (M= 5.90), or among any other study groups (p=0.16).
Arndt (study 2), 2016, USA (212)	IG vs CG, RCT	IG: Paragraph on the impact of meat consumption on health, and personal finances, and animal welfare, and the environment. CG: No intervention.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.20) and CG (M= 5.90), or among any other study groups (p=0.16).
Berndsen et al., (study 2), 2005, Netherlands (224)	IG vs. CG, CT	IG: Paragraph on animal welfare, and health, and environmental impact of eating meat. CG: No intervention control.	Attitudes towards meat measured with six scales from 1 (negative) to 9 (positive), three weeks post-intervention.	From pre- to post-intervention, attitudes towards meat did not change in a different way between IG and CG (Interaction for time x condition: p<0.09).
Tailored information provision				
Arndt (study 1), 2016, USA (212)	IG vs CG, RCT	IG: Tailored paragraph on how strongly a participant's personal levels of meat consumption affect their health, or personal finances, or animal welfare, or environment, or personal appearance depending on which consequence participants valued. CG: No intervention.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.27), and CG (M= 5.80), or among any other study groups (p=0.27).
Arndt (study 1), 2016, USA (212)	IG vs CG, RCT	IG: Tailored paragraph on how strongly a participant's personal levels of meat consumption affect their health, and personal finances, and animal welfare, and the environment, and personal appearance.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.24) and CG (M=5.80), or among any other study groups (p=0.27).

		CG: No intervention.		
Arndt (study 1), 2016, USA (212)	IG vs CG, RCT	IG: Tailored paragraph on the consequences of an average American's meat consumption on health, or personal finances, or animal welfare, or the environment, or personal appearance, depending on which consequence participants valued. CG: No intervention.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.78) and CG (M=5.80), or among any other study groups (p=0.27).
Arndt, (study 2), 2016, USA (212)	IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, or personal finances, or animal welfare, or the environment, depending on which consequence participants valued. The message stated that eating less meat is congruent with being responsible, or adventurous, or logical, or compassionate depending on participants' self-schema. CG: No intervention.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.47) and CG (M= 5.90), or among any other study groups (p=0.16).
Arndt, (study 2), 2016, USA (212)	IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, and personal finances, and animal welfare, and the environment. The message stated that eating less meat is congruent with being responsible, or adventurous, or logical, or compassionate depending on participants' self-schema. CG: No intervention.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.10) and CG (M=5.90), or among any other study groups (p=0.16).
Arndt, (study 2), 2016, USA	IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, or personal finances, or animal welfare, or the environment, depending on which consequence participants valued. The message stated that eating less meat can help fulfil one's altruistic duty. CG: No intervention.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.18) and CG (M=5.90), or among any other study groups (p=0.16).
Arndt, (study 2), 2016, USA (212)	IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, or personal finances, or animal welfare, or the environment, depending on which consequence participants valued. The message	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.34) and CG (M= 5.90), or among any other study groups (p=0.16).

		stated that eating less meat can help fulfil one's personal (egoistic) objectives. CG: No intervention.		
Arndt, (study 2), 2016, USA (212)	IG vs CG, RCT	IG: Tailored paragraph on the consequences of meat consumption on health, or personal finances, or animal welfare, or the environment, depending on which consequence participants valued.	Attitudes towards eating meat were assessed directly post-intervention on a scale from 1 ("eating meat is bad") to 7 ("eating meat is good").	Adjusted for baseline attitudes, post-intervention attitudes towards eating meat did not differ between IG (M=5.62) and CG (M= 5.90), or among any other study groups (p=0.16)
Self-monitoring and goal setting interventions				
Carfora et al., 2017; Italy (213)	IG vs CG, RCT	IG: Daily text messages for a week, encouraging participants to self-monitor their consumption of processed meat and to 'think about the regret they could experience' if they were to exceed the recommended levels of processed meat consumption (50g/d). CG: No intervention.	Affective and instrumental attitudes towards eating ≤1 portion of processed meat in the upcoming week were measured with three items on a scale from 1 (negative) to 7 (positive). Perceived behavioural control (PBC) of eating ≤1 portion of processed meat in the upcoming week was measured with seven items on a scale from 1 (low) to 7 (high). Subjective social norms (SSN) of eating ≤1 portion/w of processed meat was measured with three items on a scale from 1 (low) to 7 (high). All outcomes were assessed directly post-intervention.	The IG reported more positive instrumental attitudes (M=6.03) than the CG (M=5.22 p<0.004, d=0.63). There were no difference in affective attitudes between the IG (M=4.23) and the CG (M=4.28, p>0.05). PBC did not differ between the CG (M=4.54) and the IG (M=4.63, p>0.05). SSN did not differ between the CG (M=3.74) and the IG (M=3.93, p>0.05).
Carfora et al., 2017, Italy (214)	IG vs CG, RCT	IG: Daily text messages for a week, encouraging participants to self-monitor their consumption of red meat to not exceed a recommended maximum of two medium servings per week. CG: No intervention.	Affective and instrumental attitudes towards eating <2 medium red meat portions/w in the upcoming week were measured with three items on a scale from 1 (negative) to 7 (positive). PBC of not eating <2 medium red meat portions/w in the upcoming week was measured with seven items on a scale from 1 (low) to 7 (high). SSN of eating <2 medium red meat portions/w was measured with three items on a scale from 1 (low) to 7 (high). All outcomes were assessed directly post-intervention.	The IG reported more positive instrumental attitudes (M= 5.86) than the CG (M=5.09, p<0.001, d=0.67). There were no difference in affective attitudes between the IG (M= 4.45) and the CG (M= 4.46, p>0.05). PBC was higher in the IG (M=5.23) compared to the CG (M=4.09, p<0.05, d=0.29). SSN did not differ significantly between the CG (M=3.98) and the IG (M=4.10, p>0.05).

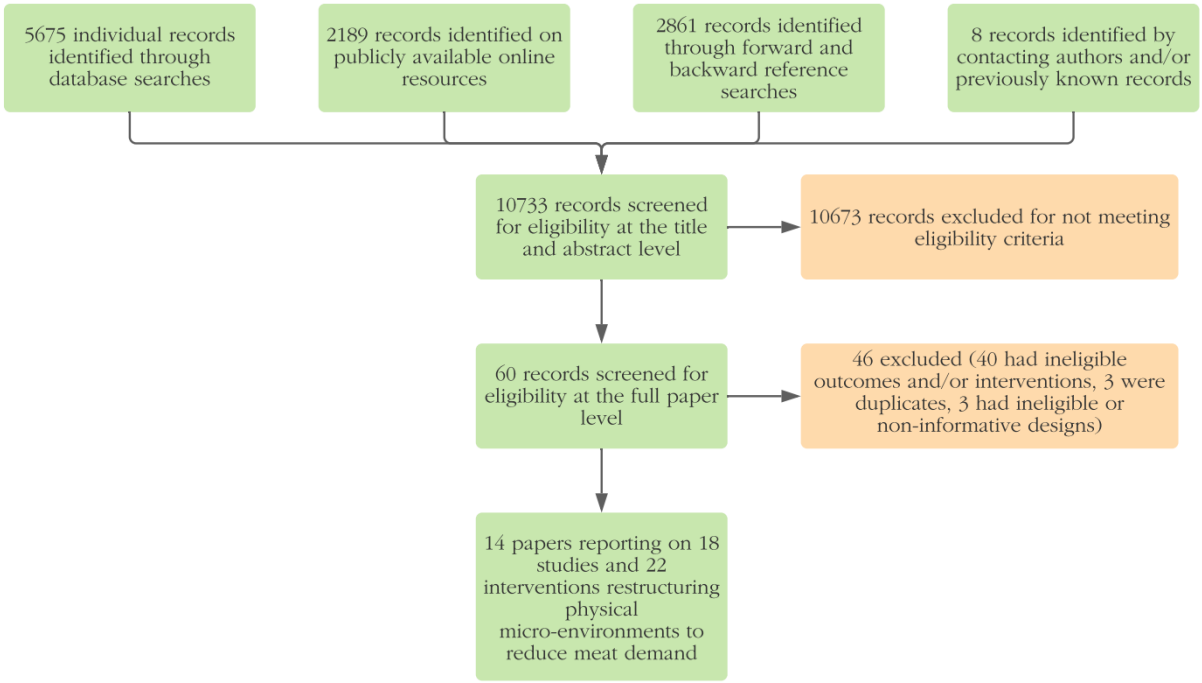
M=Mean, SD=Standard deviation, SE=Standard error, IG=Intervention group, CG=Control group, CI=Confidence interval, OR=Odds ratio.

5. Results: interventions restructuring physical micro-environments

5.1 Study selection

In the second review, I included 14 papers reporting on 18 studies and 22 interventions restructuring physical micro-environments to reduce meat demand (Fig. 2.4).

Fig. 2.4: Study selection process for the second review for interventions restructuring physical micro-environments



5.2 Study characteristics

Of the 18 studies I included, the methodological quality was strong in three, medium in eleven, and low in four. Twelve studies employed a parallel, crossover, or factorial randomised controlled trial (RCT, C-RCT, F-RCT respectively), three employed a multiple treatment reversal design (MTR), and three employed a pre-post design (PP). Thirteen studies recruited at the individual level, four recruited canteens or restaurants, and one recruited small businesses.

All studies analysed data at the level of individuals or individual food purchases. Six studies reported data on meat consumption, five reported data on meat purchases/selection, and seven reported data

on meat purchases/selection in virtual settings. Additionally, four studies reported on attitudes towards eating meat and three studies reported on at least one pre-specified biomarker of health risk. This review included 11,290 observations on individuals, individual food purchases, or individual questionnaire responses at the follow-up closest to the intervention completion. Where reported, mean age in years ranged from 20 to 52 (median=34) and the proportion of female participants ranged from 0% to 84% (median=53%). Table 2.9 summarises the study-level characteristics.

Of 22 interventions, three reduced meat portions in restaurants or in laboratory settings; three provided free meat alternatives to free living individuals; four altered the visual aspect or the hedonic appeal of meat or meat alternatives; four repositioned meat products to reduce their prominence at point-of-purchase; five manipulated menus and meal booking systems by changing the verbal description or label of meat or meat alternatives; one employed a pricing intervention; and two changed multiple elements of a university canteen and of small businesses (Table 2.10). Results pertaining to secondary psycho-social outcomes and biomarkers of health risk are summarized in tables 2.13 and 2.14.

Table 2.9: Study-level characteristics for reports evaluating interventions restructuring physical micro-environments

Study	Eligibility	Recruitment	Attrition & sample size a	Publication status	*EPHPP QATQS* b
Randomised Controlled Trial (RCT) c					
Bacon et al., 2018, UK (236)	Individuals had to be resident in the UK, have English as their first language, and not follow a diet precluding the choice of meat.	Individuals were recruited through the Prolific Academic research platform.	T1: N=564, attrition=N/Ad	Peer reviewed publication	Medium
Kongsbak et al., 2016, Denmark (237)	Individuals had to be male university students and be between 18 and 29 years old.	Individuals were recruited through advertisement on social media and on Aalborg University campus.	T1: N=65, attrition=0%	Peer reviewed publication	Medium
Kunst et al., 2016, Study 2b, Norway (238)	Individuals had to be US Americans.	Individuals were recruited through Amazon MTurk.	T1: N=101, attrition= N/Ad	Peer reviewed publication	Low
Kunst et al., 2016, Study 5, Norway (238)	N/A	Individuals were recruited through Amazon MTurk.	T1: N=190, attrition= N/Ad	Peer reviewed publication	Low
Kunst et al., 2018 (American sample), Norway (239)	Individuals had to be US Americans who consume meat and be 18+ years old.	Individuals were recruited through Amazon MTurk.	T1: N=178, attrition=N/Ad	Peer reviewed publication	Low
Kunst et al., 2018, (Ecuadorian sample), Norway (239)	Individuals had to be Ecuadorians who consume meat and be 18+ years old.	Individuals were recruited through snowball sampling on social networks.	T1: N=183, attrition= N/Ad	Peer reviewed publication	Low
McClain et al., 2013, USA (240)	Individuals had to be 18 to 23 years old, have a meal plan with the residence's dining hall, and eat at the dining hall at least 3 days/week.	A convenience sample was recruited approaching students who used one of the 4 participating cafeterias.	T1: N=525 (individual responses), attrition=N/A	Peer reviewed publication	Strong

Sorensen et al., 2005, USA (241)	Small businesses had to be manufacturing industries with 50 to 150 employees, with at least 25% of workers being first- or second-generation immigrants or people of colour, a turnover rate during the past year of less than 20%, and the capacity to decide to participate.	Eligible small business were actively approached and asked to participate.	T1: N=1740 (individual responses), attrition=N/A (8% of worksites withdrew)	Peer reviewed publication	Medium
Vermeer et al., 2009, Netherlands (242)	Individuals had to be 18+ years old.	Individuals visiting a Dutch fast food were approached and asked to participate in the study after they made their purchase.	T1: N=137, attrition=9%	Peer reviewed publication	Medium
Crossover Randomised Controlled Trial (CO-RCT) c					
Reinders et al., 2017, Netherlands (243)	Individual meals had to be of the relevant menu items (e.g. exclusion of vegetarian meals, child menus, and special offerings), coming from parties with fewer than 12 orders, and from customers who completed the questionnaires.	All eligible individual orders placed during the study period in participating restaurants were recorded. Restaurants were actively approached for recruitment.	T1: N=1006, attrition=N/A	Peer reviewed publication	Strong
Rolls et al., 2010, USA (244)	Individuals had to be 20 to 45 years old, have a BMI between 18 and 40, regularly eat 3 meals/d, like and be willing to eat all 3 foods served in the test meals. Individuals were excluded if they were dieting, had food allergies or restrictions, taking medications known to affect appetite, smokers, athletes in training, pregnant or breastfeeding, had symptoms of depression, or had disordered attitudes towards food.	Individuals were recruited through advertising in local newspapers and university mailing lists.	T1: N=48, attrition=0%	Peer reviewed publication	Medium
Factorial Randomised Controlled Trial (F-RCT) c					
Campbell-Arvai et al., 2014, USA (245)	Undergraduate students living on campus.	Individuals were actively approached and invited to take part in the experiment upon entering the dining facilities on campus.	T1: N=319, attrition=0%	Peer reviewed publication	Medium
Multiple Treatment Reversal (MTR) c,e					
Stewart, 2016, Study 1, UK (246)	University dining halls with appropriate booking systems.	The staff of eligible University dining halls was actively approached. All bookings placed during the study were recorded.	T1: N=5280 (individual orders), attrition=N/A	Unpublished	Medium

Stewart, 2016, Study 2, UK (246)	University dining halls with appropriate booking systems.	The staff of eligible University dining halls was actively approached. All bookings placed during the study were recorded.	T1: N=782 (individual orders), attrition=N/A	Unpublished	Medium
Stewart, 2016, Study 3, UK (246)	University dining halls with appropriate booking systems.	The staff of eligible University dining halls was actively approached. All bookings placed during the study were recorded.	T1: N=61 (individual orders), attrition=N/A	Unpublished	Medium
Pre-Post Design (PP) c					
Clark, 2017, UK (247)	Individuals had to be of between 21 and 50 years old, have a BMI of 18 to 28, be healthy men or females (premenopausal), have good spoken and written English, consume 4-5 portions of red and/or processed meat per week, not smoke, not have a chronic disease; not be pregnant or breast feeding; not use chronic medication (excluding over-the-counter medication & oral contraceptives), not have participated in other research three months prior to the screening, not have clinically significant findings at screening.	Individuals were recruited through advertising in newspapers, on social media pages, and in different online and offline facilities of the University of Nottingham.	T1: N=26, attrition=39.5% T2: N=22 attrition=48.8%	Unpublished	Medium
Flynn et al., 2013, USA (248)	Individuals had to have access to transportation to attend study activities, be willing to try new recipes, and be contactable by telephone.	Individuals were recruited through advertisement in and referral from emergency food pantries.	T1: N=63, attrition=26%	Peer reviewed publication	Strong
Holloway, 2012, UK (249)	Individuals had to consume meat at least 4-5 times weekly, be 18 to 30 years old, not take regular meals in hall of residence and/or not live with parents or partners, be free of chronic disease, have a BMI of 22 to 27.	Individuals were recruited through a brief advertising presentation to ≈350 students in Nottingham University.	T1: N=19, attrition=27%	Unpublished	Medium

(a) T1 and T2 respectively refer to the shortest and longest available post-intervention follow-up. This information refers to the data underlying the analyses of meat demand.
(b) The EPHPP QATQS rating is based on: (1) study design, (2) selection bias, (3) confounders, (4) blinding, (5) data collection method, (6) withdrawal and dropouts. Studies with 2+ weak ratings in the aforementioned dimensions are assigned a 'low' overall rating, studies with 1 weak rating are assigned a 'medium' overall rating, and studies with no weak ratings are assigned a 'strong' overall rating.
(c) The study design refers to the design underlying the main comparison reported in this review.
(d) These studies employed a one-off survey with an experimental component and may only have sourced data from participants who started and completed the survey. For these studies we consider attrition to be unknown.
(e) Multiple treatment reversal (MTR) designs are experimental studies in which intervention periods and control periods are sequentially alternated over an extended period of time.

5.3 Interventions' impact on the demand for meat

5.3.1 Reducing portion sizes

Two crossover RCTs found that all three interventions reducing the portion size of meat servings significantly reduced meat consumption in real restaurant settings (243) and in laboratory settings (244). In the laboratory study, reducing the portion size of meat servings by 13.5% or by 33.5% led to lower meat intakes compared to a reference meal containing 281g of meat, but participants' meat consumption did not differ between the two intervention meals with reduced meat portions. (244) Across all meals served as part of this study, participants' average meat intake never reached the maximum amount of meat served.

5.3.2 Providing meat alternatives

In three pre-post studies, all three interventions providing meat alternatives were associated with significant reductions in meat purchases or consumption. (247–249) Two such interventions provided meat-free or meat-reduced alternatives, such as mycoprotein products, to replace meat products for four or twelve weeks, (247,249) while the third intervention provided more general plant-based foods as part of a six-week plant-based cooking demonstration programme. (248) All interventions included motivational, educational, and training components to encourage reductions in the demand for meat. (247–249) In two studies with prolonged follow-up, there was some evidence to suggest that several weeks after the supply of plant-based alternatives had stopped, demand for meat remained lower than at the baseline (247,248).

5.3.3 Manipulating sensory properties

Four RCTs (N=3 RCT, N=1 F-RCT) suggested that three of four interventions manipulating the sensory properties of meat or meat alternatives significantly reduced the demand for meat in virtual food choices. Replacing the vegetarian items on a food menu with alternative vegetarian items previously rated as more appealing by people other than study participants significantly reduced

participants' demand for meat. (245) Manipulating the visual properties of a pork-roast image to also display the animal's head led to greater demand for a plant-based alternatives in 2 out of 3 RCTs of this intervention. (238,239)

5.3.4 Positioning

Four studies (N=1 RCT, N=1 F-RCT, N=2 MTR) evaluated four interventions repositioning meat products to decrease their prominence at point-of-purchase. Two such interventions reduced or were associated with reductions in meat demand in a MTR study (246) and a F-RCT study. (245) These interventions respectively repositioned meat options to appear after, rather than before, vegetarian options in online meal booking systems (i.e. online platforms typically used to allow students to select among different meal options in University canteens), (246) or repositioned meat options from standard food menus onto a board 3.5m away from participants in a simulated canteen setting. (245) Two further interventions displaying vegetarian options as the default option of an online meal booking systems or repositioning a meat product from the middle to the end of a buffet aisle were associated with reductions in meat demand, but did not reach statistically significant effects in a RCT (237) and in a MTR study. (246)

5.3.5 Labelling and manipulating point-of-purchase descriptions

Four studies (N=2 RCT, N=1 F-RCT, N=1 MTR) evaluated five interventions manipulating food menus or meal booking systems to encourage meat-free purchases by changing the verbal description or label of meat or meat alternatives, without changing the actual sensory properties of these products. One intervention altering University meal booking systems to refer to meat options as 'meat' rather than 'standard' or 'normal' was associated with reduced meat purchases in a MTR study. (246) Conversely, interventions manipulating virtual food menus to enhance the verbal description of meat-free options, (236) labelling vegetarian options as environmentally sustainable, (245) or

highlighting the animal origin of meat products by referring to 'beef and pork dishes' as 'cow and pig dishes' (238) were not found to reduce meat demand in randomised trials. (N=2 RCT, N=1 F-RCT)

5.3.6 Pricing

One RCT found no evidence to suggest that changing the price structure of three different portions of chicken nuggets ('small', 'medium', 'large') from a value pricing system (i.e. decreasing price/unit with increasing portion size) to a proportional system (i.e. stable price/unit across portion sizes) effectively promoted purchases of smaller portions in a simulated food choice task. (242)

5.3.7 Multicomponent changes to micro-environments

Two RCTs assessed two interventions restructuring several elements of the physical micro-environment. (240,241) A marketing campaign in university canteens, featuring examples of meat-free dishes at the canteens' entrance, indicators of healthy meat-free options, and educational flyers reduced meat consumption. (240) Conversely, there was no evidence that an 18-month multicomponent intervention targeting red meat consumption and other health behaviours reduced meat consumption in small businesses. (241) In this intervention, staff of the participating worksites collaborated with an expert to plan individual level and environmental level interventions to promote lower meat intakes and other health behaviours. Examples included 'policies aimed at offering healthful food options at company meetings and events', (241) but the specific changes to the physical micro-environment targeting red meat were not reported in detail, precluding more detailed analyses.

Table 2.10: Impact of interventions restructuring physical micro-environments

Paper	Sample characteristics and study comparison	Intervention	Outcome	Results
Provision of meat-substitutes and meat-free foods				
Clark, 2017 (247)	Sample size: IG: N=26 (T1), N=22 (T2) Age: Median=27 (25th-95th%: 24-32) (a) Female: 57% (a) Comparison: Pre-post	IG: 12 week intervention. Provision of meat-substitutes, plant-based recipes, monthly motivational newsletter and e-mails. Participants were asked to reduce consumption of red and processed meat by 50%.	Red and processed meat consumption frequency (servings/w) during the pre-intervention month, the last intervention month, and 2 months post-intervention, assessed with a Food Frequency Questionnaire (FFQ).	Red and processed meat consumption was lower during the last intervention month (median=4, range: <1-10) and 2 months post-intervention (average=6, range: 1-14) than at the baseline (median=10, range: 2-20, respectively $p<0.001$).
Flynn et al., 2013 (248)	Sample size: IG: N=63(b) Age: M=52, SD=17 Female: 84% Comparison: Pre-post	IG: Six week intervention. Provision of 22 plant-based recipes, sufficient meat-free foods to prepare 3 of the 22 recipes, weekly 30' plant-based cooking demonstrations and taster sessions, information that consuming meat daily is not necessary for health.	Purchase of meat products (dollars spent on meat/w) during the 4 weeks pre-intervention and the 6 months post-intervention, assessed reviewing grocery receipts.	The dollars/w spent on meat declined from the baseline (M=16.45, SD=2.20) to post-intervention (M=7.54, SD=0.71, $p<0.001$)
Holloway et al., 2012 (249)	Sample size: IG: N=19 Age: M=21, SD=3 (c) Female: 60% (c) Comparison: Pre-post	IG: 4 week intervention. Provision of meat-substitutes, 60' information-based motivational event about vegetarianism, 4 face-to-face sessions to motivate lower meat intakes, plant-based recipes, information about vegetarianism.	Red and white meat consumption (g/d), assessed using a 7 days food diary pre-intervention and during the 4*th* intervention week.	Red and white meat consumption was lower during the 4*th* intervention week (Mred≈27, Mwhite≈15) than at the baseline (M red≈78, $p<0.001$; Mwhite≈61, $p<0.001$). (d)
Downsizing meat portions				
Reinders et al., 2017 (243)	Sample size (meal orders): Intervention: N=470, control: N=536 Age: M=48.6, SD=17.5 Female: 54% Comparison: Crossover, RCT	Intervention: For 6 weeks the portion of meat (and fish) of selected meals was reduced by 12.5% and the portion of vegetables was doubled in 3 restaurants. Control: 6 weeks of business as usual in the 3 restaurants.	Meat consumption assessed subtracting the grams of meat returned to the kitchen from the average grams of meat in each of the targeted dishes.	Meat consumption from the selected dishes was significantly lower during the intervention (M=183.1, SE=2.52) than during the control period (M=211.1; SE=2.29, $p<0.001$, $\eta p2=0.064$).
Rolls et al., 2010 (244)	Sample size: N=48 Age: M=27	In a laboratory setting, participants were served a meal in which the meat component was reduced to	Meat consumption (in g), measured at each meal occasion weighing the	Meat consumption was lower during the intervention meals

	Female: 50% Comparison: Crossover, RCT	243g, the grain component was reduced to 272g, while the vegetable component was increased to 270g, compared to a reference meat with 281g meat, 180g vegetables, and 326g grains. (e)	meat serving before and after consumption.	(M=126.8, SD=48) than during the control meals (M=145.4, SD=53.3, p<0.0001).
Rolls et al., 2010 (244)	Sample size: N=48 Age: M=27 Female: 50% Comparison: Crossover, RCT	Intervention meal: In a laboratory setting, participants were served a meal in which the meat component was reduced to 187g, the grain component was reduced to 217g, while the vegetable component was increased to 360g, compared to a reference meal with 281g meat, 180g vegetables, and 326g grains. (e)	Meat consumption (in g), measured at each meal occasion weighing the meat serving before and after consumption.	Meat consumption was lower during the intervention meals (M=125.2, SD=42) than during the control meals (M=145.4, SD=53.3, p<0.0001).
Manipulation of the sensory properties of meat or alternatives				
Kunst et al., 2016, Study 2b (238)	Sample size: N=101 Age: M=35, SD=11 Female: 60% Comparison: IG vs CG, RCT	IG: Participants viewed a picture of a pork roast with the pig's head. CG: Participants viewed a picture of a pork roast without the pig's head.	Participants indicated whether they would select a vegetarian dish instead of the pork roast on a scale from 0 (very unlikely) to (100 very likely).	The demand for a vegetarian dish did not differ between IG (M=52.00, SE=5.56) and CG (M=37.88, SE=5.11, p=0.065).
Kunst et al., 2018, American sample (239)	Sample size: N=178 Age: M=36, SD=11(f) Female: 42% (f) Comparison: IG vs CG, RCT	IG: Participants viewed a picture of a pork roast with the pig's head. CG: Participants viewed a picture of a pork roast without the pig's head.	Participants indicated whether they would select a vegetarian dish instead of the pork roast on a scale from 0 (very unlikely) to (100 very likely).	The demand for a vegetarian dish was higher in the IG (M≈56, SE≈4) than in theCG (M≈29, SE≈4, t(176)=5.22, p<0.001).
Kunst et al., 2018, Ecuadorian sample (239)	Sample size: N=183 Age: M=27, SD=9 (g) Female: 58% (g) Comparison: IG vs CG, RCT	IG: Participants viewed a picture of a pork roast with the pig's head. CG: Participants viewed a picture of a pork roast without the pig's head.	Participants indicated whether they would select a vegetarian dish instead of the pork roast on a scale from 0 (very unlikely) to (100 very likely).	The demand for a vegetarian dish was higher in the IG (M≈46, SE≈4) than in the CG (M≈33, SE≈45, t(181)=2.59, p=0.01).
Campbell-Arvai et al., 2014 (245)	Sample size: Factor: N=160, No factor: N=160 Age: N/A Female: 53% Comparison: Factor vs no factor, F-RCT	Factor (IG menus): Food menus including 5 appealing meat-free options and a range of non-vegetarian dishes. No factor (CG menus): Food menus including 5 less appealing meat-free options and a range of non-vegetarian dishes.	Simulated food choices were dichotomised in meat options vs. meat-free options.	Participants viewing IG menus had lower odds of selecting meat options than those viewing CG menus (OR=0.49, 95%CI= 0.36 to 0.66).
Repositioning of meat				
Kongsbak et al., 2015 (237)	Sample size: IG: N=33, CG: N=32 Age: M=24 Female: 0%	IG: Participants served themselves ad libitum from a buffet including, in order of appearance: (1) Standard size plates, (2) salad components served in separate bowls, (3) dressings, (4) pasta, (5) bread, and **(6)**	Selection of meatballs (in g) assessed using radio-frequency identification technologies of the 'intelligent buffet'.	Selection of meatballs did not differ significantly between the CG (M=194.6, SD=78.6) and the IG (M=156.2, SD=71.1,

	Comparison: IG vs CG, RCT	**meatballs**. CG: Participants served themselves ad libitum from a buffet including, in order of appearance: (1) Standard size plates, (2) pasta, (3) bread, **(4) meatballs**, (5) mixed salad (i.e. all the salad components served together), and (6) dressings.		*p*=0.078), after adjusting for BMI, age, and selection of salad, pasta, and bread.
Campbell-Arvai et al., 2014 (245)	Sample size: Factor: N=160, No factor: N=160 Age: N/A Female: 53% Comparison: Factor vs no factor, F-RCT	Factor (IG menus): Food menus from which the meat options were removed and repositioned on a board 3.5m away. No factor (CG menus): Food menus containing a range of meat-free and meat-based options.	Simulated food choices were dichotomised in meat options vs. meat-free options.	Participants viewing IG menus had lower odds of selecting meat options than those viewing CG menus (OR=0.24, 95%CI=0.18 to 0.36).
Stewart, 2016, study 2 (246)	Sample size: Orders during the intervention period: N=384 (N= 227 meat orders, N=157 meat-free orders) Orders during the control period: N=398 (N=346 meat orders, N=52 meat-free orders) Age: N/A Female: N/A Comparison: MTR	Intervention period: Meat options appeared after meat-free options in 2 University online meal booking systems over 3 observation weeks. Control period: Meat options appeared before meat-free options in 2 University online meal booking systems over 3 observation weeks.	Number of meat-containing meals (including fish) and meat-free meals purchased.	Adjusted for college site, meal purchases over the intervention period had 0.12 times the odds of containing meat compared to meals purchased over the control period (OR=0.12, 95%CI=0.08 to 0.18, *p*<0.001). (h) The likelihood of selecting a meat option was significantly higher in one of the two college's sites in which the intervention was tested.
Stewart, 2016, study 3 (246)	Sample size: Orders during the intervention period: N=31 (N=26 meat orders, N=5 meat-free orders) Orders during the control period: N=35 (N=30 meat orders, N=5 meat-free orders) Age: N/A Female: N/A Comparison: MTR	Intervention period: For 2 weeks meat-free options were repositioned to be the default option in a University online meal booking system. Students not actively changing their selection to the meat option were served a plant-based meal. Control period: For 2 weeks meat options were left as the default option in a University online meal booking system. Students not actively changing their selection to 'vegetarian' were served meat.	Number of meat-containing meals (including fish) and meat-free meals purchased.	Meal purchases over the intervention period had 0.87 times the odds of containing meat compared to meals purchased over the control period, but this effect did not reach statistical significance (OR=0.87, 95%CI=0.23 to 3.33, *p*=0.87). (h)
Manipulating the description or labelling meat or alternatives				
Bacon et al., 2016 (236)	Sample size: IG: N=185, CG: N=194 Age: M=36	IG: Food menu containing 3 meat and 5 meat-free options, in which the description of the first meat-free dish was changed from '*Risotto Primavera*' to *'Fresh*	Simulated food choices were dichotomised into meat options (chicken cacciatora, steak frites, or	The odds of selecting a meat options did not differ between the IG and the CG (OR=1.1,

	Female: 51% Comparison: IG vs CG, RCT	*Seasonal Risotto Primavera'*. CG: Food menu containing 3 meat and 5 meat-free options.	hamburger) vs. meat-free options	*p*=0.677).
Bacon et al., 2016 (236)	Sample size: IG: N=185, CG: N=194 Age: M=35 Female: 52% Comparison: IG vs CG, RCT	IG: Food menu containing 3 meat and 5 meat-free options, in which the first meat-free dish, i.e. a *'Risotto Primavera'*, was highlighted as the *'Chef's recommendation'*. CG: Food menu containing 3 meat and 5 meat-free options.	Simulated food choices were dichotomised into meat options (chicken cacciatora, steak frites, or hamburger) vs. meat-free options	The odds of selecting a meat-based meal did not differ between IG and CG (OR=1.37, *p*=0.180).
Kunst et al., 2016, Study 5 (238)	Sample size: N=190 Age: M=34, SD=10 Female: 52% Comparison: IG vs CG, RCT	IG: Food menu with 8 meat-based meals, which were described as *'cow'* and *'pig'* options. CG: Food menu with 8 meat-based meals, which were described as *'beef'* and *'pork'* options.	Participants indicated whether they would select a meat-free meal instead of the meat options on a scale from 0 (very unlikely) to (100 very likely).	The demand for meat-free meals did not differ between the IG (M=43.12, SE=3.84) and the CG (M=33.78, SE=3.49, *p*=0.074).
Campbell-Arvai et al., 2014 (245)	Sample size: Factor: N=160, No factor: N=160 Age: N/A Female: 53% Comparison: Factor vs no factor, F-RCT	Factor (IG menus): Food menus containing a range of meat-based options and meat-free options which were differentiated with a leaf symbol indicating that eating less meat can help reduce our environmental impact. No factor (CG menus): Food menus containing a range of meat-free and meat-based options.	Simulated food choices were dichotomised into meat options vs. meat-free options.	The odds of selecting a meat-based dish did not differ between participants viewing the IG or the CG menus (OR=0.92, 95%CI=0.69 to 1.2)
Stewart, 2016, Study 1, (246)	Sample size: Orders during intervention period: N=2784 (N=2373 meat orders, N=411 meat-free orders); Orders during control period: N=2496 (N=2177 meat orders, N=319 meat-free orders) Age: N/A Female: N/A Comparison: MTR	IG period: Meat options were labelled as 'meat' instead of 'standard'/'normal' in 4 University online meal booking systems over 12 observation weeks. CG period: Meat options were labelled as 'standard'/'normal' in 4 University online booking systems over 12 observation weeks.	Number of meat-containing meals (including fish) and meat-free meals purchased.	Adjusted for college site, meal purchases over the IG period had 0.83 times the odds of containing meat compared to meals purchased over the CG period (OR=0.83, 95%CI=0.71 to 0.98, *p*=0.02).(h) The likelihood of selecting a meat option was significantly higher in some colleges compared to others.
Pricing				
Vermeer et al., 2009 (242)	Sample size: N=137 Age: M=25 SD=10 Female: 66% Comparison: IG vs CG, RCT	IG: Three portions of chicken nuggets were priced with a proportional system: €2.35 for a small portion, €3.50 for a medium portion, €5.80 for a large portion.	Simulated selection of small, medium, or large portion of nuggets was dichotomised in 'small vs other' and in 'large vs other'.	Authors found no effect of pricing on the selection of different portions sizes among the general population.

		CG: Three portions of chicken nuggets were priced with a value system: €2.75 for a small portion, €3.50 for a medium portion, €5.00 for a large portion.		
Multicomponent changes to the microenvironment				
McClain et al., 2013 (240)	Dining halls: IG: N=2, CG: N=2 Questionnaire responses: IG: N=247; CG: N=278 (i) Age: 20 Female: 53% Comparison: IG vs CG, RCT	IG: Four weeks marketing campaign, featuring, flyers, labels, healthy choice indicators of meat-free foods, and sample meat-free dishes at the entrance of the canteen. CG: Four weeks of business as usual.	Consumption frequency of high-fat meats (in servings/w) assessed at the baseline and directly after the intervention with a FFQ.	In the CG high-fat meat intake increased by 0.9 servings/w, while it decreased by 0.9 servings/w in the IG (time x condition interaction: p=0.04)
Sorensen et al., 2015 (241)	Small businesses: IG: N=13, CG: N=13 Questionnaire responses: IG: N=807, CG: N=933 (i) Age (adjusted for worksite clustering): IG=44, CG=43 Female: 33% Comparison: IG vs CG, RCT	IG: 18 month multicomponent intervention to reduce red meat intake and smoking and to increase physical activity, fruit, vegetables, and multivitamin intake. Specific interventions were designed within each worksite under the advice of a hygienist, and could have included policies aimed at offering healthful food options at company meetings, system oriented interventions, interactive activities, and education. CG: Smoking cessation services.	Consumption frequency of red meat (in servings/w) assessed with a food frequency questionnaire at the baseline and directly post-intervention. Responses were dichotomised in ' ≤3 servings/w' vs '>3 servings/w'.	The change in percentage of participants eating ≤3 servings/w of red meat did not differ between IG (+4.1%) and CG (+3%) after adjusting for worksite clustering (p=0.72).

M=Mean, SD=Standard deviation, SE=Standard error, IG=Intervention group, CG=Control group, CI=Confidence interval, OR=Odds ratio. (a) Baseline characteristics of the N=37 participants completing some secondary outcomes extracted from the doctoral thesis on which the study is based. (b) Only N=60 participants provided a complete set of grocery receipts at both time points. (c) Of the N=25 participants recruited at baseline. (d) Results were based on an independent sample t-test, while a dependent sample t-test should be employed for pre-post designs. (e) Both control and intervention meals were served to each participant on two different occasions varying the energy content of the vegetable component. For the aim of this review participants' average consumption was defined as their average consumption across the two energy-varied meals. (f) Of the 201 participants enrolled. (g) Of the 202 participants enrolled. (h) A logistic regression analysis was conducted based on raw data available from the unpublished report. (i) Questionnaires were not always completed by the same individuals at baseline and at follow-up.

5.4 Qualitative Comparative Analysis

Twenty-one intervention conditions were included in QCA. Three configurations of intervention characteristics were associated with significant reductions in meat demand among at least 75% of three or more evaluations (Table 2.11). These configurations cover 69% of the 13 interventions associated with significant reductions in meat demand.

Table 2.11: Configuration of intervention components associated with significant reductions in meat demand for interventions restructuring physical micro-environments

	Provision of meat alternatives and education Raw coverage: 23%, Internal consistency: 100%
Outcome:	(1) Reduction in actual consumption, purchase, or selection of meat
In the presence of:	(2) Provision of meat alternatives, (3) education and/or training components
In the absence of:	(4) Reducing meat portions, (5) manipulating the description/label of meat or alternatives, (6) manipulating the sensory properties of meat or alternatives (7) repositioning meat products, (8) pricing, and (9) multiple physical changes to the micro-environment
	Reduction of meat portions Raw coverage: 23%, Internal consistency: 100%
Outcome:	(1) Reduction in actual consumption, purchase, or selection of meat
In the presence of:	(2) Reducing meat portions
In the absence of:	(3) Provision of meat alternatives, (4) manipulating the description/label of meat or alternatives, (5) manipulating the sensory properties of meat or alternatives (6) repositioning meat products, (7) pricing, (8) multiple physical changes to the micro-environment, and (9) education and/or training components
	Manipulating the sensory properties of meat or alternatives Raw coverage: 23%, Internal consistency: 75%
Outcome:	(1) Reduction in the purchase or selection of meat in virtual settings
In the presence of:	(2) Manipulating the sensory properties of meat or alternatives
In the absence of:	(3) Provision of meat alternatives, (4) reducing meat portions, (5) manipulating the description/label of meat or alternatives, (6) repositioning meat products, (7) pricing, (8) multiple physical changes to the micro-environment, and (9) education and/or training components

Configuration of intervention components associated with significant reductions in meat demand. The overall solution coverage was 69%, i.e. 69% of all interventions associated with significant reductions in meat demand are covered by one of the intervention configurations above. The overall solution consistency was 90%, i.e. 90% of all interventions covered by the configurations above are associated with significant reductions in meat demand. Raw coverage refers to the percentage of all interventions associated with significant reductions in meat demand that are covered by a specific intervention configuration. Internal consistency refers to the percentage of the interventions within a given configuration that are associated with reductions in meat demand.

Conversely, there was consistently no evidence of an effect for interventions manipulating the description or labelling of meat or alternatives at point-of-purchase. This configuration is reported in

table 2.12 and covers 38% of the 8 interventions that were not found to be associated with reduced meat demand.

Table 2.12: Configuration of intervention components not found to be associated with significant reductions in meat demand for interventions restructuring physical micro-environments

	Manipulating the description or labeling meat or alternatives Raw coverage: 38%, Internal consistency: 100%
Outcome:	(1) Reduction in the purchase or selection of meat in virtual settings
In the presence of:	(2) Manipulating the description or labeling meat or alternatives
In the absence of:	(3) Provision of meat alternatives, (4) reducing meat portions, (5) manipulating the sensory properties of meat or alternatives (6) repositioning meat products, (7) pricing, (8) multiple physical changes to the micro-environment, and (9) education and/or training components

Configuration of intervention components not found to be associated with significant reductions in meat demand. The overall solution coverage was 38%, i.e. 38% of all interventions that were not found to be associated with significant reductions in meat demand are covered by the intervention configuration above. The overall solution consistency was 100%, i.e. all interventions covered by the configuration above were not found to be associated with significant reductions in meat demand. Raw coverage refers to the percentage of all interventions not found to be associated with significant reductions in meat demand that are covered by the intervention configuration above. As there is only one such intervention this number is identical to the solution coverage. Internal consistency refers to the percentage of interventions within the configuration above that are not found to be associated with reductions in meat demand.

The results of QCA were in line with my narrative synthesis suggesting that interventions reducing the portions of meat servings, providing meat alternatives with supporting educational material, or manipulating the sensory properties of meat or alternatives were associated with reduced meat demand, while there was consistently no evidence of an effect for interventions only manipulating the verbal description or the label of meat or alternatives at point-of purchase.

5.5 Secondary psycho-social outcomes

Three RCTs evaluated how four interventions highlighting the animal origin of meat products influenced attitudes towards eating meat. (238,239) Of these interventions, three negatively affected attitudes towards consuming meat by referring to 'beef and pork dishes' as 'cow and pig dishes' on a food menu and by manipulating the image of a pork roast to display the pig's head. (238,239) The latter intervention worsened attitudes towards eating meat in two of three evaluations, but was not found to influence attitudes in a study including Ecuadorian participants only. (238) No study reported data on whether the interventions enhanced participants' perceived ability to lower their

demand for meat products or whether they influenced participants' perception of the social norms around pursuing lower meat diets.

5.6 Secondary biological and anthropometric outcomes

Evidence from two pre-post designs suggested that interventions providing free meat substitutes for several subsequent weeks were associated with some beneficial changes in biomarkers of health risks: a decrease in triglycerides, total- and LDL-cholesterol with no change in HDL-cholesterol following 4 weeks of meat- substitutes provision, (249) and a reduction in LDL-cholesterol with no change in other lipid fractions or blood pressure following 3 months of meat substitutes provision. (247) There was no evidence to suggest that any of the three interventions providing meat substitutes significantly influenced weight (247–249) or blood pressure. (247)

Table 2.13: Impact of interventions restructuring physical micro-environments on secondary psychosocial outcomes

Paper	Sample characteristics and study comparison	Intervention	Outcome	Results
Manipulation of the sensory properties of meat				
Kunst et al., 2016, Study 2b.	Sample size: N=101 Age: M=35, SD=11 Female: 60% Comparison: IG vs CG, RCT	IG: Participants viewed a picture of a pork roast with the pig's head. CG: Participants viewed a picture of a pork roast without the pig's head.	Attitudes towards eating the pork roast were assessed by asking participants how negative or positive they felt about eating it on a scale from 0 (extremely negative) to 100 (extremely positive).	Attitudes towards eating the pork roast were significantly less positive in the IG (M≈45, SE≈5) than in the CG (M≈64, SE≈5, t(99)=-2.77, p=0.007).
Kunst et al., 2018, American sample	Sample size: N=178 Age: M=36, SD=11(a) Female: 42%(a) Comparison: IG vs CG, RCT	IG: Participants viewed a picture of a pork roast with the pig's head. CG: Participants viewed a picture of a pork roast without the pig's head.	Attitudes towards eating the pork roast were assessed by asking participants how negative or positive they felt about eating it on a scale from 0 (extremely negative) to 100 (extremely positive).	Attitudes towards eating the pork roast were significantly less positive in the IG (M≈38, SE≈3) than in the CG (M≈66, SE≈3, t(176)=-6, p<0.001).
Kunst et al., 2018, Ecuadorian sample	Sample size: N=183 Age: M=27, SD=9 (b) Female: 58% (b) Comparison: IG vs CG, RCT	IG: Participants viewed a picture of a pork roast with the pig's head. CG: Participants viewed a picture of a pork roast without the pig's head.	Attitudes towards eating the pork roast were assessed by asking participants how negative or positive they felt about eating it on a scale from 0 (extremely negative) to 100 (extremely positive).	Attitudes towards eating the pork roast did not differ between the IG (M≈59, SE≈2) and the CG (M≈62, SE≈2, t(181)=-0.89, p=0.377).
Manipulating the description of meat				
Kunst et al., 2016, Study 5	Sample size: N=190 Age: M=34, SD=10 Female: 52% Comparison: IG vs CG, RCT	IG: Food menu with 8 meat-based meals, which were described as *'cow'* and *'pig'* options. CG: Food menu with 8 meat-based meals, which were described as *'beef'* and *'pork'* options.	Attitudes towards eating the meat options were assessed by asking participants how negative or positive they felt about eating them on a scale from 0 (extremely negative) to 100 (extremely positive).	Attitudes towards eating the meat options were significantly less positive in the IG (M≈51, SE≈4) than in the CG (M≈69, SE≈4) t(188)=3.59, p<0.001).

(a) Of the 201 participants enrolled. (b) Of the 202 participants enrolled. M=Mean, SD=Standard deviation, SE=Standard error, IG=Intervention group, CG= Control group.

Table 2.14: Impact of interventions restructuring physical micro-environments on secondary biophysical outcomes

Paper	Sample characteristics and study comparison	Outcome	Results
		Weight	
Clark, 2017	Sample size: N=37 Age: Median 27 (25th-95th percentile: 24-32) Female: 57% Comparison: Pre-post	Weight was measured using a calibrated scale before the intervention commenced and at the end of the 12 weeks intervention.	Weight did not differ significantly between the control and the intervention period (p=0.23).
Flynn et al., 2013.	Sample size: N=63 Age: M=52, SD=17 Female: 84% Comparison: Pre-post	The Body Mass Index (BMI) was calculated at the baseline and 6 months post intervention using (1) non-fasted and clothed weight measured with an electronic scale with 50g gradation, whose accuracy was previously determined using standardized weights and (2) height (without shoes) measured with a tape.	BMI was marginally significantly lower 6 months post-intervention completion (M=32.9, SD=8.4) than at the baseline (M=33.3, SD= 8.5, p=0.05)
Holloway et al., 2012	Sample size: N=25 Age: M=21, SD=3 Female: 60% Comparison: Pre-post	Weight with light clothing was measured to the nearest 0.01 kg using a digital scale at the baseline and at the end of the 4 weeks intervention	The weight among males was M=74.1 (± 12.8) at baseline and 73.4 (± 10.9) at the intervention completion. The weight among females was M=59 (± 8.1) at baseline and M=59.2 (± 7.8) at the intervention completion. The author reports "no significant effects on body weight".
		Blood lipids	
Clark, 2017	Sample size: N=37 Age: Median 27 (25th-95th percentile: 24-32) Female: 57% Comparison: Pre-post	Total cholesterol, total TAG, LDL-cholesterol and HDL-cholesterol were assessed using a Pentra 400 clinical chemistry analyser on a 16 ml blood sample taken via venepuncture. Blood lipids were assessed before the intervention commenced and at the end of the 12 weeks intervention.	Total cholesterol (M=-6.8%, p=0.082), HDL cholesterol (p=0.807), and total TAG (p=0.864) did not decrease significantly over the intervention period, while LDL cholesterol did (M=-9.7%, p=0.012).
Holloway et al., 2012	Sample size: N=25 Age: M=21, SD=3 Female: 60% Comparison: Pre-post	Total cholesterol, HDL-cholesterol, and total TAG were measured using enzymatic colorimetric techniques with a Horiba Analyser. LDL-cholesterol was calculated using the Friedewald Equation. Analyses were performed on an 8-millilitre 12-hour overnight fasting blood sample collected by venepuncture at the baseline and at the end of the 4 weeks intervention.	Total cholesterol (baseline: 4.45±0.53, follow-up: 4.05±0.66 p<0.001), LDL cholesterol (baseline: 2.40±0.36, follow-up: 2.15±0.46, p=0.007), and total TAG (baseline: 1.14±0.53, follow-up: 0.88±0.31, p=0.016) were significantly lower at post intervention, while HDL cholesterol was not (baseline: 1.53±0.39, follow-up: 1.5±0.38, p=0.47). (a)

		Blood pressure	
Clark, 2017	Sample size: N=37 Age: Median 27 (25th-95th percentile: 24-32) Female: 57% Comparison: Pre-post	Systolic blood pressure (SBP) and diastolic blood pressure (DSB) were assessed at the baseline and at the end of the 12 weeks intervention.	Neither SBP (p=0.2) nor DBP (p=0.32) changed over the intervention period.

(a) Results were reported for thoroughness, however these data were based on an independent sample t-test, while a dependent sample t-test is more appropriate for pre-post designs. M=Mean, SD=Standard deviation, IG=Intervention group, CI=Confidence interval, OR=Odds ratio, HDL=High-density lipoprotein, LDL=Low-density lipoprotein, TAG=Triacylglyceride, SBP=systolic blood pressure, DBP=diastolic blood pressure.

6. Discussion

6.1 Summary of results

Evidence from experimental intervention studies suggests that while there is only weak evidence on the effectiveness of behavioural interventions to reduce the demand for meat, some interventions targeting conscious determinants of human behaviour and/or restructuring physical micro-environments could contribute towards reducing the demand for meat.

The review of interventions targeting conscious determinants of human behaviour found that six lifestyle counselling interventions designed to reduce red and processed meat consumption led to (215,216) or were associated with reduced meat consumption. (226,229–231) Evidence from RCTs suggested that two self-monitoring interventions reduced red (214) or processed meat consumption (213) during the intervention period and enhanced intentions to not exceed recommended levels of consumption.

Providing non-tailored information on the health, or environmental, or socio-political, or animal welfare consequences of eating meat was associated with reduced intended consumption and virtual selection of meat in 16 out of 17 interventions. (204,217–219,222–224,227,228) However, there was no evidence that any of six such interventions influenced actual behaviour. (204,218,223,224) Only four of fourteen interventions providing information about multiple consequences of eating meat were associated with reductions in meat consumption, purchases, or selection. (212,220,224,232–234)

None of the ten tailored educational interventions or of the four interventions implicitly highlighting animal welfare issues was found to reduce actual (220) or intended meat consumption. (212,221) Participants' attitudes towards eating (less) meat generally mirrored their

intentions to do so. There was no robust evidence pertaining to any of the other secondary psychosocial outcomes or biomarkers of health risk.

The review of interventions restructuring physical micro-environments found that in two crossover RCTs all three interventions reducing meat portions reduced meat consumption, (243,244) and in three pre-post studies all three interventions providing free meat alternatives were associated with reductions in meat demand (247–249) with some evidence of a sustained impact. (247,248) Three of four interventions manipulating the sensory properties of meat or meat alternatives reduced meat demand in randomised trials (238,239,245) and two of four interventions repositioning meat products to reduce their prominence at point-of-purchase led to, or were associated with reductions in meat demand in a F-RCT and a multiple treatment reversal study. (237,245,246) However, only one of five interventions manipulating the verbal description of meat or meat alternatives at point-of-purchase was associated with reduced demand for meat in a multiple treatment reversal study. (236,238,245,246) One pricing intervention evaluated in a virtual environment was not found to influence meat purchases in a RCT. (242) One of two interventions manipulating multiple elements of physical micro-environments effectively reduced meat consumption in a RCT. (240,241)

Interventions manipulating the sensory properties or the description of meat products to highlighting their animal origin negatively affected attitudes towards meat consumption in three of four randomised trials. (238,239).There was some evidence from pre-post studies suggesting that providing meat alternatives was associated with improved blood lipids profiles (247,249) but there was no evidence that it was associated with weight loss or changes in blood pressure. (247–249)

6.2 Strengths of the systematic reviews

These reviews were the first two published systematic reviews of behavioural interventions aiming to reduce the demand for meat. In these reviews, I employed gold standard methods aiming to minimise bias. I conducted extensive searches to identify all relevant records and included unpublished manuscripts and studies not primarily focussing on reducing meat demand to reduce the risk of publication bias.

I kept the scope of my reviews broad to allow capturing a wide range of intervention approaches, which is important to inform policy when a field of research is in its infancy. Additionally, I used exploratory QCA, a novel methodological technique within systematic reviews, to identify configurations of intervention characteristics associated with and those not found to be associated with significant reductions in the demand for meat. This will provide additional data to inform the development of future interventions tackling the demand for meat.

6.3 Limitations of the systematic reviews

However, the results of these reviews should be interpreted in the context of some methodological limitations affecting the reviews themselves and/or the studies they included. Considering the novelty of this research field, I decided to review all relevant interventions, regardless of the design or methodological quality of the study in which they were evaluated. While this might have helped to prevent publication bias, it might also have increased the proportion of studies with weaker methodological quality.

Having also included non-randomised studies, it was not always possible to make direct causal inferences on the interventions' effectiveness. Some studies were not powered to detect statistically significant changes in meat demand (e.g. 34) and should therefore be interpreted with caution. Many studies were implemented in high income countries, limiting the generalizability

and applicability of our results to these settings. The outcome measures often relied on self-reported meat consumption or approximated estimates, which may have introduced bias and error variance.

Additionally, many studies reported participants' selection of meat products in virtual settings, which is only a suboptimal measure of meat demand in real-life settings and may thus lack external validity. (250,251) Many studies only measured outcomes during or shortly after the intervention, so it is difficult to draw conclusions on lasting intervention effects. Future studies should employ well-powered RCTs with longer follow-up to allow for causal inferences to be drawn on the interventions' effectiveness and to better understand their longer term impact.

I did not assess the extent to which theory was used to develop interventions or whether the use of theory enhanced intervention effectiveness. Future research might explore this issue in more detail. It is unlikely that my reviews would have identified meaningful patterns of how theory affected intervention effectiveness, since many studies did not explicitly elaborate on theory usage and those that did drew from very heterogenous theories or clinical psychology principles, including Self-regulation theory, Theory of planned behaviour, Behaviour change wheel, Social cognitive theory, Transtheoretical model of health, Cognitive dissonance, Dual process model of human behaviour, Acceptance commitment therapy, and Motivational interviewing.

For the review targeting conscious determinants of human behaviour, particular caution should be exercised when interpreting the results of lifestyle counselling, as my search algorithm might have failed to identify all such interventions. Titles and abstracts of these studies often referred to 'multiple health behaviours' as the intervention target, and it is possible that papers specifically mentioning 'meat consumption', and therefore identified by my search algorithm, were more likely to be those finding significant results for this specific outcome.

For the review of interventions restructuring physical micro-environments, particular caution should be exercised when interpreting the study by Stewart. This study, suggested that positioning meat after vegetarian options in online meal booking systems was associated with lower selection of meat among University students. (246) However, anecdotal evidence collected by the study author suggested that many individuals involved in the study later asked to change their selection to meat. Particular caution should therefore be given when interpreting the findings of this study and future research should investigate how to encourage people that were cued into selecting plant-based options to pursue this dietary choice.

The synthesis of my reviews was augmented by an exploratory QCA, which represents a sophisticated technique to descriptively identify patterns within data, but not to infer causality of effects. In particular, combinations associated with no evidence of effectiveness should not be thought as 'ineffective', as 'absence of evidence does not equal evidence of absence'. (252) Similarly, since I did not exclusively include RCTs, combinations associated with effectiveness do not necessarily support an underlying causal mechanism. It must also be noted that my QCA did not differentiate between studies of different quality and size, which might have affected some of the results.

Finally, my choice to use the EPHPP's QATQS tool to assess the methodological quality of the studies included allowed me to assess different study designs with one single tool, but I recommend caution when comparing quality scores between different study designs as a 'weak' randomised trial might still provide greater causal inferences on the effectiveness of an intervention compared to a 'medium quality' observational study.

6.4 Findings in the context of existing evidence

The results of both reviews were broadly in line with general insights from behavioural sciences and with the literature on interventions to promote other dietary changes. Lifestyle counselling and self-monitoring interventions have previously emerged as promising approaches to change different eating behaviours (253–255). However, the resources needed to implement lifestyle counselling pose a barrier to its scalability. Moreover, existing evidence on lifestyle counselling targeting the general population, rather than people suffering from ill-health, is less clear (253) suggesting that our findings on lifestyle counselling may not apply to the general population.

Educational interventions providing rational reasons for eating less meat may have underpinned the observed changes in conscious intentions. Nevertheless, unconscious psychosocial and environmental cues that influence behaviour in real-life settings (202,207) may have prevented these effects from translating into actual behaviour outside experimental settings. Interventions targeting unconscious determinants of human behaviour (202,207,208) may therefore play an important role to help overcome this intention-behaviour gap. (210)

Conversely, the non-significant findings on tailored education are in contrast with the literature highlighting the importance of tailoring information. (256,257) Nevertheless my findings were only based on two papers that found no evidence of effectiveness for any of the interventions they tested, regardless of tailoring. (212,220) It is therefore possible, that intervention characteristics other than tailoring or methodological limitations of the aforementioned studies contributed to these non-significant results. However, it is also possible that individuals do not substantially benefit from receiving information about issues that they already value as important consequences of meat consumption (which was the tailoring method employed by some interventions), as these arguments might have naturally exhausted their potential for prompting behavioural change.

Finally, while providing information was not found to directly influence behaviour, future research should explore whether this approach might contribute towards reducing demand for meat in other ways. For example, providing information on the benefits of eating less meat might increase the public's acceptability for more structural interventions to reduce meat consumption.

The results of the review of interventions restructuring physical micro-environments were also largely in line with past research on the effectiveness of behavioural interventions aiming to promote other environmentally sustainable or healthy behaviours. (202) Congruently with my findings on portion sizes, a recent systematic review concluded that reducing portion sizes may "contribute to meaningful reductions in the quantities of food people select and consume". (258) However, despite its effectiveness, reducing meat portions in a restaurant setting was found to decrease customers' satisfaction with the meat dish, raising questions about the acceptability of this strategy to food providers. (243)

A recent meta-analysis suggested that positioning food products influences purchasing behaviour, (259) and interventions repositioning meat products to be less prominent at point-of-purchase were consistently associated with lower meat demand, though only some reached statistical significance.

The results of interventions providing free meat alternatives were consistent with previous research indicating that interventions involving the provision of specific foods effectively changed eating behaviours. (260,261) The growing range of meat-substitutes might open new opportunities for interventions aiming at reducing meat demand through the promotion of comparable alternatives. (262) Preliminary evidence suggests that replacing meat with these foods may also be associated with reduced cardiovascular risk factors but the studies on which

this evidence is based were affected by methodological limitations and more structural investigations are needed to confirm or dispute these findings.

Manipulating the sensory properties of meat and meat-free products seemed promising to encourage lower meat demand and was implemented through two strategies: improving the hedonic appeal of meat alternatives at point-of-purchase (245) or highlighting the animal origin of a meat product by displaying the animal's head. (238,239) The effectiveness of the former approach was in line with past research on the association between the hedonic appeal of foods and purchasing intentions, (263,264) while the effectiveness of the latter approach was in contrast with past studies, which found no evidence to suggest that leading participants to reflect on the animal suffering involved in the production of meat reduced their demand for meat. (221) It is possible that highlighting the animal suffering involved in producing meat in a more graphical way (i.e. displaying the pig's head) offers more promise to reduce meat demand than highlighting animal suffering through written information and abstract tasks.

I found little evidence that altering the verbal description of meat or alternatives reduced demand for meat, which is in contrast with past research suggesting that changing the verbal description of vegetable products to enhance their perceived hedonic value influenced consumption. (265,266)

Finally, one study found no significant effect of a pricing intervention to reduce the demand for meat. However there is a substantial body of evidence, suggesting that price is an important determinant of food choices, including a recent systematic review of RCTs that I conducted with colleagues at Oxford. (251) Further research exploring the effectiveness of pricing strategies to reduce the demand for meat is therefore warranted.

6.5 Conclusion

Overall, my reviews highlighted that behavioural interventions can effectively reduce people's short-term meat demand and that some behavioural approaches offer greater promise than others. However, the greatest learning from my reviews was that the evidence on the effectiveness of interventions aiming to reduce the demand for meat was lacking, highlighting the need for the development and robust evaluation of more such interventions. The second part of my DPhil aimed to contribute towards addressing this research gap. The next chapters outline how I developed a novel behavioural intervention to reduce meat consumption and the results of a randomised controlled trial that I employed to evaluate its effectiveness.

Chapter 3: Intervention Development

1. Chapter summary

Chapter 1 outlines how meat consumption can detrimentally affect the natural environment and human health. However, my systematic reviews only identified a very limited number of interventions to reduce meat consumption, highlighting a need to develop more such interventions. This chapter presents the work I conducted to develop a novel multi-component behavioural intervention to reduce meat consumption. I developed my intervention using the Behaviour Change Wheel (BCW) methodology. First, I selected the target behaviour and decided to focus on reducing meat consumption among regular meat eaters. Second, I conducted a literature review exploring barriers preventing meat eaters from eating less meat and identified five putative barriers, including (i) behavioural control (e.g. low availability of plant-based options or cooking skills), (ii) attitudes (e.g. thinking that eating less meat is not enjoyable), (iii) social norms (e.g. thinking that eating meat is common), (iv) meat attachment (e.g. feeling that meals are incomplete without meat), and (v) eating identities (e.g. identifying as meat-eaters). Third, I designed the intervention content. This involved selecting appropriate intervention functions from the BCW, operationalising these functions though behaviour change techniques (BCTs), and translating the selected BCTs into concrete intervention materials. These steps were informed by my systematic reviews, behavioural science frameworks, consultations with psychology and nutrition experts, and co-design activities with members of the general public. The resulting intervention included four intervention functions and seven BCTs:

- **Provision of meat substitutes:** The first function was 'environmental restructuring' and was enacted through the provision of free plant-based meat substitutes for four consecutive weeks.
- **Recipes:** The second intervention function was 'training' and was enacted through the provision of plant-based recipes.

- **Infographics:** The third intervention function was 'education' and was enacted through the provision of infographics about the health and environmental benefits of eating less meat.
- **Success stories:** The last intervention function was 'modelling' and was enacted through success stories of people who reduced their meat intake and identified as flexitarians.

This intervention was named ***Re****placing* ***M****eat with* ***A****lternative* ***P****lant-based Products*. Parts of this chapter were published in a peer reviewed journal: Bianchi F, Aveyard P, Astbury NM, Cook B, Cartwright E, Jebb SA. Replacing meat with alternative plant-based products (RE-MAPs): protocol for a randomised controlled trial of a behavioural intervention to reduce meat consumption. BMJ Open. 2019.(267)

2. Introduction

Chapter 1 outlines how meat consumption detrimentally affects the environment and human health. However, my systematic reviews only identified a very limited number of interventions to reduce meat consumption, highlighting a need for researchers to develop more such interventions.(268,269) This chapter presents the work I conducted to address this need by developing a novel multi-component behavioural intervention to reduce meat consumption (RE-MAP: **Re**placing **M**eat with **A**lternative **P**lant-based products).(267)

3. Applying the Behaviour Change Wheel

I developed RE-MAP by following the Behaviour Change Wheel (BCW) methodology, which I selected because (i) it provides a clear step-by-step process for how to develop behavioural interventions, (ii) it collates insights from multiple behavioural theories, (iii) it outlines how to integrate theory within the intervention development process, and (iv) it was previously used to develop interventions to change eating behaviours.(270–275) According to the BCW, behavioural interventions can be developed following a number of iterative phases, including:

- Defining the target behaviour that the intervention should encourage;
- Identifying the barriers preventing the target behaviour from being performed; and
- Developing the content and implementation strategy of the intervention.

The sections below describe the activities I conducted as part of these phases and explain how each phase informed the final intervention.

4. Defining the target behaviour

4.1 Defining the target behaviours: the BCW methodology

The first BCW intervention development phase involves defining the behaviour that the intervention aims to promote.(270–272) The target behaviours can be defined through three

steps. First, the fundamental problem tackled by the intervention needs to be described in *behavioural* terms. For example, instead of developing an intervention to tackle 'anthropogenic global warming', intervention designers should focus on concrete human behaviours contributing to climate change, such as eating meat or driving cars. This exercise will generate a pool of candidate target behaviours. Second, intervention designers should select the final behavioural target from this pool of candidate target behaviours by considering:

- **Impact:** The relative *impact* that changing different candidate behaviours would have on the underlying problem, e.g. whether global warming would be mitigated more effectively through reductions in meat consumption or car driving.
- **Co-benefits:** The *synergistic co-benefits* of changing different candidate behaviours, including the increase in other desirable behaviours (e.g. reducing car driving could increase physical activity) or mitigation of other relevant problems (e.g. reducing meat consumption for environmental reasons could synergistically improve human health).
- **Feasibility:** The *feasibility and ease* of changing different candidate target behaviours, e.g. whether it is easier to reduce meat consumption or car driving.

Third, the selected target behaviour should be described in as much detail as possible. In so far as it is useful, by the end of this phase designers should explicitly state 'who needs to perform what behaviour, when, where, with whom, and how often'.(270–272)

4.2 Defining RE-MAP's target behaviour

The process described above represents the ideal way of selecting behavioural targets. However, in practice making the aforementioned decisions in a rational and evidence-based way is nearly impossible, as it would require (i) data and resources to objectively compare the impact of changing different candidate behaviours on the underlying problem, (ii) the ability to consider all possible co-benefits of changing different candidate behaviours, and (iii) a system to quantify the ease of changing these behaviours.

If at all possible, collating this information would represent an extremely challenging research project in its own rights. Additionally, some decisions required to select the behavioural target are dependent on the skills of intervention designers: A behavioural scientist specialising in eating behaviours might find it easier to reduce meat consumption, while an urban designer might find it easier to reduce car driving. As such, I used the aforementioned BCW procedure as a framework to consider different issues pertaining to the target behaviour in a structured and systematic way, rather than as a step-by-step guide.

4.3 RE-MAP's target behaviour

The broad focus of my intervention on reducing meat consumption was determined before I started the active intervention development and was informed by the literature on the health and environmental benefits of eating less meat (impact and co-benefit criteria in section 3.1) and my pre-existing knowledge in applying behavioural insights to change eating behaviours (feasibility criteria in section 3.1). During the first intervention development phase I, therefore, focussed primarily on refining my target behaviour in the following ways:

- I decided to target consumers, as I envisaged suppliers to be less receptive to interventions reducing meat consumption due to competing commercial interests.(276–278)

- I excluded seafood from my behavioural target, as fish consumption in the UK is well below recommended levels for a healthy diet and its environmental impact differs from that of meat.(4,93,279)

- Even if there is no strong evidence that white meat consumption detrimentally affects health and its environmental impact is lower than that of ruminant meat, I decided to include white meat in my behavioural target, since small individual environmental

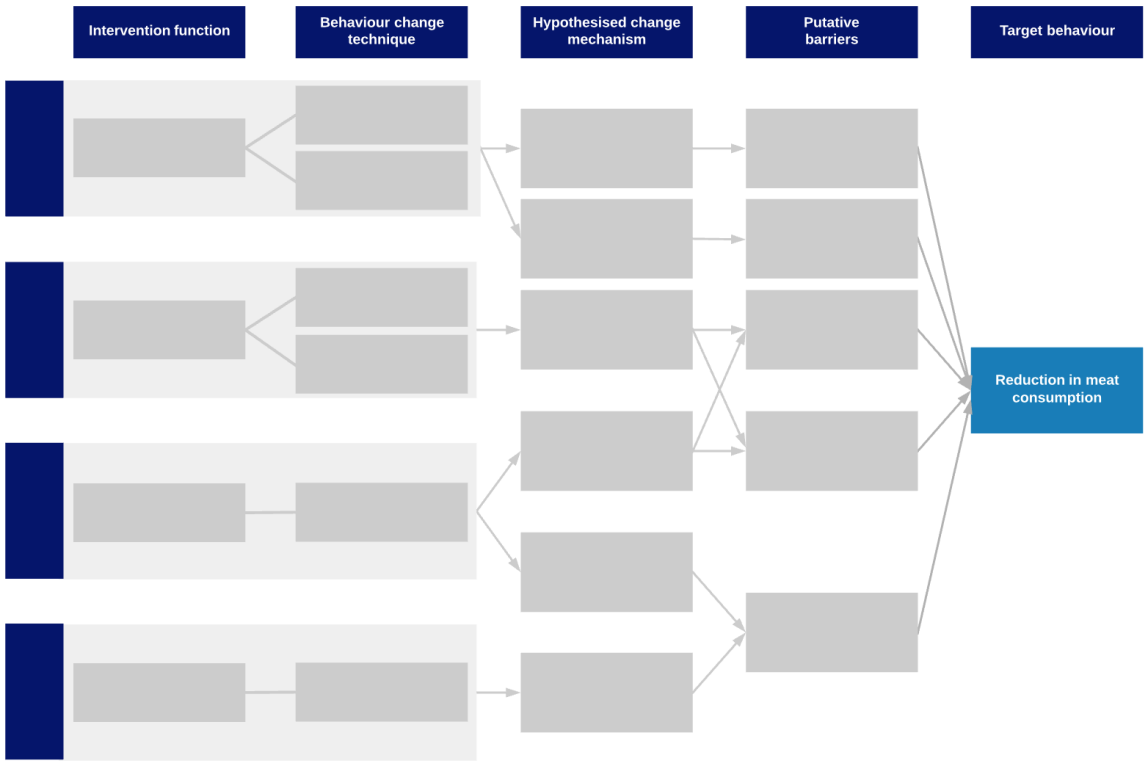
benefits can add up to meaningful absolute benefits at the population level.(4,86,136) Additionally, if poultry consumption increased to meet decreasing demand for red meat, this could have adverse consequences from an animal welfare perspective.

- I decided to focus on frequent meat eaters, because these consumers have greater potential to reduce their meat intakes and achieve greater environmental benefits compared to infrequent meat eaters.

- Finally, I decided to focus on reducing meat consumption rather than on promoting exclusively plant-based diets, as I considered this behavioural target more achievable.(280,281)

RE-MAP's behavioural target was therefore defined as 'reducing the consumption of any non-seafood meat product among regular meat eaters' (henceforth: reducing meat consumption, Fig. 3.1).

Fig. 3.1: RE-MAP's behavioural target



5. Identifying barriers preventing the target behaviour

5.1 Identifying barriers preventing the target behaviour: the BCW methodology

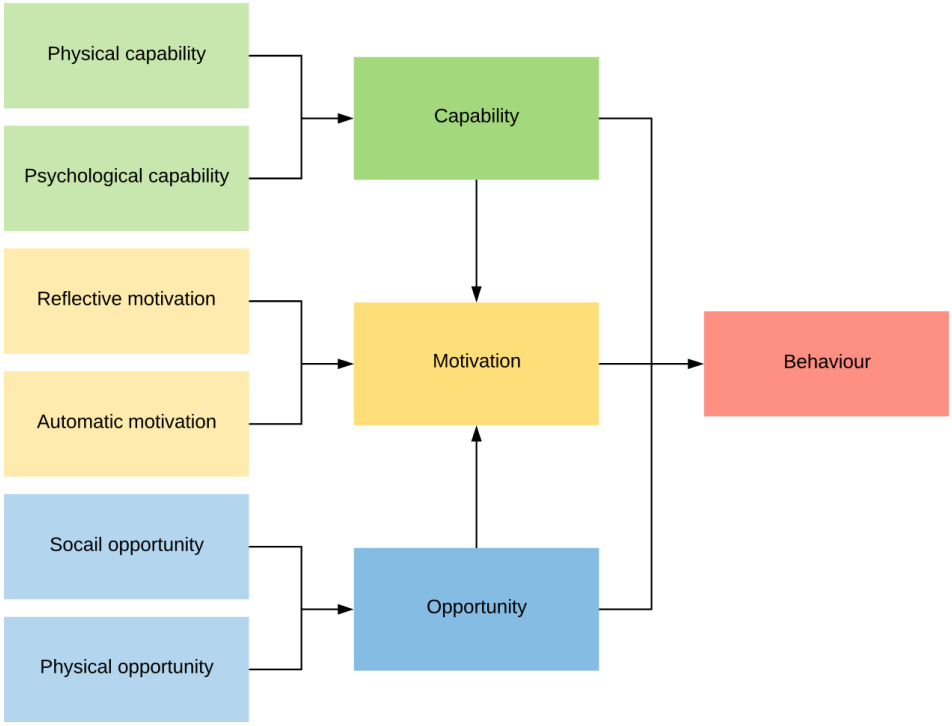
Having defined the target behaviour, the second intervention development phase in BCW involves undertaking a behavioural analysis to identify the barriers preventing this behaviour and what needs to change to promote it.(270–272)

There are numerous activities that can inform this analysis, including qualitative interviews (e.g. asking people what prevents them from eating less meat), exploratory data analyses (e.g. analysing whether specific people consume more meat), and literature reviews (e.g. reviewing studies investigating what prevents people from eating less meat).

Each method presents different strengths and limitations and the most appropriate approach depends on the nature of the target behaviour. For example, if the target behaviour is primarily driven by conscious behavioural determinants (e.g. voting in national elections) then qualitative interviews might be appropriate, as people are typically able to elaborate on the conscious determinants of their behaviours. However, interviews might be less appropriate to analyse behaviours that are strongly determined by subconscious automatic determinants (e.g. food purchasing habits).

The BCW recommends using the Capability – Opportunity - Motivation (COM-B) Model to identify and organise putative barriers preventing the target behaviour (Fig. 3.2).(270) This model collates insights from many behavioural theories and suggests that people will only perform a behaviour if they have the capability, opportunity, and motivation to do so.

Fig. 3.2: Capability Opportunity Motivation Behaviour (COM-B) Model



5.2 Identifying barriers preventing reductions in meat consumption

While COM-B provides a useful framework to diagnose human behaviour, this model was not specifically developed to identify factors that might prevent reductions in meat consumption. I, therefore, decided to adapt the BCW methodology and employ a more data driven approach to identify the barriers preventing people from eating less meat.

My behavioural analysis involved a review of the academic literature focussing on the determinants of meat consumption. This approach allowed me to efficiently (i) draw from a variety of study designs and wider behavioural science principles, (ii) identify factors affecting meat consumption consciously and subconsciously, and (iii) consider factors affecting meat consumption that are not featured in existing behavioural models. As this work aimed to inform the content of an intervention to reduce meat consumption, I focused on identifying *modifiable* rather than unmodifiable structural barriers.

5.3 The behavioural barriers in RE-MAP's logic model

My literature review identified five key modifiable psychosocial barriers, which might prevent people from reducing their meat consumption:

- **Behavioural control:** Some people might not reduce their meat intake due to sub-optimal behavioural control, including actual or perceived lack in internal capabilities (e.g. cooking skills) and external opportunities (e.g. low availability of plant-based alternatives). Empirical studies consistently find behavioural control to predict reductions in meat consumption.(282–285) Additionally, a recent review of factors associated with meat consumption in high income countries identified the lack of behavioural control, poor cooking skills, and low availability of appetising meat-free foods as important barriers preventing reductions in meat intake.(41)

- **Attitudes:** Some people might not reduce their meat intake due to negative functional attitudes (e.g. thinking that eating less meat is not beneficial) and hedonic attitudes (e.g. thinking that eating less meat is not enjoyable) towards eating less meat. Negative functional attitudes might be the result of knowledge gaps, while negative hedonic attitudes might be the result of people's familiarity with meat and unfamiliarity with plant-based meat substitutes. Mere exposure describes people's tendency to develop a liking towards things simply as they become more familiar with them, and this process appears to affect liking for food preferences.(286–288) Empirical studies consistently find attitudes to be important predictors of intended and actual meat consumption.(41,282–285,289–291)

- **Meat attachment:** Some people might not reduce their meat intake because they are strongly attached to eating meat. The concept of meat attachment is similar to attitudes in that it captures the enjoyment of eating meat. However, meat attachment also includes

aspects that are not covered by attitudes, such as the belief that humans are entitled to eat meat, the feeling of being dependent upon meat, and the automatic affinity towards meat.(283) Researchers only started to investigate this construct in recent years, but there is already convincing evidence that meat attachment predicts intentions to eat less meat, even after controlling for attitudes, behavioural control, and other potential psychosocial confounders.(283,292,293) These insights suggest that meat attachment might prevent people from eating less meat through independent mechanisms.

- **Social norms:** Human behaviour is strongly influenced by the actual or perceived behaviour of peers.(294) Some people might, therefore, not reduce their meat intake due to actual or perceived social norms of consuming meat.(283,284,295,296) Social norms can influence human behaviour through numerous routes, including cognitions (e.g. believing that a behaviour is unlikely to be harmful if most people perform it), motivations (e.g. intrinsic desire to be seen as an 'ingroup' by behaving like peers), and practical factors (e.g. difficulty in accommodating different diets in a single household). Regardless of the underlying mechanism, there is consistent evidence suggesting that "perceptions of normative behaviour by […] peers who favour meat consumption" represents an important barrier preventing people from eating less meat.(41)

- **Eating identities:** My literature review suggested that eating identities might also prevent people from eating less meat. Eating identities refer to how people perceive and describe themselves in relation to their food choices.(282,297,298) These identities primarily influence food choices through two routes: (i) some people might choose to consume specific foods in an attempt to construct, affirm, or express their identity and (ii) some people might avoid specific foods if these food are perceived to be incongruent with their identity.(282) For example, people who identify as 'meat eaters' might not eat meat substitutes simply because they perceive these foods to be for 'vegetarians' and are,

therefore, not compatible or even contradict with their meat eating identity. Food choices can be used to "construct and preserve narratives of the self" and there is compelling evidence on the impact that eating identities have on food choices, including meat consumption.(27,282,283,298–300)

Having identified the putative barriers preventing reductions in meat consumption, the last step of the intervention development phase involved specifying 'what should change' to tackle these barriers and promote the target behaviour. I identified six such mechanisms of change.

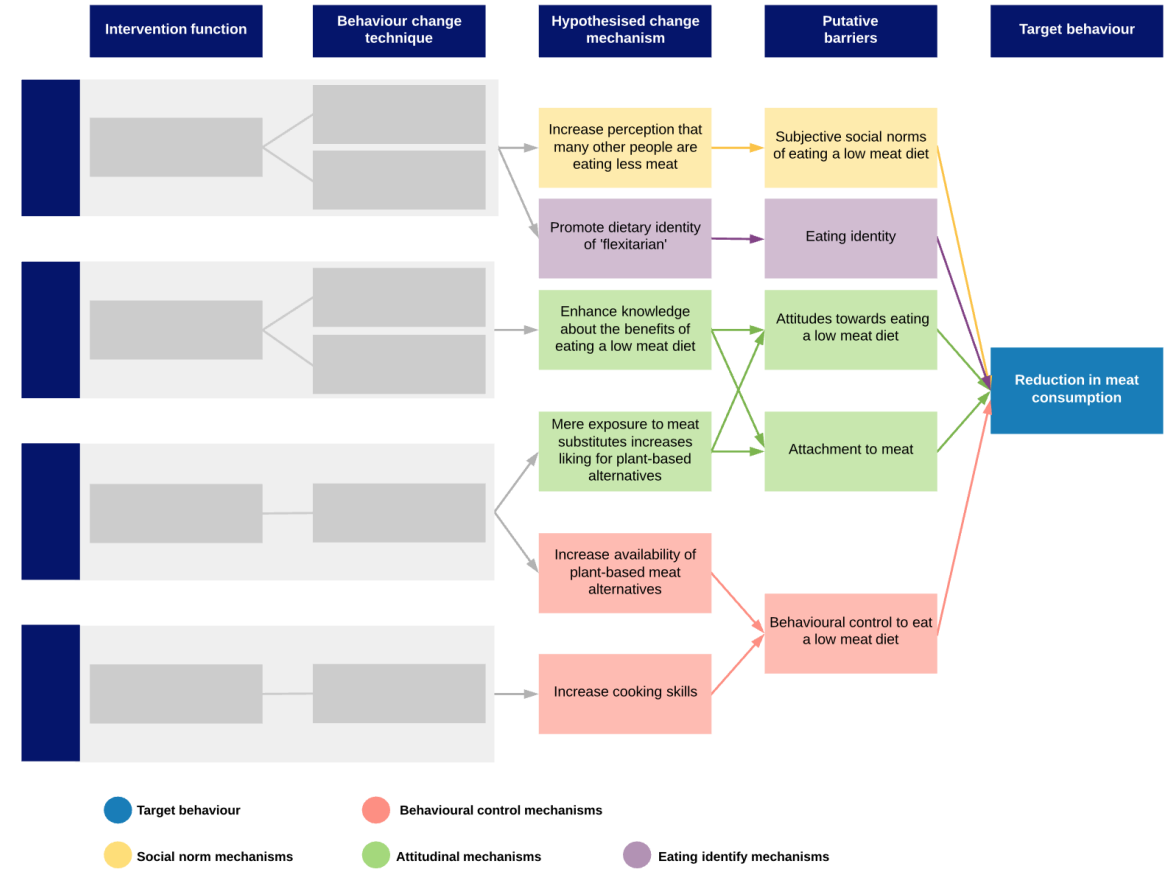
- To enhance behavioural control of eating less meat, I hypothesised that (i) cooking skills should be enhanced and (ii) the availability of plant-based substitutes should be increased.

- To promote more favourable attitudes towards eating less meat and reduce meat attachment, I hypothesised that (iii) plant-based meat substitutes should be made more appealing and (iv) knowledge of the health and environmental benefits of low meat diets should be enhanced.

- To tackle the eating identity and social norm barriers, I hypothesised that (v) eating identities associated with reduced meat consumption and (vi) the perception that other people are reducing their meat intake should be promoted.

Figure 3.3 summarises the putative modifiable barriers preventing reductions in meat consumption and the hypothesised mechanisms of change required to tackle these barriers.

Fig. 3.3: RE-MAP intervention development: behavioural target, putative modifiable barriers, change mechanisms

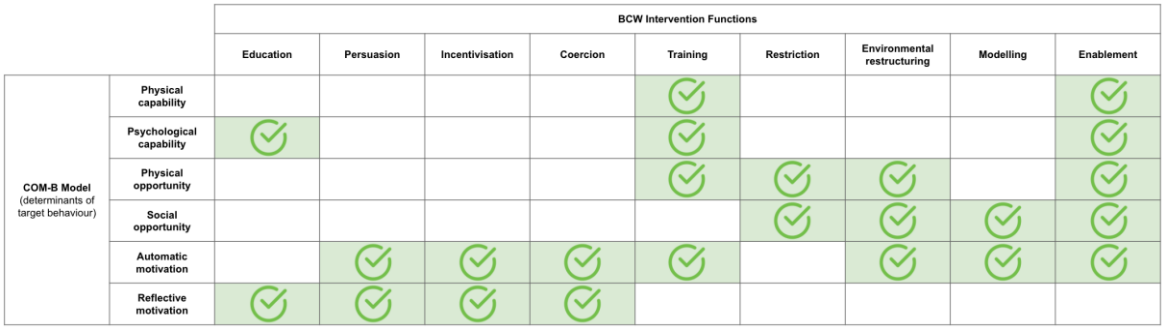


6. Developing the intervention content

6.1 Developing the intervention content: the BCW methodology

The final intervention development phase in BCW involves designing the intervention content and implementation strategy. This process includes three steps. First, intervention designers select the BCW functions to be included in their intervention. BCW functions are 'broad categories of means by which an intervention can change behaviour', such as education (i.e. increasing knowledge and understanding), training (i.e. imparting skills), or environmental restructuring (i.e. changing the physical or social context).(270) The BCW methodology includes matrices outlining which functions are most likely to successfully tackle barriers related to the different areas of the COM-B model. As such, if COM-B were used to identify the barriers preventing the target behaviour, BCW provides explicit guidelines for which intervention functions should be used (Fig. 3.4).

Fig. 3.4: Links between COM-B and BCW intervention functions (270)



Second, intervention designers should specify the behaviour change techniques (BCTs) they will use to operationalise the selected intervention functions. BCTs are specific 'active intervention ingredients designed to bring about behaviour change' (e.g. providing information about health consequences') and can be selected from a range of taxonomies.(301,302)

Third, intervention designers should define how they will implement their intervention, by translating BCTs into concrete intervention components and specifying how each component will be delivered. For example, the BCT 'providing information about health consequences', could be operationalised as an information leaflet, a campaign, or an educational session and could be delivered digitally or in person.

6.2 Developing the content for the RE-MAP intervention

As I did not use COM-B to conduct my behavioural analysis (see section 4.3), I could not select intervention functions by directly applying the BCW matrix of linkinking intervention functions to COM-B. Instead, I started by mapping the putative barriers preventing meat reductions identified through my behavioural analysis onto the COM-B components.

Specifically, (i) my behavioural control barrier included elements of COM-B's psychological capability and physical opportunity, (ii) my attitudes and meat attachment barriers included elements of COM-B's automatic and reflective motivation, and (iii) my identity and social norm

barriers included elements of COM-B's social opportunity and automatic motivation. This mapping exercise then enabled me to select intervention functions based on the aforementioned BCW's matrices (Fig. 3.5).

Fig. 3.5: Links between barriers of RE-MAP's target behaviour, COM-B, and BCW intervention functions

		Putative determinants of meat consumption identified through the RE-MAP behavioural analysis	BCW Intervention Functions								
			Education	Persuasion	Incentivisation	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
COM-B Model (determinants of target behaviour)	Physical capability						✓				✓
	Psychological capability	1. Behavioural control	✓				✓				✓
	Physical opportunity	1. Behavioural control					✓	✓	✓		✓
	Social opportunity	1. Eating identity 2. Social norms						✓	✓	✓	✓
	Automatic motivation	1. Attitudes 2. Meat attachment 3. Eating identity 4. Social norms		✓	✓	✓	✓		✓	✓	✓
	Reflective motivation	1. Attitudes 2. Meat attachment	✓	✓	✓	✓					

Once I decided which functions to include in RE-MAP, I operationalised these functions by selecting BCTs from the BCT taxonomy and the CALO-RE taxonomy.(301,302) My selection of BCTs was informed by (i) my systematic reviews, (ii) general behavioural science principles, and (iii) consultations with behavioural science experts. I then designed the implementation strategy for the intervention, by translating the BCTs into concrete intervention materials. This exercise was supported by two co-creation public engagement activities:

- **Online collection of success stories case studies:** The first public engagement activity involved collecting case studies of people who successfully reduced their meat intake through a request in the departmental newsletter, the patient and public

involvement (PPI) mailing list, and personal social networks. These stories informed the content of some aspects of the RE-MAP intervention.

- **Improving information materials through focus groups:** The second public engagement activity was a focus group with four people who were regular meat eaters and five people who were attempting to reduce their meat consumption to gather qualitative feedback about the initial iteration of the RE-MAP intervention components and intervention materials (Fig. 3.6).

Fig. 3.6: Pictures from the co-creation focus groups



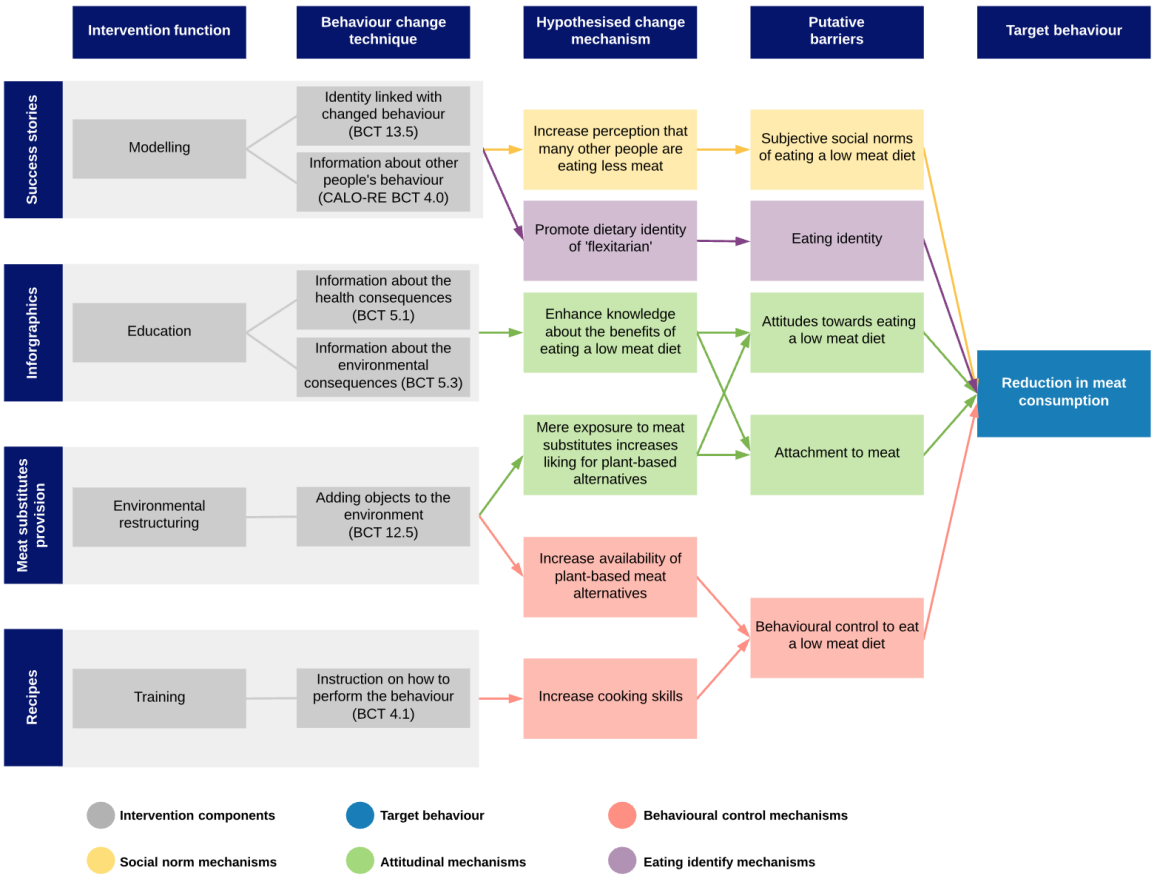
6.3 The RE-MAP intervention content and implementation strategy

The result of the exercises described above was the ***Re****placing* ***M****eat with* ***A****lternative* ***P****lant-based Products* (RE-MAP) intervention, a multicomponent programme including four intervention functions and seven BCTs enacted through four intervention components, including:

- The provision of free plant-based meat substitutes for four consecutive weeks
- Recipes of plant-based meals
- Infographics about the health and environmental benefits of eating less meat, and
- Success stories of people who reduced their meat consumption.

Jointly, these four intervention components were hypothesised to promote all the required mechanisms of change and to tackle all the putative barriers, which I identified through my behavioural analysis (Fig. 3.7). The content and implementation strategy for each intervention component are described below.

Fig. 3.7: Full logic model for the RE-MAP intervention



6.3.1 Provision of meat substitutes

The first intervention function in RE-MAP was 'environmental restructuring' and was enacted through the BCT 'adding objects to the environment' (BCT taxonomy 12.5). In practice, this BCT was implemented by providing a supply of free plant-based meat substitutes for four consecutive weeks. Intervention recipients could select meat substitutes from a catalogue of commercially available products and order enough products for their household. Ordering occurred at the start of the intervention and two weeks into the intervention and products were delivered directly to recipients' homes by a UK retailer. This intervention component aimed to enhance behavioural control to eat less meat by making plant-based meat substitutes more readily available. Additionally, this component aimed to reduce meat attachment and generate more favourable attitudes towards eating less meat by increasing the appeal of plant-based meat substitutes through a process of mere exposure (Fig. 3.7).(286) Plant based meat substitutes tend to be higher in fibre and lower in saturated fatty acids compared to similar meat products. However, many plant-based meat substitutes contain similar levels of energy and have similar or higher levels of sodium than comparable meat products. Crucially, the relative healthfulness of the nutritional composition of plant-based meat substitutes strongly depends on the meat products that they replace: replacing a processed meat sausage for mycoprotein pieces is likely to result in some nutritional benefits, while replacing a lean chicken breast for processed plant-based sausages might not. [c] Due to the potential risk of the intervention resulting in the replacement of healthier meat products for less healthy meat substitutes, the trial evaluating RE-MAP will assess the intervention impact on the nutritional composition of recipients' diets as well as the intervention's short-term impact on objectively measured biomarkers of health risk, such as weight, blood pressure, and blood lipid profiles (see Chapter 4).

[c] A general overview of the relative healthfulness of meat and meat substitutes was published in Frontiers in Sustainable Food Systems by Santo and colleagues in the 2020 paper "Considering plant-based meat substitutes and cell-based meats: A public health and food systems perspective".

The decision to use meat substitutes as part of this intervention component was based on (i) my systematic reviews suggesting that interventions providing free meat substitutes could effectively reduce meat consumption, (ii) the behavioural science principle that people are more likely to successfully reduce a detrimental behaviour by substituting it with a similar yet less harmful behaviour, and (iii) the practical timely opportunity posed by the increase in commercially available meat substitutes. My public panel supported the decision to include meat substitutes in RE-MAP, as they thought that meat eaters would find replacing meat with meat substitutes easier than abruptly transitioning to a plant-based diet. The public panel also suggested adding more vegetables- and pulses-based meat substitutes (e.g. bean burgers) to the RE-MAP catalogue of meat substitutes available to participants. Additionally, the public panel suggested referring to 'meat substitutes' as 'meat alternatives', as the former label was perceived to have the negative connotation of a 'food pretending to be something it is not'. Both suggestions were integrated into the final version of this intervention component. Fig. 3.8 displays four example pages from the final RE-MAP meat substitutes catalogue. The full catalogue contained 126 products, which were chosen with the help of an expert in nutrition sciences (Appendix 1).

Fig. 3.8: RE-MAP meat substitutes catalogue (example pages)







6.3.2 Recipes

The second intervention function in RE-MAP was 'training' and was enacted through the BCT 'instructing how to perform the behaviour' (BCT taxonomy 4.1). In practice, this BCT was implemented by providing two cookbooks outlining plant-based recipes. The first cookbook was developed by me and outlined recipes involving meat substitutes. This booklet was delivered at the start of the intervention to ensure recipients had the required skills to incorporate meat substitutes in their meals (Fig. 3.9). The second cookbook was a commercially available book; 'A girl called Jack' and was delivered during the fourth intervention week. This cookbook predominantly included plant-based recipes, but also some meat-containing recipes. I selected this book because I had hypothesised that towards the end of the intervention, recipients would be ready to explore meat free dishes beyond meat substitutes. Additionally, I thought that the inclusion of some meat-containing recipes would reinforce the intervention's aim of reducing meat consumption rather than giving up meat completely.

Fig. 3.9: Example pages of the RE-MAP meat substitutes recipe booklet



The aim of the recipes was to increase recipients' actual and perceived behavioural control of consuming less meat by ensuring they had the required cooking skills and confidence to prepare plant-based meals. The inclusion of this component was primarily driven by the behavioural analysis, which identified lack of cooking skills as a barrier preventing reductions in meat consumption. Additionally, my systematic reviews identified some evidence to suggest that providing recipes as part of multi-components interventions might help recipients to eat less meat.(268) The public panel supported the inclusion of recipes in RE-MAP to enhance recipients' cooking skills and encouraged using 'A girl called Jack' as part of the intervention.

6.3.3 Infographics

The third intervention function in RE-MAP was education and was enacted through the BCTs 'providing information about the health and environmental consequences' of eating meat (BCT taxonomy 5.1 and 5.3). In practice, these BCTs were implemented through three bespoke sets

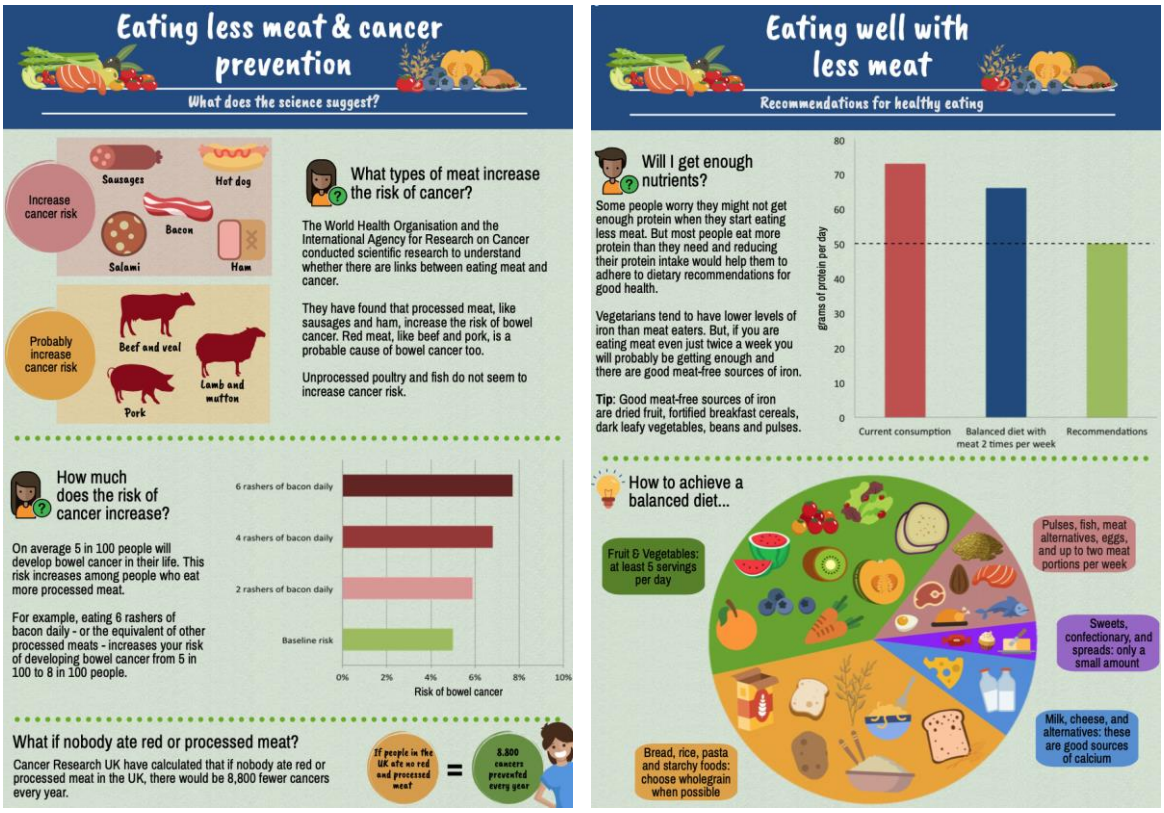
of infographics. The first set of infographics was delivered at the start of the intervention and included an overview of the health and environmental benefits of eating less meat (Fig. 3.10).

Fig. 3.10: Example pages of the RE-MAP introduction infographics



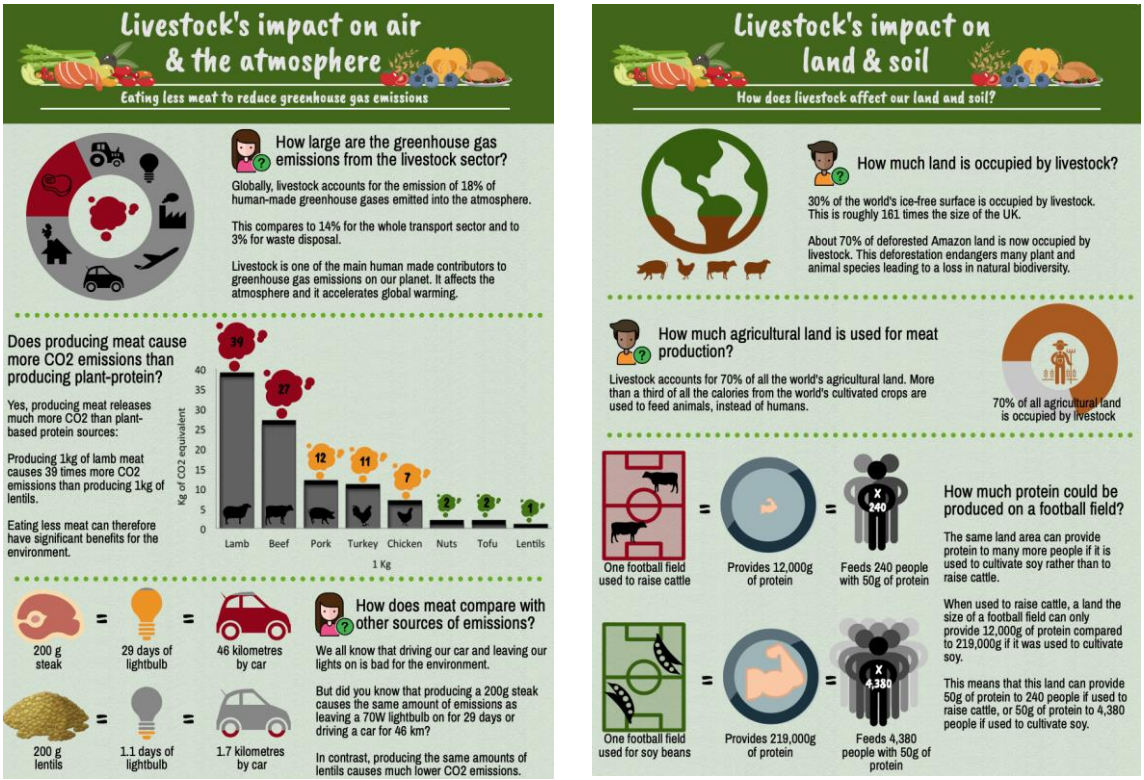
The second set of infographics was delivered during the second intervention week and included four A4 pages on the health benefits of eating less meat (Fig. 3.11). These infographics covered (i) the recommended levels of meat consumption, (ii) the links between meat consumption and chronic health conditions, (iii) how meat contributes towards salt and saturated fat intake, and (iv) how to eat healthily with less meat. I aimed to present the links between meat consumption and the health consequences as 'potential benefits of eating less meat' rather than 'potential risks of eating meat', as there is some evidence that positively framed messages might be more effective at promoting preventative behaviours.(303) Additionally, I presented these associations as absolute rather than relative risk changes, as the former are more likely to be meaningful to members of the public.

Fig. 3.11: Example pages of the RE-MAP infographics on meat consumption and health



The third set of infographics was delivered during the third intervention week and included four A4 pages outlining the environmental benefits of eating less meat (Fig. 3.12). These infographics covered the impact of meat production on (i) greenhouse gas emissions, (ii) land use and degradation, (iii) water use and pollution, and (iv) biodiversity loss. To increase engagement and make the environmental benefits of eating less meat more tangible, I often compared the environmental impact of meat with that of plant-based protein-rich products and that of carrying out other common activities (e.g. driving cars, taking showers).

Fig. 3.12: Example pages of the RE-MAP infographics on meat production and the environment



Jointly, the infographics aimed to enhance knowledge about the impact of eating meat and subsequently reduce meat attachment and promote positive attitudes towards eating less meat. This component was informed by my systematic reviews, which found that providing information about the health and environmental impact of eating meat promotes positive attitudes towards meat reduction. The public panel thought that the infographics were interesting, engaging, and easy to understand. However, the panel also suggested (i) further emphasising that even minimally reducing meat consumption can be beneficial, (ii) replacing some text with visual graphs, and (iii) using simpler language. With the help of the public panel, behavioural science experts, and communication experts I modified the infographics to integrate these suggestions.

6.3.4 Success stories

The fourth and last intervention function in RE-MAP was 'modelling' and was enacted through the BCTs 'identity associated with changed behaviour' (BCT taxonomy 13.5) and 'information about other people's behaviour' (CALO-RE BCT 4.0). In practice, these BCTs were implemented through three printed success stories of people who reduced their meat consumption (Fig. 3.13). These success stories aimed to influence eating identities by promoting the concept of flexitarian identities and by influencing perceived social norms of eating less meat highlighting that other people reduce their meat intake.

I also included a section where recipients could write their own success story to encourage recipients' active engagement with these resources. Public engagement activities were key to inform the development of the success stories. Through the departmental newsletter, the patient and public involvement (PPI) mailing list, and personal social networks, I prompted people who reduced their meat consumption to share the story of how they implemented this dietary transition. I then developed three success story vignettes summarising the main themes emerging from this public engagement activity. The success story vignettes outlined:

- What motivated people to eat less meat
- Which strategies people used to successfully cut down their meat intake
- Which challenges people faced during their dietary transition, and
- How people overcame these challenges.

The decision to highlight people's challenges in reducing meat consumption and how they overcame these struggles was informed by the concept of implementation intentions (if-then plans). These plans represent a self-regulatory behavioural strategy enhancing people's ability to translate their intentions into action by prompting them to think about what obstacles could prevent them from implementing their intentions ("if obstacle X happens") and what they will

do to overcome these obstacles ("then I will overcome the obstacle by doing Y").(304,305) To make the success stories more personable, I also included the pictures and a short illustrative biography of three people who agreed to be included in these resources.

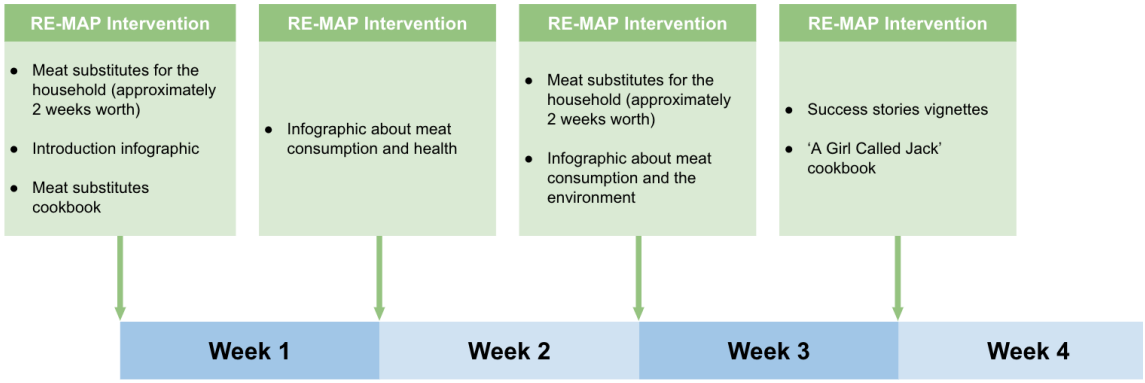
Fig. 3.13: Example pages of the RE-MAP infographics on meat production and the environment



7. Discussion

In summary, this chapter outlined how I developed RE-MAP, a four week multi-component intervention aiming to reduce meat consumption among regular meat eaters by providing (i) free meat substitutes for the household for four consecutive weeks, (ii) plant-based recipes, (iii) infographics about the health and environmental benefits of eating less meat, and (iv) success stories of people who reduced their meat consumption. All intervention materials were sent to recipients by post except for the meat substitutes, which were chosen by recipients from a catalogue and delivered directly to participants by a UK retailer. Figure 3.14 visualises the full intervention schedule.

Fig. 3.14: RE-MAP intervention schedule



To the best of my knowledge, this is the first behavioural intervention aiming to reduce meat consumption through the aforementioned combination of intervention components. The development of RE-MAP was informed by the BCW framework, insights from my systematic reviews, iterative consultations with behavioural science and nutrition experts, and co-creation exercises with members of the general public. Each of these elements contributed to the intervention development in unique ways.

First, the use of the BCW framework helped to clearly define the target behaviour, identify putative barriers specifically preventing meat reductions, and tailor the intervention content to tackle these barriers. Second, my systematic reviews enabled me to select intervention

components that successfully contributed towards reducing meat consumption or towards tackling putative determinants of meat consumption in previous interventions, thus enhancing RE-MAP's potential to deliver impact. Third, consultations with behavioural science and nutrition experts informed pragmatic decisions about issues for which there was no clear theory or evidence to rely upon, such as what products to include in the meat substitutes catalogue, how long to deliver the intervention for, and what specific content to include in the infographics. Last but not least, the co-creation exercises with members of the general public enhanced the potential effectiveness and acceptability of RE-MAP by ensuring that each intervention component was relevant, engaging, and accessible for its target audience. Additionally, some members of the general public became part of the intervention itself by providing the content and pictures underlying the success stories.

Despite the value of this process, I also faced numerous challenges throughout the intervention development.

- First, I decided not to directly use COM-B for my behavioural analysis. While this might have enabled me to identify niche constructs relevant to meat intake (e.g. attachment to meat), all barriers I identified were related to components of COM-B and using this model directly might have resulted in a more efficient production of a similar output.
- Second, it was challenging to pre-specify how many substitutes recipients could select as part of the intervention, because (i) I wanted to ensure they could cater for other household members, (ii) I wanted to provide recipients with the opportunity to try a wide range of products, and (iii) commercially available 'product units' contained different numbers of meat substitutes portions. I, therefore, decided to let recipients determine how many products they wanted to order and advised them to order enough products to cater for their households for four weeks.

- Third, it was difficult to strike a balance between scientific accuracy and engagement in the infographics, particularly because (i) the size of meat's impact on health and the environment varied considerably across the academic literature, (ii) many epidemiological studies only reported the relative risk increases rather than the absolute risk increases of developing chronic conditions at different levels of meat consumption, and (iii) directly comparing the environmental impact of meat production to other human activities is sometimes considered inappropriate (albeit still prevalent in the literature) due to the different routes through which the environment is affected by different activities.

- Lastly, developing the intervention materials required a large amount of time and financial resources, as I developed the RE-MAP infographics, success stories, and a recipe booklet from scratch. Aiming to enhance recipients' engagement with these resources, I decided to deliver the materials as colour-printed resources rather than digitally. Future research might explore how to adapt this intervention to become a more viable option to scale.

However, before spending resources on adapting RE-MAP, proof-of-concept evidence on its effectiveness is required. In the next chapter, I present the results of a randomised controlled trial testing the impact of RE-MAP on meat consumption.

Chapter 4: Replacing Meat with Alternative Plant-based Products (RE-MAP): A Randomised Controlled Trial

1. Chapter summary

Chapter 3 outlined how I developed a novel behavioural intervention (RE-MAP) aiming to reduce meat consumption by providing free meat substitutes for four weeks, plant-based recipes, infographics about the health and environmental benefits of eating less meat, and success stories of people who reduced their meat intake. This chapter reports results of a randomised controlled trial evaluating the impact of RE-MAP on recipients' meat consumption, other aspects of the diet, putative psychosocial determinants of meat and meat substitutes consumption, biomarkers of cardiovascular health, and markers of environmental degradation at four and eight weeks from baseline. In total 113 completed the nine weeks study. Relative to the control, the intervention led to a 63 g/d reduction in meat consumption at four weeks and to a 39 g/d reduction at eight weeks. The intervention increased the consumption of meat substitutes at both follow up but there was no evidence that it changed the consumption of other main food groups, energy, or macro- and micronutrient intake, except for saturated fat that decreased at both follow up, fibre that increased at the first follow up, and monounsaturated fat that decreased at the second follow up. The intervention increased intentions, attitudes, perceived norms, and perceived control to eat a low meat diet and to use substitutes, it increased the odds of adopting a reduced-meat eating identity, and it reduced meat attachment at both follow up. The intervention led to significant weight loss but there was no evidence that it affected blood pressure, blood lipid profiles, or body composition. Finally, RE-MAP reduced GHG emissions and land use from recipients' diets. I previously published parts of this chapter: Bianchi F, Aveyard P, Astbury NM, Cook B, Cartwright E, Jebb SA. Replacing meat with alternative plant-based products (RE-MAPs): protocol for a randomised controlled trial of a behavioural intervention to reduce meat consumption. BMJ Open. 2019 May 1;9(5):e027016.(267)

2. Methods

2.1 Study objectives and ethics

The primary aim of my randomised controlled trial was to examine the effectiveness of the RE-MAP intervention in reducing meat consumption compared to a no intervention control condition both during and after the intervention delivery. Additionally, the trial aimed to evaluate the impact of the intervention on the consumption of other food groups, the nutritional composition of the diet, putative psychosocial determinants of eating a low meat diet and of using meat substitutes, selected biological markers of cardiovascular health risk, and markers of environmental degradation. The trial was granted ethical approval by the Medical Sciences Interdivisional Research Ethics Committee (IDREC) of the University of Oxford (Ref: R54329/RE001) (Appendix 2).

2.2. Study design and recruitment

To evaluate the intervention, I employed a two-arm parallel group individually randomised controlled trial. The study was conducted in Oxford and I recruited participants from the general population through advertisements in public buildings, newspapers, mailing lists, and social media using variations of the leaflet shown in figure 4.1.

Fig. 4.1: Study advertisement material





Individuals contacting me per e-mail received a written information sheet summarizing the study protocol and were asked to confirm their interest in taking part (Appendix 3 and 4). I then phoned all individuals confirming their interest to provide more details on the study, answer any outstanding question, and screen them against the eligibility criteria outlined in table 4.1.

Table 4.1: Eligibility criteria

Inclusion criteria	Exclusion criteria
• ≥18 years old • self-report to eat meat regularly (≥5 times per week) • belong to an adult-only household • willing to try meat substitutes • own adequate food storing facilities • possess a device compatible with the requirements of the online food diary • provide informed consent	• have relevant food allergies • suffer from an eating disorder • report to be pregnant or plan pregnancy over the study period • belong to the same household as a previously enrolled participant • report consuming meat substitutes more than once a week on average • return baseline dietary records of insufficient quality for analysis • deemed unable to adhere appropriately to the study protocol for other reasons

All eligibility criteria were assessed at the aforementioned telephone screening, except for those pertaining to whether participants returned a baseline dietary of sufficient quality for analysis and to whether they consumed sufficient amounts of meat. These criteria were assessed based on participants' food diary returned at the baseline visit prior to randomisation. I invited all individuals who met the eligibility criteria at the first telephone screening to attend an enrolment appointment, which took place in a clinical room of Green Templeton College in central Oxford.

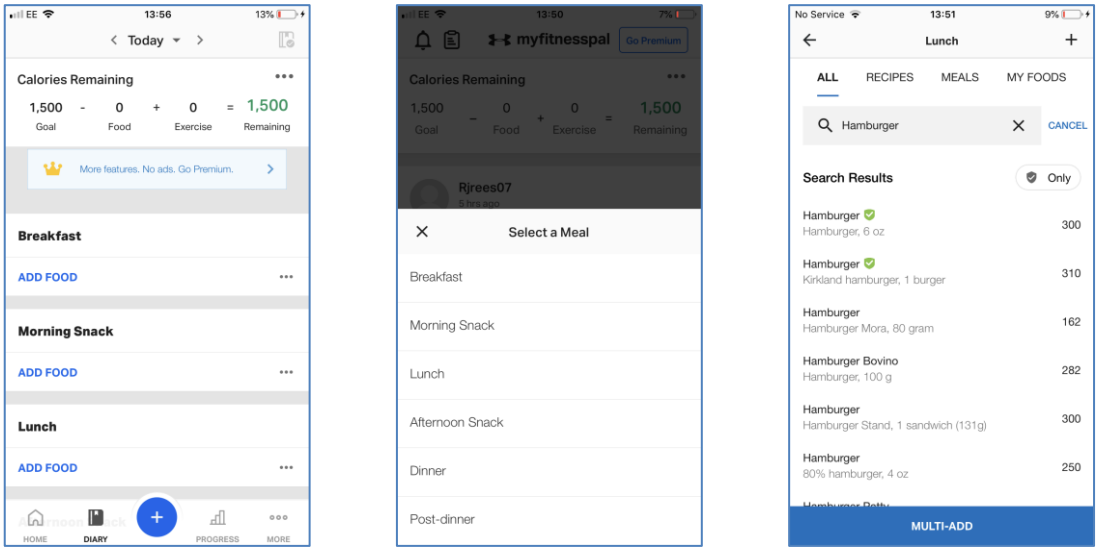
2.3 Study appointments and procedures

The study consisted of four visits: the enrolment appointment, the baseline visit, and two follow up visits. During the enrolment appointment, I collected written informed consent from interested individuals (see information sheet and informed consent in appendices 3 and 4), witnessing this by means of dated signature. I then set up the online food diaries on the phones of consenting individuals. The online food diary I used for this study was the commercially

available Myfitnesspal app (Fig. 4.2), which I selected because it allowed users to add many foods to their diary by simply scanning the barcodes and because it automatically generates data on energy, macro-, and micronutrients intake. Setting up Myfitnesspal on participants' phones involved (i) giving them free access to the app's premium feature to provide an enhanced user experience and unlock the data sharing features needed for the study, (ii) creating six possible meal entries per day (breakfast, mid-morning, lunch, mid-afternoon, dinner, and post-dinner) for the course of the study, and (iii) ensuring that I could remotely access participants' food diaries at any time over the course of the study by means of a password. During the enrolment appointment, I trained participants in how to keep an accurate food diary. This involved (i) asking them to complete a mock food diary by scanning foods into the app and inserting foods manually, (ii) estimating the weight of different foods I had brought to the visit, and (iii) instructing participants to preferably use Myfitnesspal's validated food items over the course of the study. This last step was needed because the energy and nutritional information for the food options available in Myfitnesspal rely on user-entered data, which is sometimes incomplete. Myfitnesspal checks the completeness of this nutritional information for a substantial proportion food options in their database and marks these validated items with a green tick (Fig. 4.2). I asked participants to preferably use these options to preserve data quality.

Fig. 4.2: Myfitnesspal food diary interface

Main interface | Pre-specified meals | Validated food items



Following the enrolment appointment, participants completed a seven days food diary over the week leading up to the following appointment, the baseline visit (T0). Participants not keeping sufficiently detailed diaries and those eating meat on less than five eating occasions over the week were discontinued. During the baseline visit I collected the food diaries, asked participants to answer an online psychosocial questionnaire, and measured participants' blood lipids profile, blood pressure, weight, and body composition. During the baseline visit, I also collected data on participants' demographic characteristics, their self-control, and their levels of food neophobia. At the end of the baseline visit I randomised participants to one of the two study conditions.

Participants allocated to the intervention group received the four weeks RE-MAP intervention involving the provision of free meat substitutes for the household, infographics about the health and environmental benefits of eating less meat, success stories of people who reduced their meat consumption, and recipes, as described in chapter 3. Participants allocated to the control condition received no support to reduce their meat consumption.

I invited all participants to attend a follow up visit four weeks later - at the end of the intervention and control period - and another follow up visit at eight weeks from baseline, i.e. four weeks after the completion of the intervention and control period. I asked participants to keep a seven-days food diary over the seven days leading up to each of these follow up visits. During the follow-up appointments, I collected the respective food diaries, and collected the same outcome measures that were collected at the baseline, including the psychosocial questionnaire, blood lipids, blood pressure, weight, and body composition.

2.4 Sample size

Due to the lack of research studies directly comparable to the RE-MAP trial, I made the pragmatic *a-priori* decision to terminate recruitment once 100 volunteers had completed the four

weeks follow-up, which was the primary end-point of the study. This decision was primarily based on practical considerations regarding the time and financial constraints of my DPhil. A power analysis based on this pragmatically selected sample size suggested that 100 participants completing the primary outcome measure would be sufficient to detect a medium effect size of d=0.6 with a power of 1-beta=0.84 and a two-tailed alpha criterion of p=0.05. I considered this to offer sufficient statistical power to detect an effect worth detecting, considering the high intensity, duration, and financial cost of the intervention.

2.5 Randomisation and blinding

Participants' group allocation was based on a computer-generated randomisation sequence, produced by an independent statistician. The randomisation sequence was designed to individually allocate participants to the intervention or control condition in a 1:1 ratio and to achieve a proportional sex balance in the two conditions through sex stratification and random blocks of four or eight participants.

I was blind to the randomisation sequence throughout the study. The group allocation for each participant was revealed to me through a bespoke randomisation programme after the baseline food diary had been returned. Due to the nature of the intervention, both participants and myself were not blind to participants' group allocation after randomisation. As such, to reduce the risk of social desirability bias affecting participants' food diaries and questionnaire responses, I frequently reminded participants that there were no right or wrong answers, that all data collected was anonymised, and that nobody in the research team was going to judge their eating habits. To reduce the risk of bias during data coding and data entry, the members of the research team responsible for coding the food diaries and entering the data in a bespoke online database were blind to participants' group allocation.

2.6 Outcomes

2.6.1 Primary outcome

The primary outcome was the change in the mean daily grams of meat consumed between the baseline (T0) and the four-week follow-up (T1).

2.6.2 Secondary outcomes

The secondary outcomes were:

- the change in mean daily grams of meat consumed between the baseline (T0) and the eight-week follow-up (T2)
- the change in the intention to eat a low meat diet between the baseline (T0) and both follow-up (T1, T2)
- the change in attachment to meat, eating identities, and in attitudes, perceived behavioural control, and subjective social norm of eating a low meat diet between the baseline (T0) and both follow-up (T1, T2)

2.6.3 Pre-specified exploratory outcomes

The pre-specified exploratory outcomes were:

- the change in the number of meals containing foods from other main food groups between the baseline (T0) and both follow-up (T1, T2)
- the change in mean daily intake of energy and selected macro-, and micronutrients between the baseline (T0) and both follow-up (T1, T2)
- the change in intentions, attitudes, perceived behavioural control, and subjective social norms of using meat substitutes between the baseline (T0) and both follow-up (T1, T2)
- the change in blood lipid profiles (total cholesterol, HDL cholesterol, triglycerides, LDL cholesterol, non-HDL cholesterol, LDL:HDL cholesterol ratio) between the baseline (T0) and both follow-up (T1, T2)

- the change in systolic and diastolic blood pressure between the baseline (T0) and both follow-up (T1, T2)
- the change in body mass index between the baseline (T0) and both follow-up (T1, T2)
- the change in body fat percentage between the baseline (T0) and both follow-up (T1, T2)
- the change in the desire for meat-substitutes to be similar to meat between the baseline (T0) and both follow-up (T1, T2)

2.6.4 Additional exploratory outcomes

I conducted two additional post-hoc exploratory analyses to estimate the environmental impact of the RE-MAP intervention, which were not pre-specified in the protocol. These analyses focused on following outcomes:

- the change in GHG emissions associated with participants' overall weekly diet and weekly consumption of main food groups between the baseline (T0) and both follow-up (T1, T2)
- the change in land use associated with participants' overall weekly diet and weekly consumption of main food groups between the baseline (T0) and both follow-up (T1, T2)

2.7 Measurements

This section outlines when and how the study outcomes were measured. Table 4.2 provides a summary of the trial activities and outcome measurements at each stage of the trial.

Table 4.2: Study activities and outcomes collection schedule

	Telephone screening	Enrolment visit	Baseline visit	4 week follow-up	8 week follow-up
Enrolment					
Eligibility screening	X				
Informed consent		X			
Randomisation			X		
Intervention					
RE-MAP					
Control					
Demographic and psychosocial traits (Questionnaire sample in appendix 5)					
Demographics			X		
Food neophobia			X		
Self-control scale			X		
Dietary measurements (Questionnaire sample in appendix 5)					
Food diary			X	X	X
Retrospective eating questionnaire			X	X	X
Psychosocial variables (Questionnaire sample in appendix 5)					
Attitude towards eating a low meat diet and using meat substitutes			X	X	X
Perceived behavioural control of eating a low meat diet and using meat substitutes			X	X	X
Subjective social norm of eating a low meat diet and using meat substitutes			X	X	X
Intention to eat a low meat diet and to use meat substitutes			X	X	X
Attachment to meat			X	X	X
Eating identity			X	X	X
Desire for similarity between meat and meat substitutes			X	X	X
Biophysical outcomes					
Height			X		
Weight			X	X	X
Body composition			X	X	X
Blood pressure			X	X	X
Blood lipids profile			X	X	X
Environmental outcomes (Methodological assumptions in appendix 6)					
GHG emissions			X	X	X
Land use			X	X	X

2.7.1 Socio-demographic characteristics

- **Demographic characteristics:** At the baseline, participants were asked to self-report on their age, sex, highest degree, household income, household composition, ethnicity, and nationality. These data will be collected through an online questionnaire.

2.7.2 Psychological trait characteristics

- **Food neophobia:** At the baseline, participants' trait food neophobia was measured using a questionnaire scale adapted from Pliner and Hobden including six items with a 7-point scale (disagree strongly – agree strongly).(306)

- **Self-control:** At the baseline, participants' self-control was assessed using a questionnaire scale adapted from Tangney et al. including eight items with a 7-point scale (disagree strongly – agree strongly).(307)

2.7.3 Dietary measurements

- **Meat consumption:** Meat consumption was measured in grams per day by disaggregating meat and meat containing products recorded on participants' seven days food diaries. I developed a disaggregation procedure that involved (i) estimating the weight of the overall product, (ii) estimating the proportion of the product that was meat, (iii) converting the weight of uncooked meat to the weight of cooked meat, if appropriate, and (iv) categorising meat into the different sub-types. Each step is described in more detail below.

  Estimating the weight of meat-containing products: To estimate the portion size of meat-containing products, I developed the following method: If participants reported the weight of a product in grams, then I used the self-reported weight for the

disaggregation process. If participants did not reported the weight of the product but reported the its brand, then I used publicly accessible resources to find the weight of the specific branded product. If no brand information was provided, I used the Food Standard Agency (FSA) Portion Size Manual to estimate the weight of the product based on a suitably similar product. If the FSA Portion Size Manual did not have information on a suitably similar product, I searched for the weight of similar products on the website of the largest UK retailer. If this website also did not provide information about the weight of a similar product, I searched for this information on other online resources or on the webpage of other UK retailers.

Disaggregating meat from meat-containing products: Once the weight of a meat containing product was established, it was necessary to estimate the proportion of this weight consisting of edible meat. For example, in a 400 grams Sainsbury's ready-made lasagne, only 68 grams are beef. I developed following rules to guide this work: If the product weight was based on a specific supermarket product, I used the ingredient list of that specific product to determine the proportion of the product weight consisting of meat. If the product weight was based on the FSA Portion Size Manual, I used the database outlining the meat content of many meat-containing products used by the National Diet and Nutrition Survey (NDNS). If there was no sufficiently similar product on the NDNS disaggregation database, I used the ingredient list of a suitably similar product sold by a UK retailer to estimate the proportion of the product weight consisting of meat. If the quantity of meat within a meat-containing product was not reported on the ingredient list, I assumed it was 1.5% of the product weight. This is because supermarkets are required to provide the specific amount of any ingredient making up 2% or more of the overall product (Quantifiable Ingredient Declaration, QUID) and because any ingredient making up less than 5% of the overall product weight is rounded

to the nearest 0.5. When participants reported the weight of a meat product that typically contains bones (e.g. pork rib, chicken wing), I assumed the weight referred to the meat only, unless it was otherwise stated. If the product weight explicitly included the bones weight, I used McCance and Widdowson's edible conversion fractions to calculate the meat weight without the bone.(308) I assumed that the fat of meat products was consumed, unless otherwise stated. When more than one interpretation of the aforementioned rules was possible, I made the assumption resulting in overestimating participants' meat consumption. For example, if a participant reported the weight of a meat-containing pizza without specifying if it was thin crust or deep pan, I assumed it was thin crust to allocate a greater proportion of the weight to the toppings and therefore to the meat.

Converting meat in cooked weight: The last step involved converting the weight of meat products recorded as uncooked to the equivalent cooked weight, when appropriate. To perform these conversions, I used the cooking weight change fractions of McCance and Widdowson. These fractions describe the percentage weight change of specific meat products that occur throughout the cooking process. If participants did not specify whether they recorded the weight of meat containing items as cooked or uncooked but provided additional brand and portion size information (e.g. 1 Herta Frankfurter, 35g), I checked the branded product online to determine whether the weight was reported as cooked (e.g. Herta Frankfurter packaging states that 1 raw frankfurter is 35g). If this did not provide sufficient information to determine whether the reported weight was for the cooked or uncooked product, I assumed that the product was recorded as cooked to make the assumption resulting in the largest amount of estimated meat consumption. Similarly, if no specific cooking method was reported, I assumed that the product was cooked with the method linked with the lowest percentage weight reduction.

Categorisation of meat: All disaggregated meat products were then categorised as being either processed or unprocessed red ruminant meat, pork meat, white meat, or game and other meats. Processed meat was defined as meat that had been transformed through salting, curing, fermentation, smoking or other processes to enhance flavour or improve preservation. Some of the most commonly reported processed meat products included sausages, bacon, ham, corned beef, burgers, meatballs, and black pudding. Unprocessed meat was defined as meat not undergoing any of the aforementioned processes, but included meat that underwent basic mincing.

I excluded the food diary days in which energy intake was <1000 kcal, which I considered unlikely to represent habitual consumption. This threshold was set arbitrarily due to pragmatic constraints of my DPhil. Employing an energy intake thresholds that was tailored to the specific energy requirements of different participants (e.g. based on age and sex) would have been a more sophisticated approach but would have been practically more difficult to implement. Future studies might consider setting different thresholds for men and women, as a reasonable proxy for the energy requirement of different participants. No upper limit was used to exclude dietary days, as I considered it unlikely for people to mistakenly add foods that they did not consume. Other specific assumptions used to disaggregate or categorise meat products are reported in Box 4.1. I was assisted in enacting this protocol to obtain estimates of disaggregated meat consumption with the support of a research assistant.

Box 4.1: Assumptions used to disaggregate meat products in participants' 7 days food diaries

a. If unspecified, salami, chorizo, and pepperoni was assumed to be made with pork meat.
b. If unspecified, schnitzel was assumed to be pork meat.
c. If a branded processed meat product contains >1 type of processed meat (e.g. pepperoni often contains a mix of beef and pork), I decided to record it as 100% of the first meat listed for simplicity.

d. When participants reported eating a bacon/sausage roll or burger without specifying the quantity of bacon/sausage, it was assumed it contained two rashers of bacon or two sausages.
e. If unspecified, meatballs were considered to be made with beef.
f. If unspecified, 'gyoza' and 'dumplings' were assumed to be made with pork.

- **Number of meals containing other foods:** The consumption frequency of other food groups was measured by counting the meals in participants' seven days food diaries containing:
    - Unprocessed pork meat
    - Unprocessed red meat from ruminants
    - Unprocessed poultry or game meat
    - Processed meat
    - Mycoprotein meat substitutes
    - Soy-based or textured vegetable protein meat substitutes
    - Other meat substitutes (e.g. bean burgers)
    - Milk and yoghurt
    - Cheese
    - Dairy-free milk and yoghurt alternatives
    - Dairy-free cheese alternatives
    - Fish and seafood
    - Eggs
    - Pulses other than those in meat substitutes
    - Vegetables other than those in meat substitutes
    - Starchy foods other than those in meat substitutes
    - Nuts and seeds other than those in meat substitutes
    - Fruit
    - Savoury and sweet snacks
    - Soft drinks
    - Alcoholic drinks

Composite meals, such as ready meals and composite homemade meals were split into the different food groups they contained. If participants reported a specific branded product, I used the ingredient list of the specific product to determine the main food groups contained in said product. If no branded product was specified, I used the ingredient list of suitably similar commercially available products sold by the largest UK retailer. For home-made composite dishes, I used the ingredient list from the BBC Good Food recipe website to determine the main food groups contained in the product. For example, if a participant reported eating a 'home-made cottage pie' and gave no indication of what it contained, I assumed it contained one serving of meat, one of starchy food, and one of vegetables. As I did for disaggregated meat consumption, I excluded the food diary days in which energy intake was <1000 kcal also for this measure.

I also used a retrospective eating questionnaire asking participants to recall the number of eating occasions on which they had the foods listed above over the week of their food diary. When designing the study, I decided to include this questionnaire as a contingency plan, since I was not confident that participants would complete their food diaries. Since this was not the case, I only used the responses to this retrospective questionnaire in sensitivity analyses.

- **Energy and nutritional intake:** The daily average energy intake and nutritional composition of participants' diets was measured using data exported from the seven days online food diaries. The macronutrients captured by Myfitnesspal included total fat, saturated fat, monounsaturated fat, polyunsaturated fat, fibre, protein, total carbohydrate, and sugar. The micronutrients captured by the food diary included sodium, iron, calcium, potassium, vitamin A, vitamin C. Zinc was not measured as part of this trial because it could

not be automatically captured through the digital food diary employed for the study. I excluded the food diary days in which energy intake was <1000 kcal for estimating participants' average daily energy and nutritional intake.

2.7.4 Psychosocial variables

- **Meat attachment:** Attachment to meat was measured using the validated sixteen items meat attachment questionnaire. This questionnaire provided sub-scores for meat hedonism, dependence to meat, affinity to meat, and entitlement to eat meat.(283)
- **Eating identity:** The online questionnaire asked participants to report whether they identified as meat-eater, omnivore, flexitarian, pescatarian, vegetarian, vegan, or to specify another eating identity ("*When it comes to your eating identity, which of these do you identify with the most?"*). Those identifying as 'meat eaters' and 'omnivores' were coded as having a 'meat-eating' identity, those identifying as 'flexitarians' were coded as having a 'meat reducing' identity, and those identifying as 'pescatarian', 'vegetarian', or 'vegan' were coded as having a 'non meat-eating' identity.

- **Theory of planned behaviour variables:** Attitudes, subjective social norms, and perceived behavioural control to eat a low meat diet and to use meat substitutes were assessed using three questionnaire items designed following Francis et al. (309) on a 7-point scale (disagree strongly – agree strongly). Intentions to eat a low meat diet and to use meat substitutes were assessed using a single item on a 7-point scale (disagree strongly – agree strongly).

- **Desire for similarity between meat and substitutes:** Participants' desire for meat substitutes to be similar to meat was assessed using 11 questionnaire items asking participants whether they wanted different aspects of meat substitutes (e.g. their taste, texture, smell etc) to be as similar as possible to meat on 7-point scale (disagree strongly –

agree strongly). Participants were also asked whether they wanted meat substitutes to be as similar to meat as possible overall. This scale was adapted from Hoek et al. (310)

2.7.5 Physical measures

- **Blood lipids:** Blood lipids profiles (total cholesterol, HDL cholesterol, triglycerides, LDL cholesterol, non-HDL cholesterol, LDL:HDL cholesterol ratio) were measured with a finger prick blood sample using Alere Cholestech LDX® device.

- **Height:** Height was measured to the nearest 0.1cm using a stadiometer. Participants were asked to remove their shoes before their height was measured.

- **Weight:** Weight and body composition were measured using an electronic scale (SC-240 MA, Tanita Japan), which recorded participants weight to the nearest 0.1kg and measured the proportion of body fat to the nearest percentage point using bioelectrical impedance.

- **Blood pressure:** Seated systolic and diastolic blood pressure were measured as the average of the second and third reading of three seated readings.

2.7.6 Environmental outcomes

- **GHG emissions from diet:** The GHG emissions linked with participants' weekly diets were estimated in kg of CO_2-eq for ruminant meat, pork meat, white meat, and all other food groups for which I assessed consumption frequency through prospective food diaries (see section 2.7.3). Estimating GHG emissions involved three steps:

  First, I estimated participants' consumption quantity of the different food groups in grams per week. For meat products, I used the data from disaggregated food diaries to

estimate these quantities. For other food groups, I multiplied the 'number of weekly meals' containing a specific food group (as assessed through the prospective food diaries) by a standard portion size for said food. Portion sizes were primarily estimated using data from the British Nutrition Foundation and British Dietetic Association portion size booklets. The specific portion sizes and data sources used to estimate consumption of each food group are reported in Appendix 6.

Second, I estimated the kg of CO_2-eq emitted to produce 1 gram of each food group included in my analysis using the publicly available database by Poore and Nemecek.(24) As this database did not include any information on the environmental impact of mycoprotein (or a reasonable proxy thereof), I used the results of a separate lifecycle analysis conducted by Head and colleagues to estimate the GHG emissions associated with producing mycoprotein.(311)

Third, I estimated the weekly GHG emissions of participants' diets by multiplying their consumption of different foods (in grams/week) times the GHG emissions of these foods (in kg of CO_2-eq/gram of food produce). As it was impossible to make reasonable assumptions about the environmental footprint of 'snacks' without more granular information about this food group, snacks were excluded from this analysis.

- **Land use from diet:** The land use (in m^2) associated with participants' weekly diets was estimated by applying the same methodology, data sources, and assumptions as those employed to estimate GHG emissions, except that I multiplied participants' consumption of food groups (in grams/week) times the m^2 of land used to produce 1 gram of each food included in the analysis.

Similar to the analysis on GHG emissions, data on the land required to produce the foods included in this analysis were based on the database by Poore and Nemecek, except for the data on mycoprotein, which was extrapolated from the lifecycle analysis by Head and colleagues.(24,311) Appendix 6 outlines the estimated GHG emissions in kg of CO_2-eq/g and the land use in m^2/g of each food included in this analysis, together with the underlying data sources and assumptions.

2.7.7 Adverse consequences

- Any study-related adverse event was recorded and reported to the Research Ethics Committee in accordance to Good Clinical Practice (GCP).

2.8 Retention

I used reminder text messages to increase attendance to the four study visits. Additionally, participants received a financial compensation for partaking in each of the 3 assessment visits. Participants were informed that they had the right to withdraw from the study at any time and that I had the right to discontinue them from the study if they became ineligible and/or significantly deviated from the study protocol. The data of withdrawn participants was only deleted if participants explicitly requested this.

2.9 Statistical analysis plan

2.9.1 Descriptive statistics

I used descriptive statistics to characterise the sample in terms of age, gender, ethnic origin, household income, highest educational attainment and the baseline level of each study outcome. The results of these analyses were reported as mean and standard deviation for continuous variables and as count and percentage for categorical variables. I treated responses to likert scales

as continuous variables to allow for more meaningful analyses of these outcomes. Descriptive statistics were reported separately for the intervention and control group.

2.9.2 Definition of population for analysis and imputation techniques

Following the intention to treat approach, participants were analysed according to the study group they were allocated to, irrespective of the treatment they actually received. The main analysis was based on available data points only, as I primarily aimed to investigate the intervention effect among people who remained engaged with the programme in this early proof of concept trial. For total, processed, and unprocessed meat consumption, I conducted sensitivity analyses imputing missing data with a Baseline Observation Carried Forward (BOCF) approach.

2.9.3 Statistical analysis of meat consumption and other continuous outcomes

To determine whether the changes in meat consumption at the four and eight week follow up differed significantly between the intervention and the control group, I employed linear mixed effects models. I included fixed effects for randomised group, visit, the interaction between visit and randomised group, baseline meat consumption, and sex. I included random effects for participants' intercept and slope to account for repeated measures on the same participant. The mixed effect models tested the null hypothesis that there was no intervention effect on meat consumption. The null hypothesis was tested against a two-tailed criterion p-value of alpha=0.05. The adjusted treatment effects were reported with their 95% confidence intervals. The same statistical approach was employed to test whether the intervention led to significant changes in all other secondary and exploratory continuous outcomes.

2.9.4 Statistical analysis of categorical outcomes

Participants' eating identity was the only outcome treated as categorical. To determine whether the intervention increased participants' odds of adopting a reduced- or non-meat eating identity at the four and eight week follow up I employed an ordinal logistic regression model. Three categories of dietary identity were included in the model and ordered as follows:

1. **Non-meat eating identity**, including vegetarians, vegans, and pescatarians
2. **Reduced meat eating identity**, including flexitarians
3. **Meat eating identity**, including omnivores and meat eaters

The outcome of the ordinal logistic regression model was participants' dietary identity at the four and eight week follow up, and the predictors were the randomised group, visit, the interaction between visit and randomised group, baseline eating identity, and sex. The ordinal logistic regression model tested the null hypothesis that there was no intervention effect on eating identities. The null hypothesis was tested against a two-tailed criterion p-value of alpha=0.05. The adjusted treatment effects were reported as odds ratios (OR) and the respective 95% confidence intervals. The odds ratios described the odds of moving up one category on the aforementioned list of eating identities (e.g. moving from meat eating identity to reduced-meat eating identity) in the intervention group over the odds of moving up one category on the same list of eating identities in the control group.

2.9.5 Interaction between intervention effect and baseline characteristics

To explore whether the intervention impact on total, processed, and unprocessed meat consumption was influenced by participants' self-control, I conducted mixed effects linear models with an additional interaction effect. The fixed effects included in these models were a three-way interaction term between randomised group, visit, and self-control, the main effects of each of these variables, and sex. The random effects included in the models were participants' intercept and slope to account for repeated measures on the same participant. In these analyses,

participants' self-control was treated as a dichotomous outcome to describe those above and those below the median level of self-control.

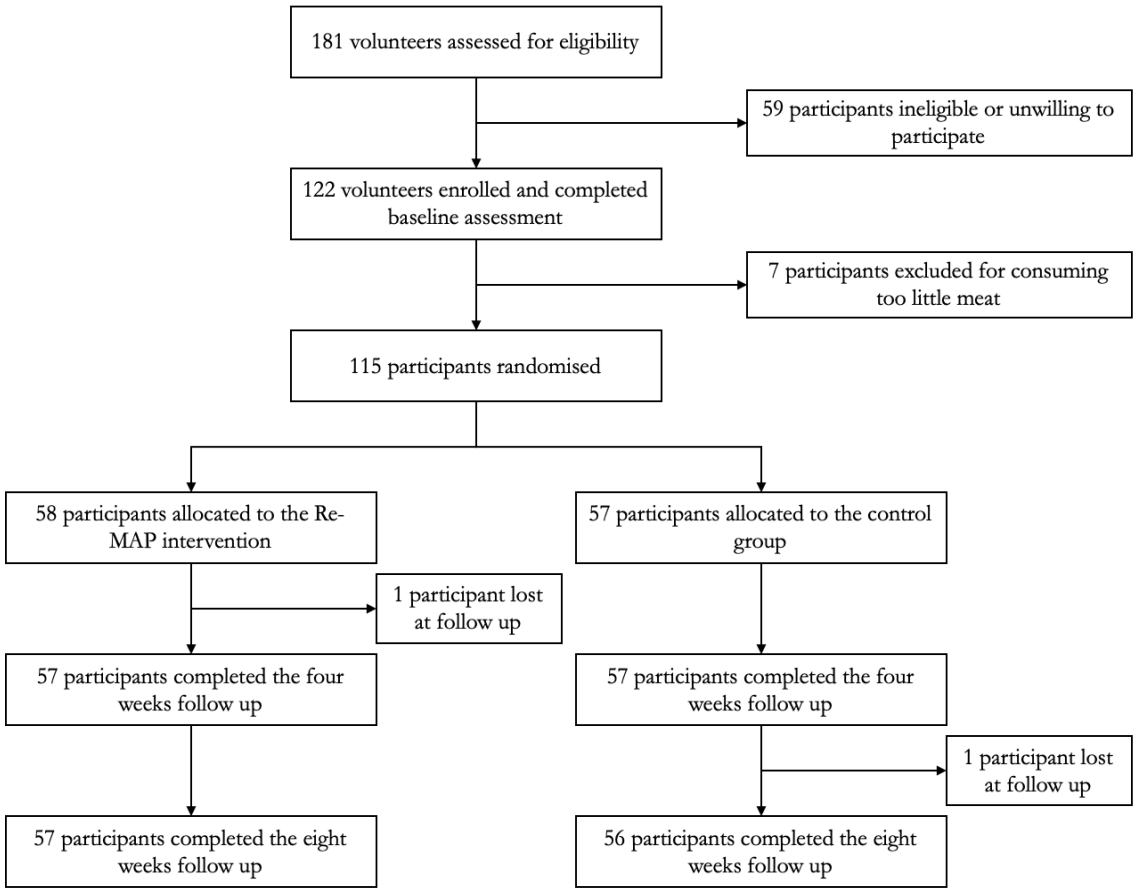
The mixed effect models tested the null hypothesis that there was no significant interaction effect between participants' baseline meat consumption, the intervention, and the study visit. The null hypothesis was tested against a two-tailed criterion p-value of alpha=0.05. The same statistical approach was employed to test whether the intervention impact on total, processed, and unprocessed meat consumption changed depending on their food neophobia (dichotomised at the sample median) or sex (dichotomised as male and female). In the models testing the interaction between the intervention effect and sex, I did not include sex as a separate fixed effect factor since this variable was already included as an interaction and main effect as part of the three way interaction term. All statistical analyses were undertaken in Stata 16.0.

3. Results

3.1 Recruitment and baseline demographic characteristics

All participants were recruited between the 29th of June 2018 and the 10th of October 2019. In total, 181 volunteers contacted the research team to enrol in the study and 122 met the eligibility criteria at the first screening and consented to take part in the study. Of the 122 participants who enrolled, seven were excluded after the baseline assessment because their meat consumption was below the eligibility criteria. These participants were not randomised. Of 115 randomised participants, 58 were allocated to receive the intervention and 57 were allocated to the control group. Two participants were lost at follow up, one in each study group (Fig. 4.3).

Fig. 4.3: Trial profile



Values refer to participants providing data for the primary outcome

The baseline demographic characteristics were well balanced between study groups (Table 4.3). The mean age of participants was 35 (SD=11) years, 75 were female (65%), and 79 (69%) were

British. Overall most participants had a University degree, with 44% having obtained a Bachelor or equivalent as their highest degree and 41% having obtained a higher degree. The median annual income at the baseline was £20.000 – £29.000 pa. Forty-six participants lived with a partner, 30 lived in a household with another adult, and 27 lived in a single household.

Table 4.3: Baseline demographic characteristics

	Control (N=57)	Intervention (N=58)
Age in years	37 (12)	33 (11)
Gender		
female	37 (65%)	38 (66%)
male	19 (33%)	19 (33%)
Other or prefer not to say	1 (2%)	1 (2%)
Ethnic origin		
White	43 (75%)	50 (86%)
Chinese	2 (4%)	4 (7%)
Black Caribbean	0 (0%)	1 (2%)
Black African	1 (2%)	0 (0%)
Other or prefer not to say	9 (16%)	3 (5%)
Household income		
£0-£9,999	1 (2%)	1 (2%)
£10,000 - £19,999	7 (12%)	7 (12%)
£20,000 - £29,999	14 (25%)	8 (14%)
£30,000 - £39,999	9 (16%)	10 (17%)
£40,000 - £49,999	4 (7%)	3 (5%)
£50,000 - £59,999	4 (7%)	8 (14%)
£60,000 - £69,999	4 (7%)	5 (9%)
£70,000+	4 (7%)	10 (17%)
Do not know or prefer not to say	10 (18%)	6 (10%)
Highest educational degree		
GCSE or equivalent	1 (2%)	4 (7%)
A-level or equivalent	5 (9%)	7 (12%)
BSc or equivalent	23 (40%)	28 (48%)
Higher degree (MSc, PhD or equivalent)	28 (49%)	19 (33%)

Data are mean and standard deviation or number and percentage

3.2 Intervention impact on meat consumption

The primary outcome was total meat consumption at the four weeks follow up measured from seven days food diaries. On average, participants' food diaries contained 6.9 (SD=0.3) valid

days at the baseline, 6.8 (SD=0.4) valid days at the four weeks follow up, and 6.8 (SD=0.5) valid days at the eight weeks follow up. At the baseline, participants consumed 132 g/d (SD=75) of total meat. Baseline meat consumption by study group is reported in table 4.4.

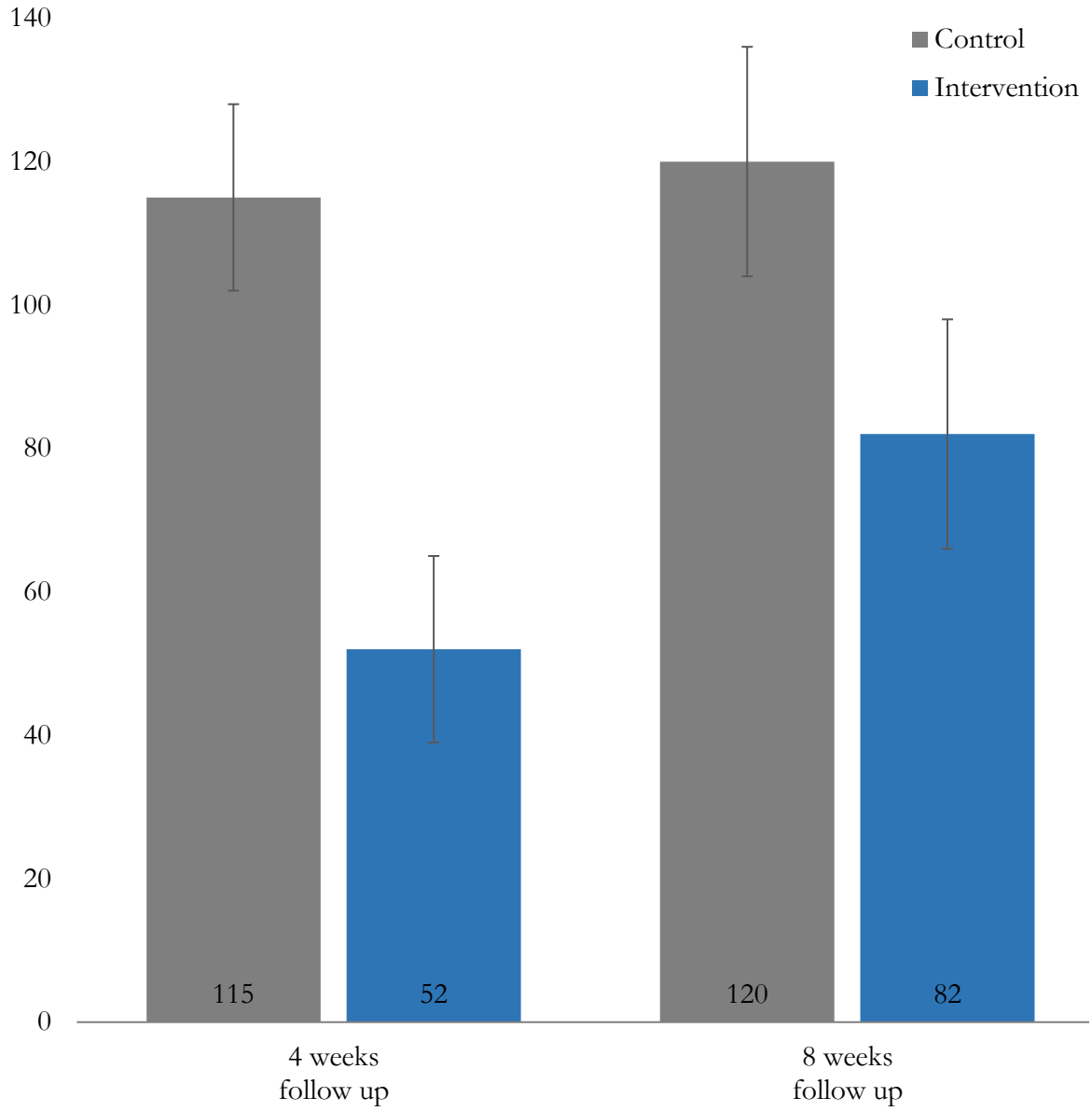
Table 4.4: Baseline meat consumption in g/d

	Control (N=57)	Intervention (N=58)
Total meat	134 (72) Range: 24 to 326	130 (79) Range: 18 to 358
Total processed meat	44 (38) Range: 0 to 187	52 (52) Range: 0 to 275
Total unprocessed meat	90 (56) Range: 14 to 249	77 (63) Range: 0 to 310
Red meat	78 (58) Range: 3 to 257	75 (63) Range: 3 to 324
Red processed meat	39 (37) Range: 0 to 187	44 (48) Range: 0 to 224
Red unprocessed meat	39 (43) Range: 0 to 219	31 (42) Range: 0 to 234
Red ruminant meat	33 (29) Range: 0 to 130	28 (29) Range: 0 to 143
Red ruminant processed meat	8 (13) Range: 0 to 55	7 (13) Range: 0 to 51
Red ruminant unprocessed meat	25 (28) Range: 0 to 87	21 (25) Range: 0 to 143
Pork meat	45 (44) Range: 0 to 196	48 (50) Range: 0 to 231
Pork processed meat	31 (32) Range: 0 to 157	37 (42) Range: 0 to 182
Pork unprocessed meat	14 (27) Range: 0 to 157	11 (26) Range: 0 to 159
White meat	55 (42) Range: 0 to 193	53 (40) Range: 0 to 170
White processed meat	5 (10) Range: 0 to 43	8 (14) Range: 0 to 73
White unprocessed meat	51 (39) Range: 0 to 193	45 (38) Range: 0 to 170
Game meat	1 (3) Range: 0 to 21	1 (4) Range: 0 to 18
Game processed meat	0 (1) Range: 0 to 6	0 (2) Range: 0 to 14
Game unprocessed meat	1 (3) Range: 0 to 21	1 (4) Range: 0 to 18

Data are mean meat consumption g/d, standard deviations, and ranges disaggregated from 7 days food diaries.

Adjusted total meat consumption at the four weeks follow up was 115 g/d (95% CI 102 to 128) in the control group and 52 g/d (95% CI 39 to 66) in the intervention group. At the eight weeks follow up, adjusted total meat consumption was 120 g/d in the control group (95% CI 104 to 137) and 82 g/d in the intervention group (95% CI 66 to 98) (Fig. 4.4).

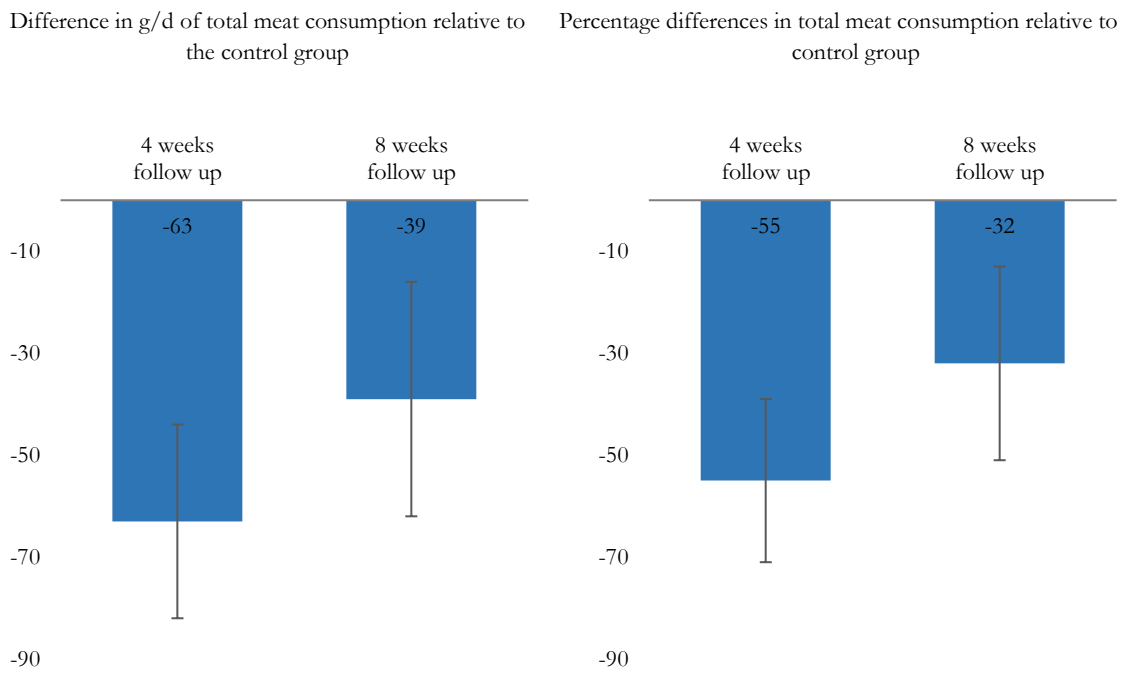
Fig. 4.4: Total meat consumption in g/d



Mixed effect models with fixed effects for randomised group, baseline meat consumption and gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. N=114 at four weeks and N=113 at eight weeks.

Relative to the control group, the intervention led to a 63 g/d (95% CI 44 to 82, p<0.0001) reduction in meat consumption at the four weeks follow up and to a 39 g/d (95% CI 16 to 62, p=0.0009) reduction at the eight weeks follow up (Fig. 4.5). These differences represented a 55% and a 32% reduction in meat consumption relative to the control group at the four and eight weeks follow up, respectively (Fig. 4.5).

Fig. 4.5: Adjusted differences in total meat consumption relative to the control group

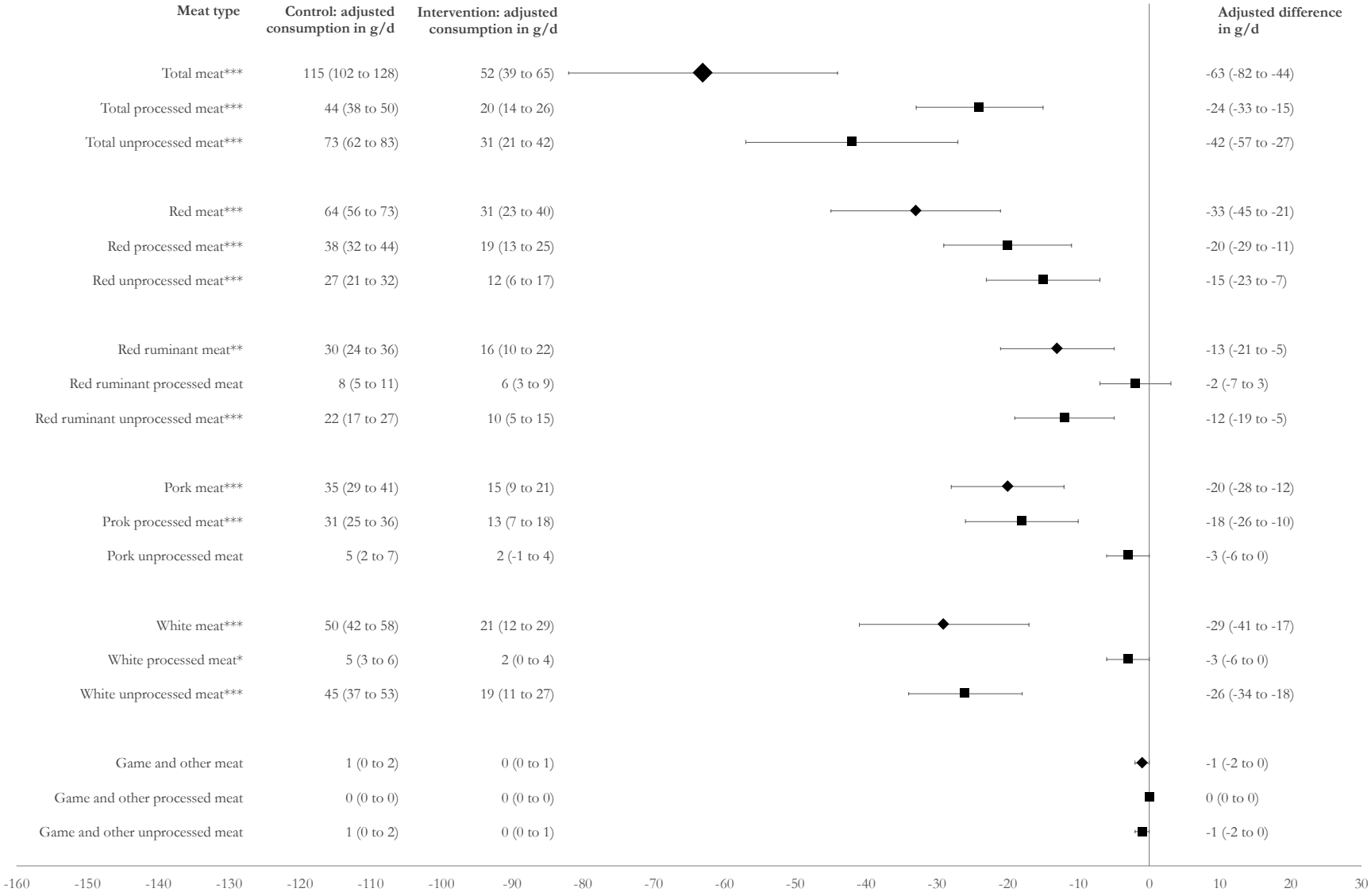


Mixed effect models with fixed effects for randomised group, baseline meat consumption and gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. N=114 at four weeks and N=113 at eight weeks.

3.2.1 Intervention impact on sub-types of meat

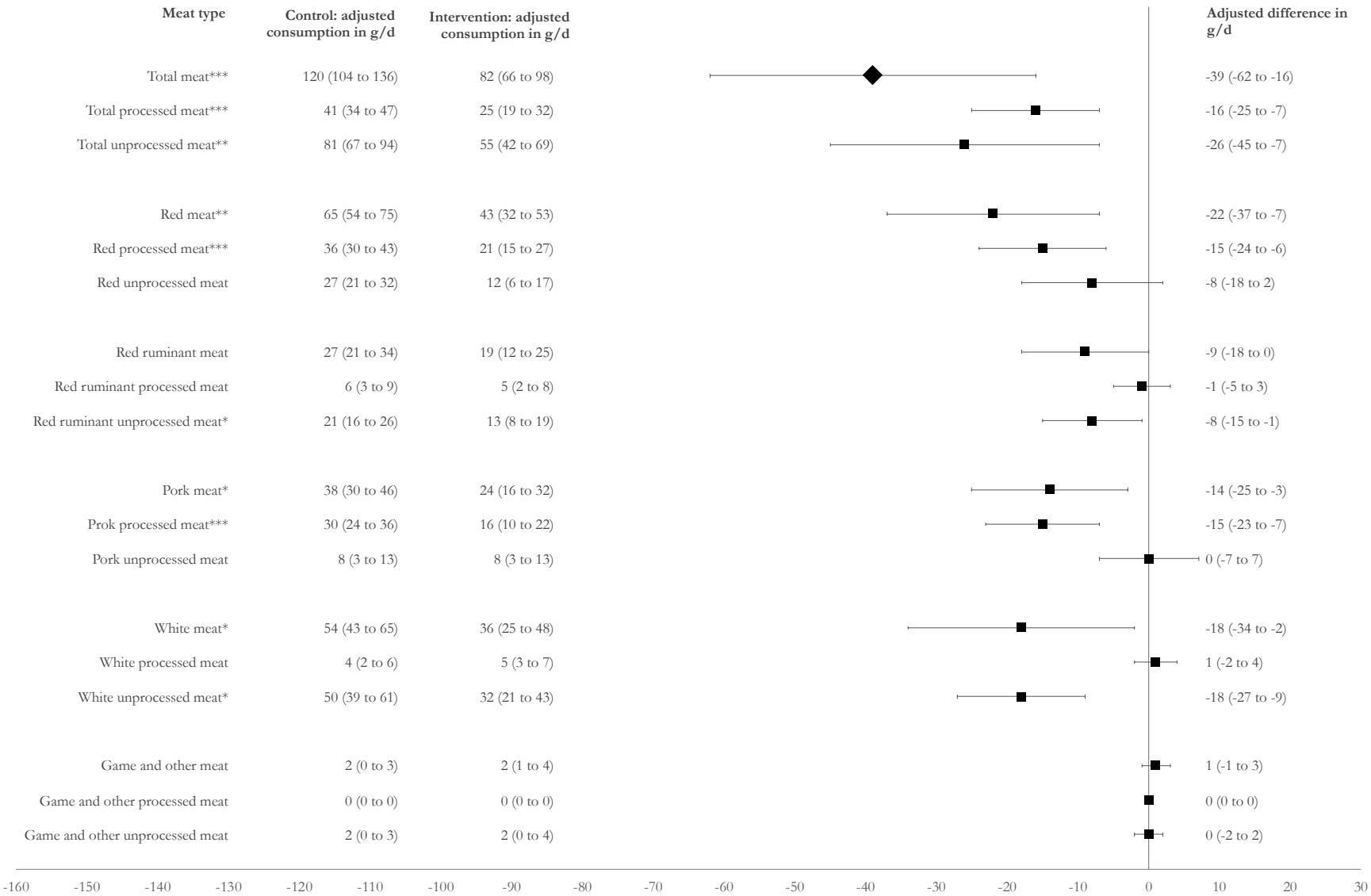
Exploratory analyses suggested that at the four weeks follow up, the intervention led to a 42 g/d reduction in unprocessed meat consumption and a 24g/d reduction in processed meat consumption relative to the control group (95% CI 27 to 57 and 95% CI -15 to -32, both $p<0.0001$). These effects respectively represented a 57% and a 54% difference in unprocessed and processed meat consumption between the intervention and the control group. At the four weeks follow up, the intervention significantly reduced the consumption of all other sub-types of processed and unprocessed meat relative to the control group, except for processed red ruminant meat, unprocessed pork meat, and game meat (Fig. 4.6). The aforementioned group differences in meat consumption were of smaller magnitude at the eight weeks follow up but continued to be statistically significant, except for those pertaining to red ruminant meat, unprocessed red meat, and processed white meat. All meat sub-types for which there was no evidence of an intervention effect at the four weeks follow up were not found to be affected by the intervention at eight weeks (Fig. 4.7).

Fig. 4.6: Impact of the intervention on meat consumption in g/d at the four weeks follow up



Mixed effect models with fixed effects for randomised group, baseline consumption of the respective meat type and gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. N=114. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

Fig. 4.7: Impact of the intervention on meat consumption in g/d at the eight weeks follow up

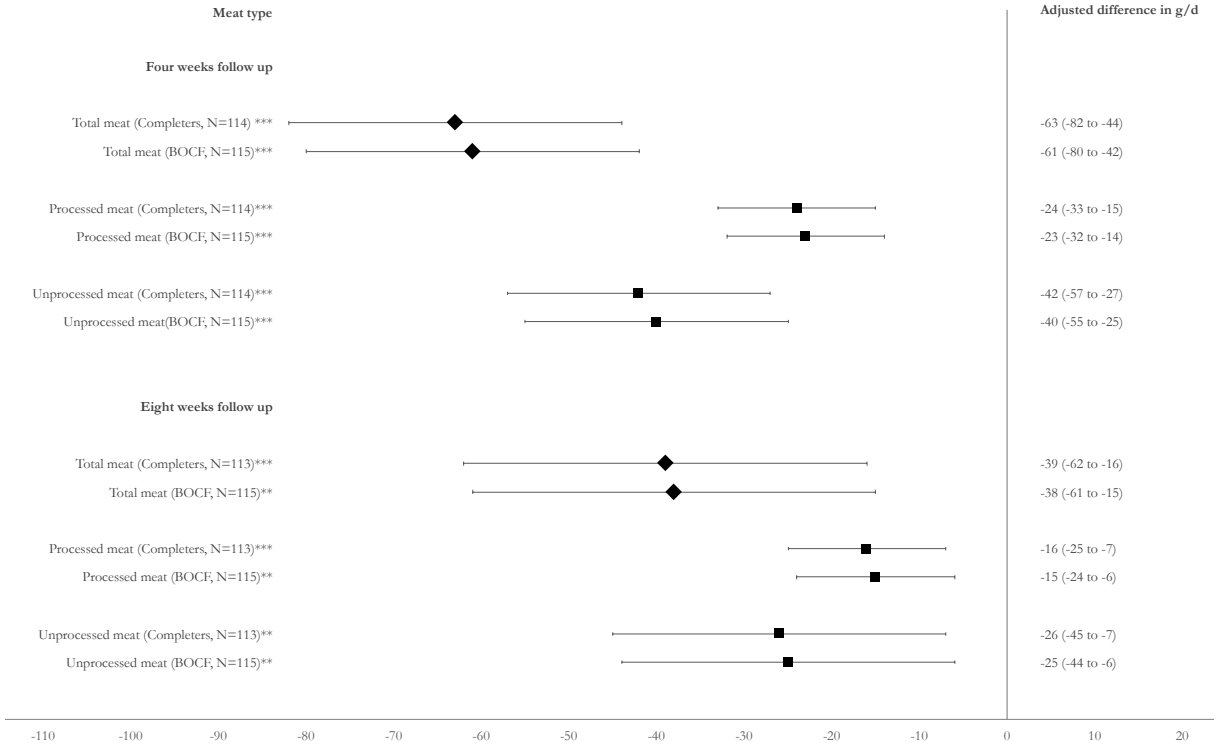


Mixed effect models with fixed effects for randomised group, baseline consumption of the respective meat type and gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. N=113. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

3.2.2 Sensitivity analysis

Baseline observation carried forward (BOCF) analyses suggested that the estimated intervention impact on total meat consumption from the main analysis was extremely robust to this imputation technique at both follow up: Compared to the main analyses, in BOCF analyses the estimated intervention impact on total meat consumption only decreased by 2 g/d and by 1 g/d at the four and eight weeks follow up, respectively. The BOCF results for processed and unprocessed meat were also consistent with those from the main analyses (Fig. 4.8).

Fig. 4.8: Impact of the intervention on meat consumption in g/d in main and BOCF analyses



Mixed effect models with fixed effects for randomised group, baseline consumption of the respective meat type and gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

3.2.3 Intervention impact on meat consumption by sex

There was a significant interaction between sex and the intervention impact on total meat consumption (p=0.0271) but not processed (p=0.3720) and unprocessed meat consumption (p=0.0663). At the four weeks follow up the intervention led to greater reductions in meat consumption among male than female participants relative to the control group (adjusted differences: -88 g/d, 95% CI -119 to -56, p<0.0001 and -45 g/d, 95% CI -68 to -23, p=0.0001, respectively). At

the eight weeks follow up reductions in meat consumption in the intervention relative to the control group were similar between male and female participants (adjusted difference=-32 g/d, 95% CI -71 to 7, p=0.1077 and -40 g/d, 95% CI -68 to -11, p=0.0061, respectively) (Fig. 4.9).

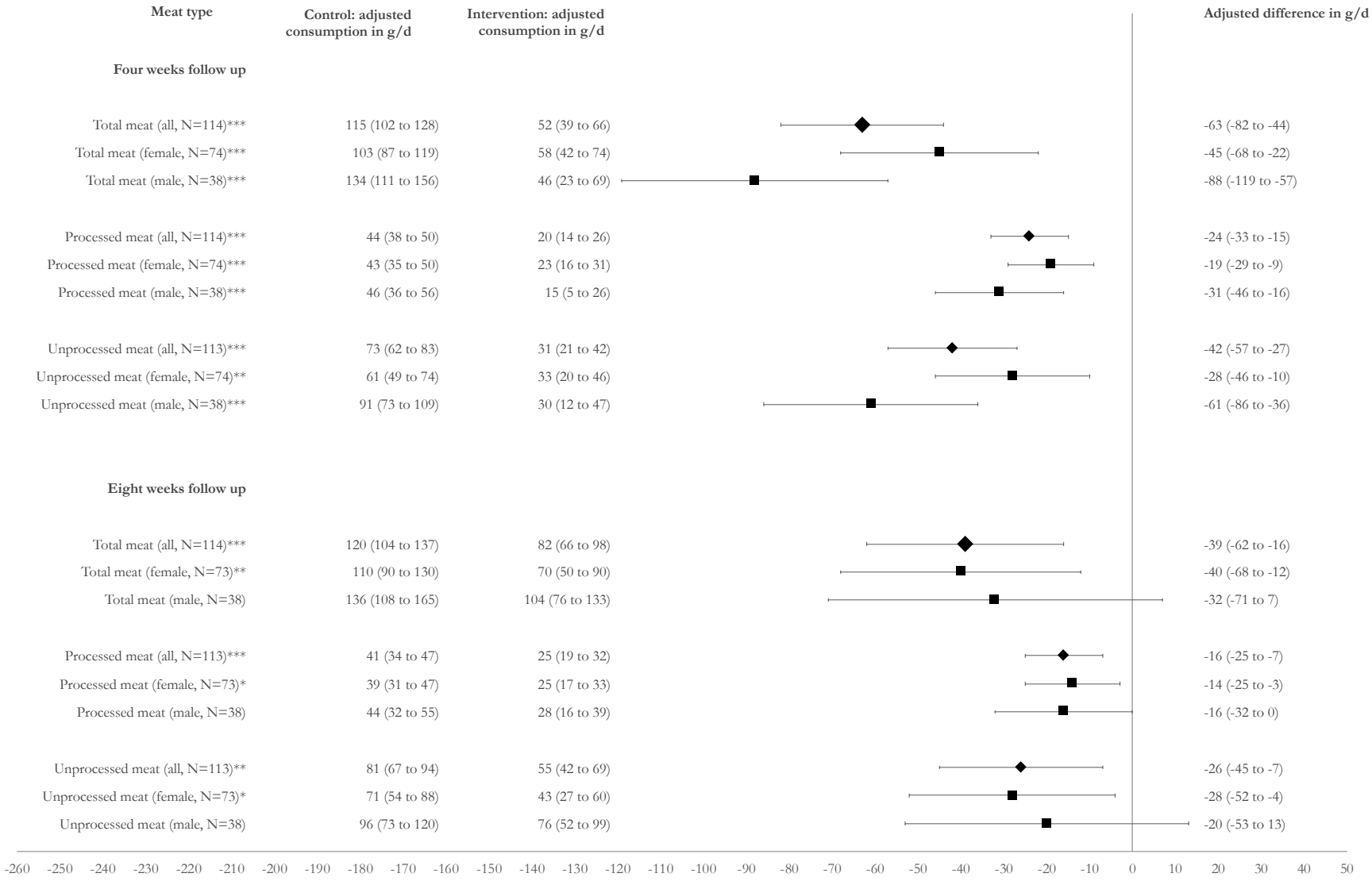
3.2.4 Intervention impact on meat consumption by self-control

There was no evidence of a significant interaction between participants' self-control and the intervention impact on total (p=0.7538), processed (p=0.7672), or unprocessed meat (p=0.7335), suggesting that the intervention impact on meat consumption did not differ significantly between people with lower and higher levels of self-control (Fig. 4.10).

3.2.5 Intervention impact on meat consumption by neophobia

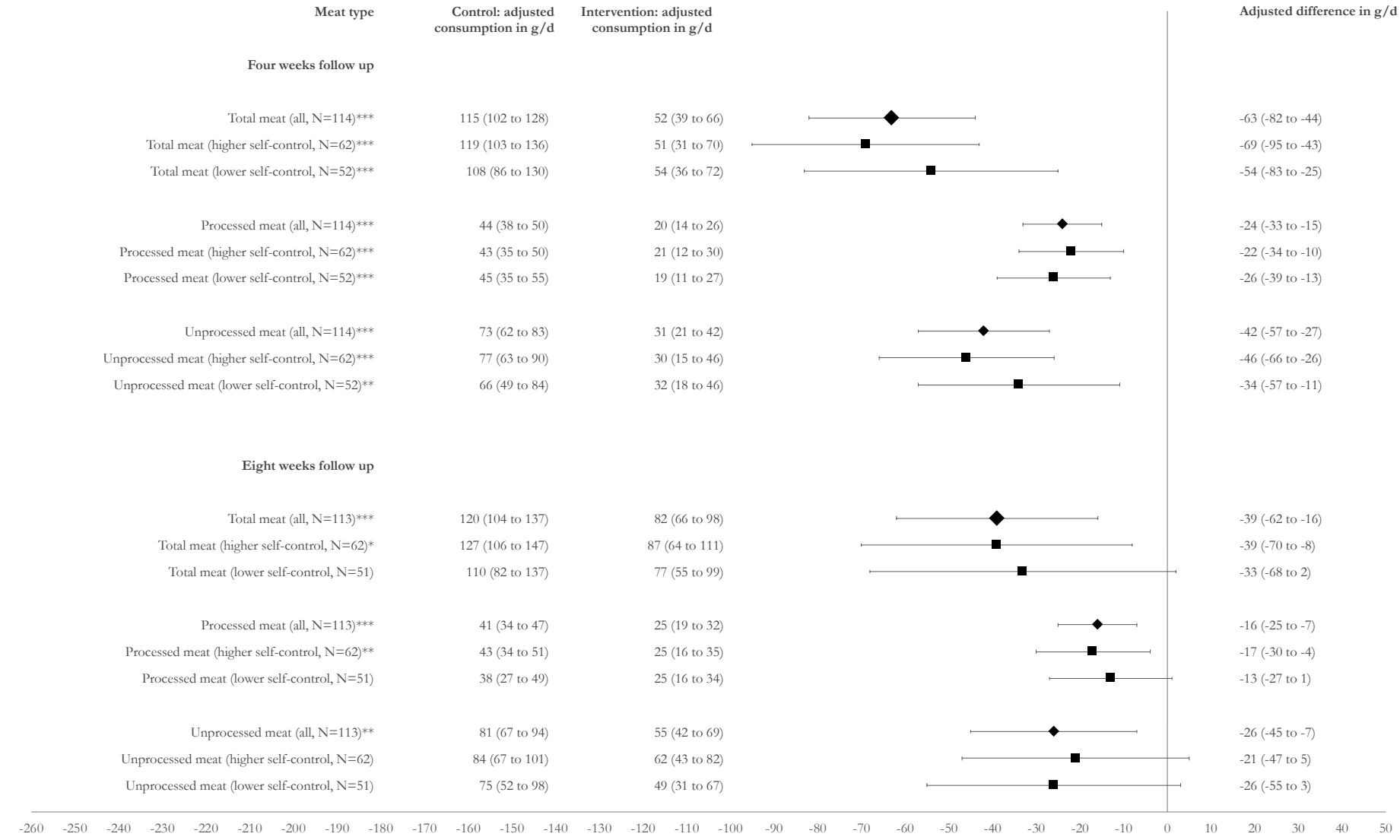
There was no evidence of a significant interaction between participants' neophobia and the intervention impact on total (p= 0.2120), processed (p= 0.3232), or unprocessed meat (p= 0.4935). These results suggest that the intervention impact on meat consumption did not differ significantly between people with lower and higher levels of neophobia (Fig. 4.11)

Fig. 4.9: Impact of the intervention on meat consumption by sex



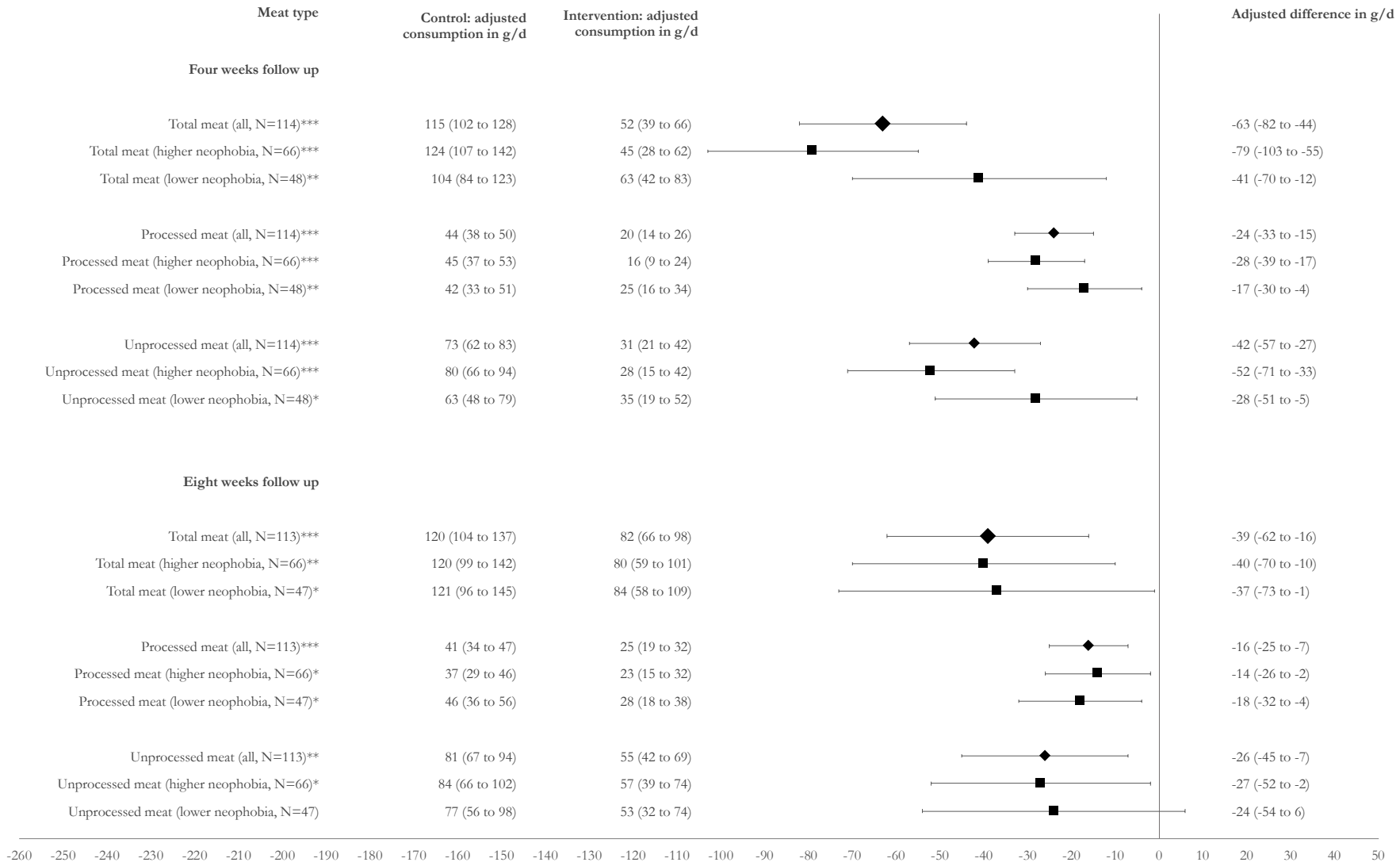
Mixed effect models with fixed effects for randomised group, gender, interaction of randomised group and gender, and baseline consumption of the respective meat type, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

Fig. 4.10: Impact of the intervention on meat consumption by self-control



Mixed effect models with fixed effects for randomised group, self-control, interaction of randomised group and self-control, gender, and baseline consumption of the respective meat type, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

Fig. 4.11: Impact of the intervention on meat consumption by neophobia



Mixed effect models with fixed effects for randomised group, neophobia, interaction of randomised group and neophobia, gender, baseline consumption of the respective meat type, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

3.3. Intervention impact on the consumption frequency of meat, meat substitutes, and other food groups

At the baseline, participants consumed 10.3 (SD=3.7) servings of meat and 0.3 (SD=0.7) servings of meat substitutes per week. The baseline weekly consumption frequency of meat, meat substitutes, and other food groups is reported in table 4.5.

Table 4.5: Baseline consumption frequency of meat, meat substitutes, and other food groups

	Control (N=57)	Intervention (N=58)
Meals containing food groups per week		
Processed meat	4.6 (3.2)	5.3 (3.1)
Unprocessed white meat	3.4 (1.9)	3.3 (2.2)
Unprocessed red ruminant meat	1.5 (1.6)	1.3 (1.3)
Unprocessed pork	0.8 (1.5)	0.5 (1)
Mycoprotein meat substitutes	0.1 (0.2)	0.1 (0.3)
Soy meat substitutes	0.2 (0.6)	0.1 (0.5)
Other meat substitutes	0.1 (0.2)	0.1 (0.6)
Cheese	4.3 (2.5)	4.7 (2.9)
Milk and yoghurt	8.6 (5.8)	7.4 (5)
Cheese substitutes	0 (0)	0 (0)
Milk and yoghurt substitutes	0.6 (1.8)	1.1 (2.6)
Fish	2.1 (1.5)	1.8 (1.6)
Starchy foods	15.3 (4.8)	15.7 (4)
Fruit	8.7 (5.8)	7.4 (5.5)
Vegetables	11.6 (4)	10.8 (3.6)
Pulses	2 (2)	2.1 (2.2)
Eggs	1.9 (1.7)	2 (2)
Nuts and seeds	1.8 (2.7)	1.9 (3.1)
Snacks	9 (5.2)	9 (5)
Soft drinks	1.3 (2.4)	1.3 (2.2)
Alcoholic drinks	2 (2.8)	2 (2.4)
Servings of food groups per week		
Total meat	10.4 (4)	10.2 (3.5)
Total meat substitutes	0.3 (0.6)	0.4 (0.8)
Total meat and meat substitutes	10.6 (4)	10.6 (3.4)

Data are means and standard deviations. Unprocessed white meat includes unprocessed game and 'other' meat.

Exploratory analyses suggested that the intervention significantly reduced the consumption frequency of meat and increased the consumption frequency of meat substitutes, leaving the consumption frequency of other principal food groups unchanged (Fig. 4.12).

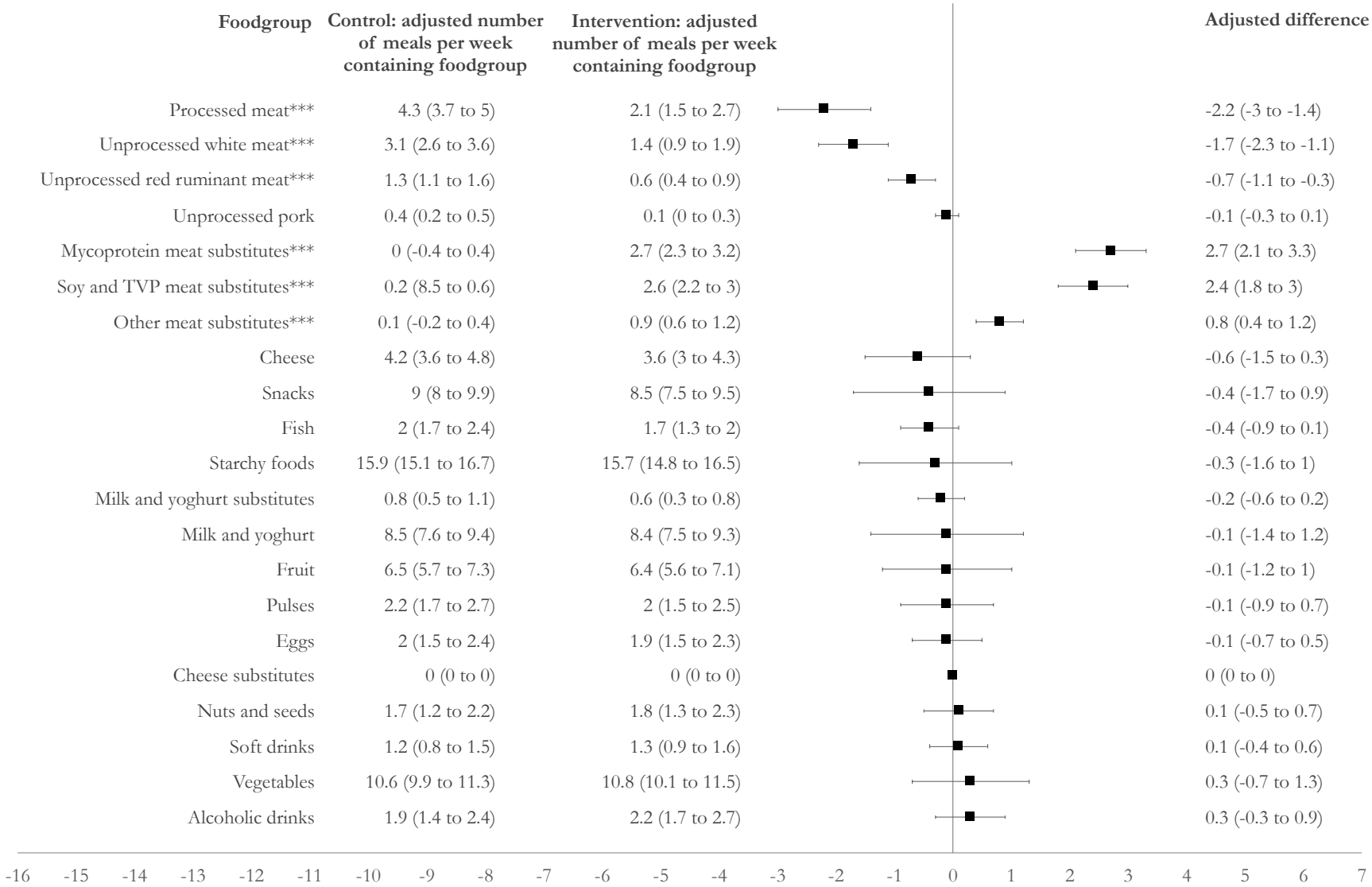
At the four weeks follow up, the interventions reduced the number of weekly meals containing processed meat (adjusted difference: -2.2 , 95% CI -3 to -1.4, p<0.0001), unprocessed white meat (adjusted difference: -1.7, 95% CI -2.3 to -1.1, p<0.0001), and unprocessed red ruminant meat (adjusted difference: -0.7, 95% CI -1.1 to -0.3, p=0.0003) relative to the control group, while there was no evidence that it significantly reduced the number of weekly meals containing unprocessed pork (adjusted difference: -0.1, 95% CI -0.3 to 0.1, p=0.1324).

Concomitantly, the intervention increased the number of weekly meals containing mycoprotein-based meat substitutes (adjusted difference: 2.7, 95% CI 2.1 to 3.3, p<0.0001), soy-based meat substitutes (adjusted difference: 2.4, 95% CI 1.8 to 3, p<0.0001), and other types of meat substitutes (adjusted difference: 0.8, 95% CI 0.4 to 1.2, p<0.0001) relative to the control group.

The aforementioned group differences in the consumption frequency of meat and meat substitutes were smaller but continued to be statistically significant at the eight weeks follow up, except for those pertaining to unprocessed red ruminant meat. There were no statistically significant differences in the consumption frequency of any other food group between the intervention and control group at any follow up (all p*s*>0.05) (Fig. 4.12 and 4.13).

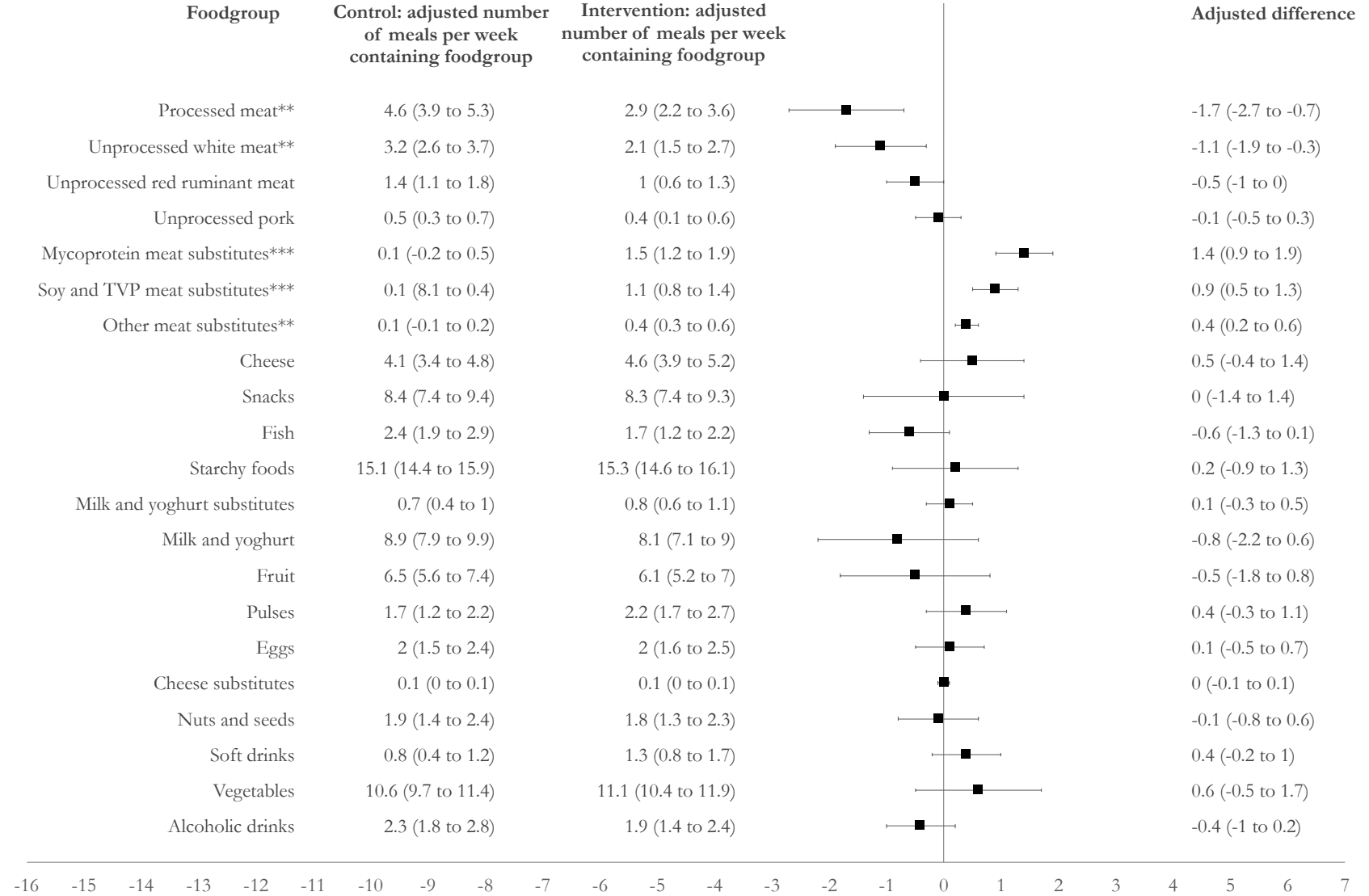
Sensitivity analyses using a retrospective food frequency questionnaire as an alternative measure of food consumption frequency supported the insight that relative to the control group the intervention reduced the consumption frequency of meat, increased the consumption frequency of meat substitutes, and left all other main components of participants' diets unchanged (Appendix 7).

Fig. 4.12: Impact of the intervention on consumption frequency of food groups at the four weeks follow up



Mixed effect models with fixed effects for randomised group, baseline consumption of the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. N=114. Unprocessed white meat includes unprocessed game and 'other' meat. Stars refer to the adjusted differences and represent * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

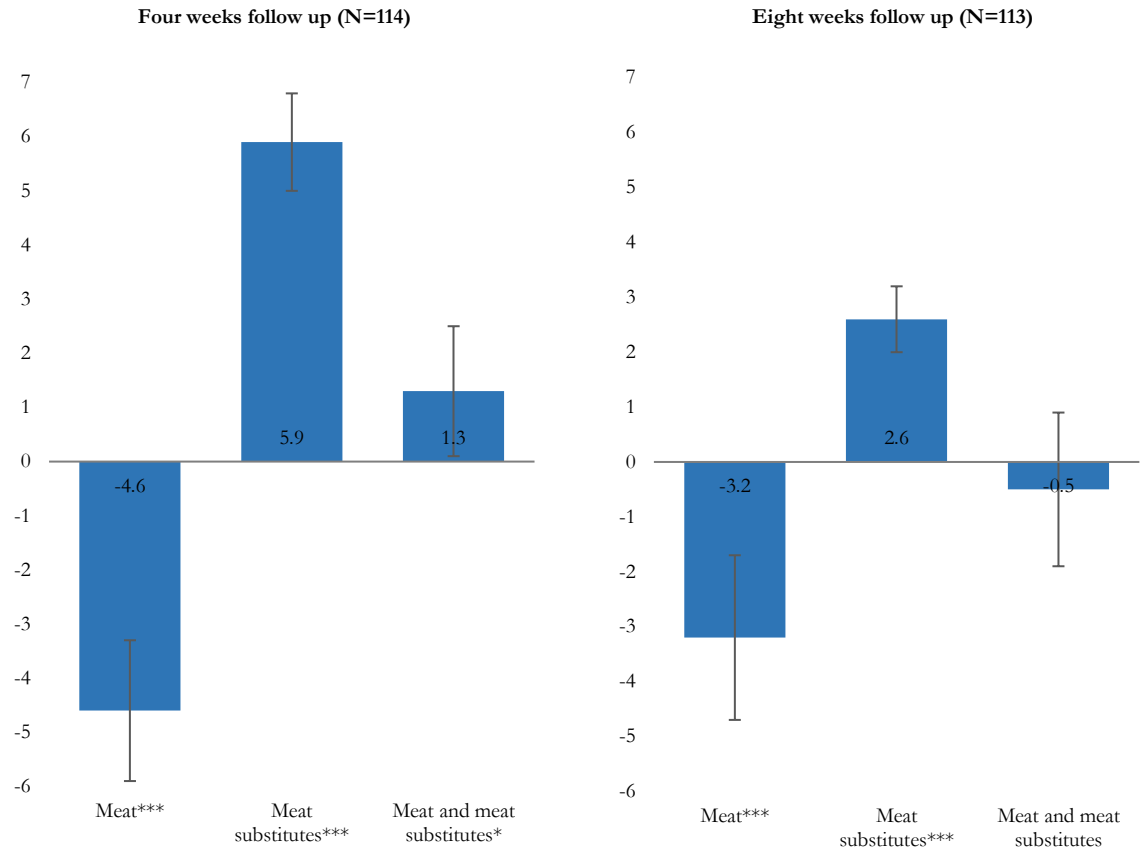
Fig. 4.13: Impact of the intervention on consumption frequency of food groups at the eight weeks follow up



Mixed effect models with fixed effects for randomised group, baseline consumption of the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. N=113. Unprocessed white meat includes unprocessed game and 'other' meat. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

Analyses exploring the impact of the intervention on the number of weekly servings of meat, meat-substitutes, and meat and meat substitutes combined showed that at the four weeks follow up the intervention significantly reduced the number of meat servings, while it increased the number of meat substitutes servings and the number of meat and meat substitutes servings combined relative to the control group. At the eight weeks follow up, the intervention still reduced the number of meat servings and still increased the number of meat substitutes servings relative to the control group, but there was no evidence that it changed participants' consumption frequency of meat and meat substitutes servings combined. These results suggest that at the four weeks follow up participants in the intervention group consumed more meat substitutes servings than the ones they needed to replace their avoided meat servings. Conversely, at the eight weeks follow up participants in the intervention group only ate as many meat substitute servings as they needed to replace their avoided servings of meat (Fig. 4.14).

Fig. 4.14: Impact of the intervention on weekly servings of meat and meat substitutes



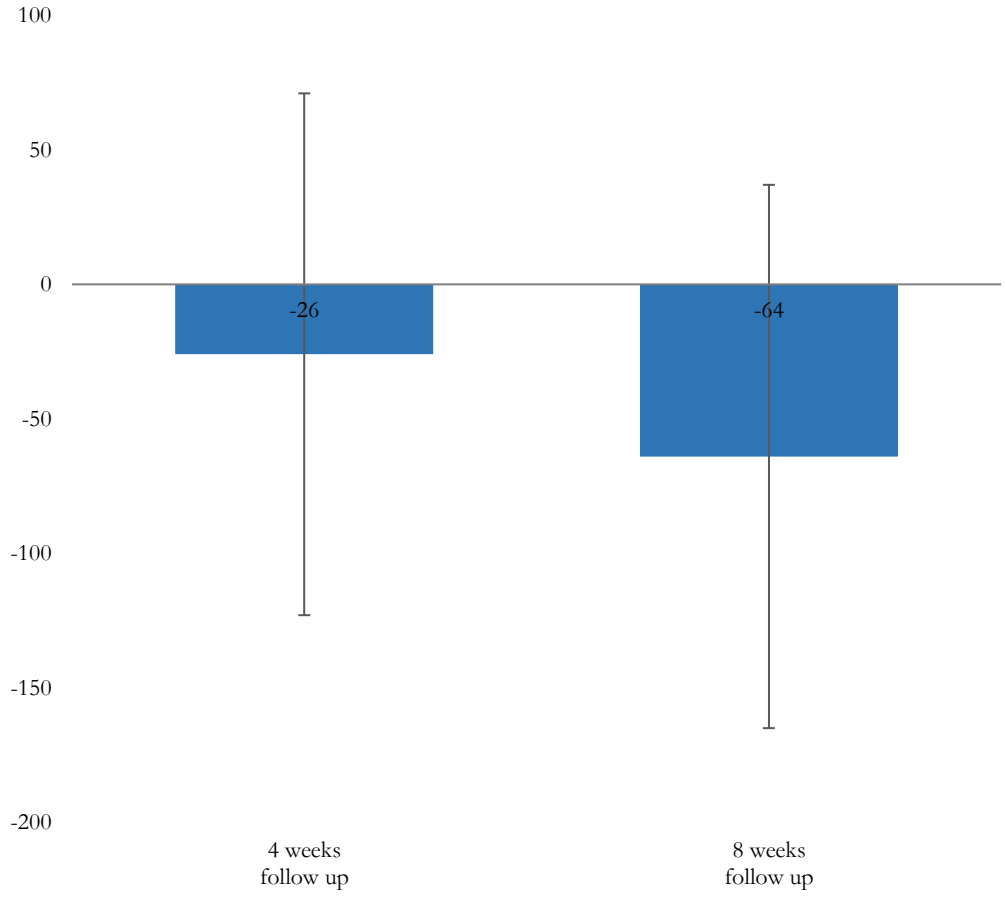
Mixed effect models with fixed effects for randomised group, baseline consumption of the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

3.4. Intervention impact on energy and nutrients intake

3.4.1 Energy intake

Overall there was no evidence that the intervention significantly changed participants' energy intake. In the control group, participants consumed 1936 kcal (SD=444) at the baseline, 1877 kcal (SD=451) at the four weeks follow up, and 1865 kcal (SD=463) at the eight weeks follow up. In the intervention group, participants consumed 1917 kcal (SD=413) at the baseline, 1836 kcal (SD=424) at the four weeks follow up, and 1784 kcal (SD=345) at the eight weeks follow up. There was a consistent trend indicating greater reductions in energy intake in the intervention compared to the control group, however these differences did not reach statistical significance at the four and eight weeks follow up (adjusted differences: -25.87, 95% CI -123 to 71, p=0.6 and -64, 95% CI -165 to 37, p=0.2121) (Fig. 4.15).

Fig. 4.15: Adjusted differences in energy intake in kcal in the intervention relative to the control group



Mixed effect models with fixed effects for randomised group, baseline energy intake (kcal), gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

3.4.2 Macronutrient intake

Participants' baseline macronutrient intake by group is reported in table 4.6. For most macronutrients there was no evidence that the intervention significantly affected intake at either follow up. However, relative to the control, the intervention reduced the intake of saturated fatty acids at both follow up (-2 g/d, 95% CI -4 to 0, p=0.0361 and -4 g/d, 95% CI -8 to 0, p=0.0368), reduced the intake of monounsaturated fatty acids at the eight weeks follow up (-2.7 g/d, 95% CI -4 to -1, p=0.0026), and increased the intake of fibre at the four weeks (2 g/d, 95% CI 0 to 4, p=0.0394) (Fig. 4.16).

3.4.3 Micronutrient intake

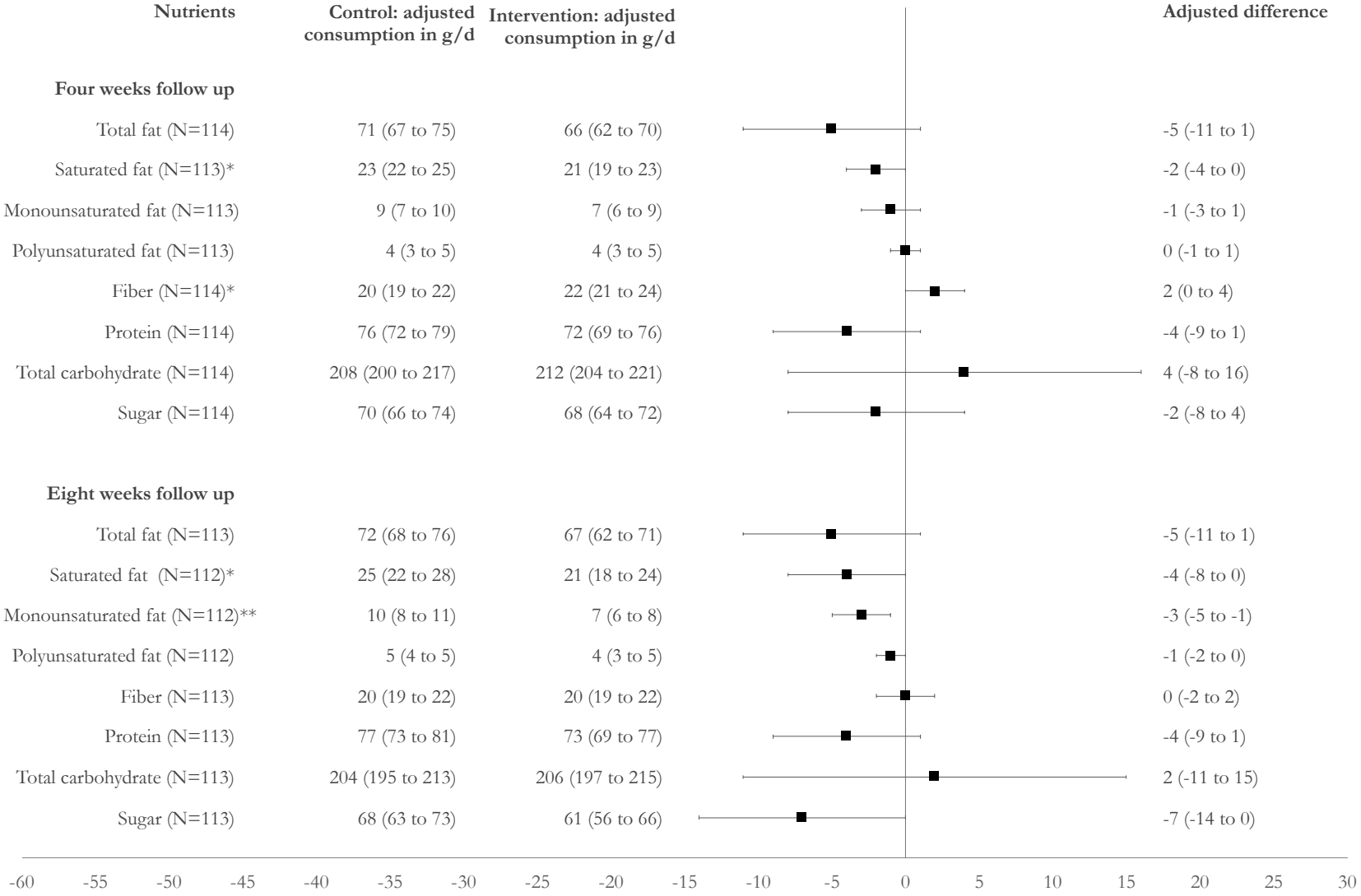
Participants' baseline micronutrient intake by study group is reported in table 4.6. There was no evidence that the intervention significantly changed the intake of any micronutrient relative to the control group at either follow up (Fig. 4.17).

Table 4.6: Baseline intake of macro- and micronutrients

	Control	Intervention
Macronutrients in g/d		
Total fat (N=115)	73 (25)	72 (24)
Saturated fat (N=114)	24 (9)	23 (10)
Monounsaturated fat (N=114)	9 (6)	9 (6)
Polyunsaturated fat (N=114)	5 (4)	4 (3)
Fiber (N=115)	21 (8)	20 (8)
Protein (N=115)	82 (24)	82 (24)
Total carbohydrate (N=115)	215 (54)	209 (55)
Sugar (N=115)	74 (29)	67 (27)
Micronutrients in mg/d		
Sodium (N=115)	1965 (811)	1908 (933)
Vitamin A (N=114)	748 (1014)	599 (550)
Vitamin C (N=114)	110 (88)	95 (95)
Iron (N=114)	6 (4)	5 (4)
Calcium (N=114)	470 (291)	483 (306)
Potassium (N=114)	1160 (635)	961 (531)

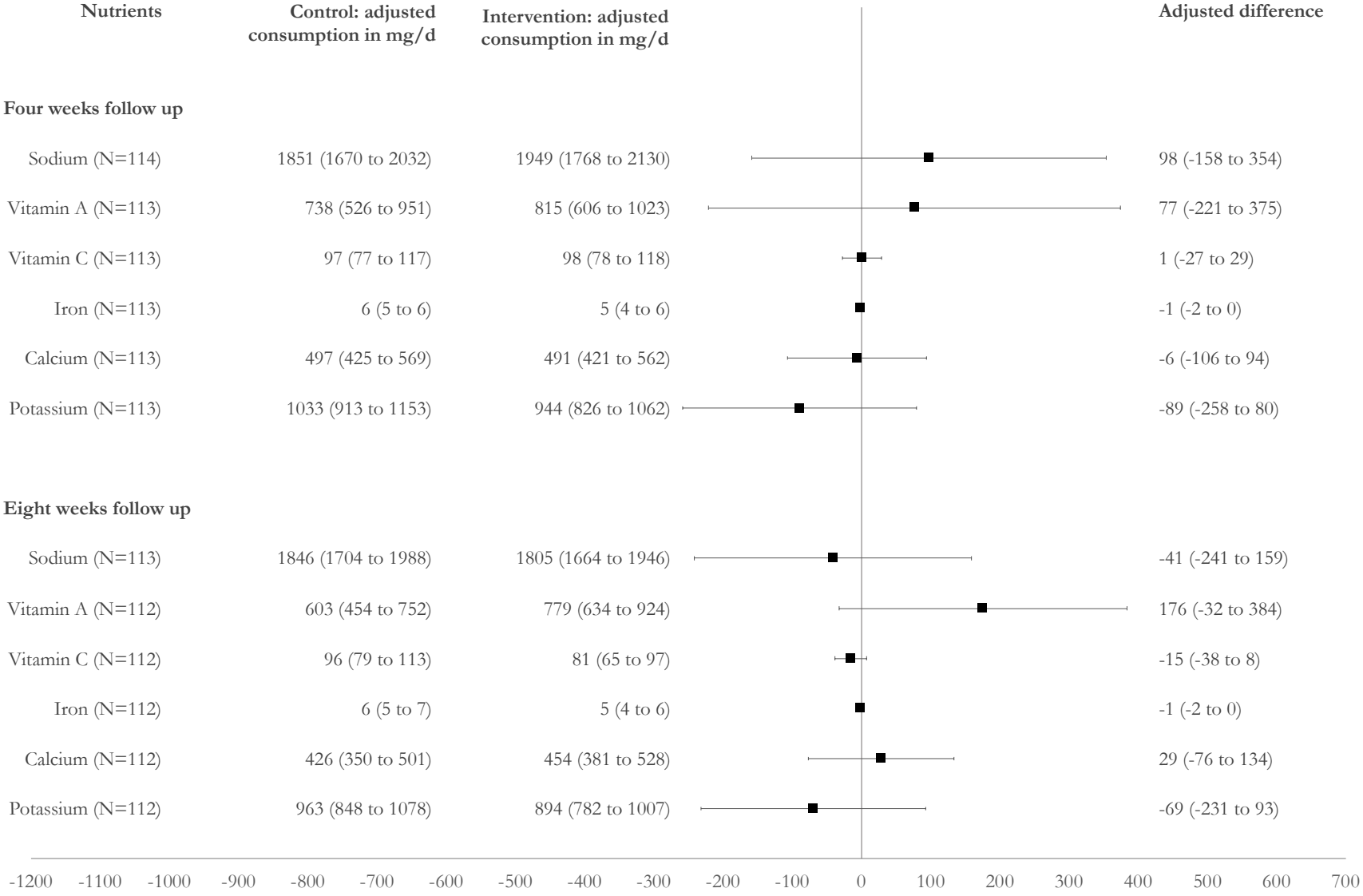
Data are means and standard deviations.

Fig. 4.16: Impact of the intervention on macronutrients intake in g/d



Mixed effect models with fixed effects for randomised group, baseline intake of the respective macronutrient, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

Fig. 4.17: Impact of the intervention on micronutrients intake in mg/d



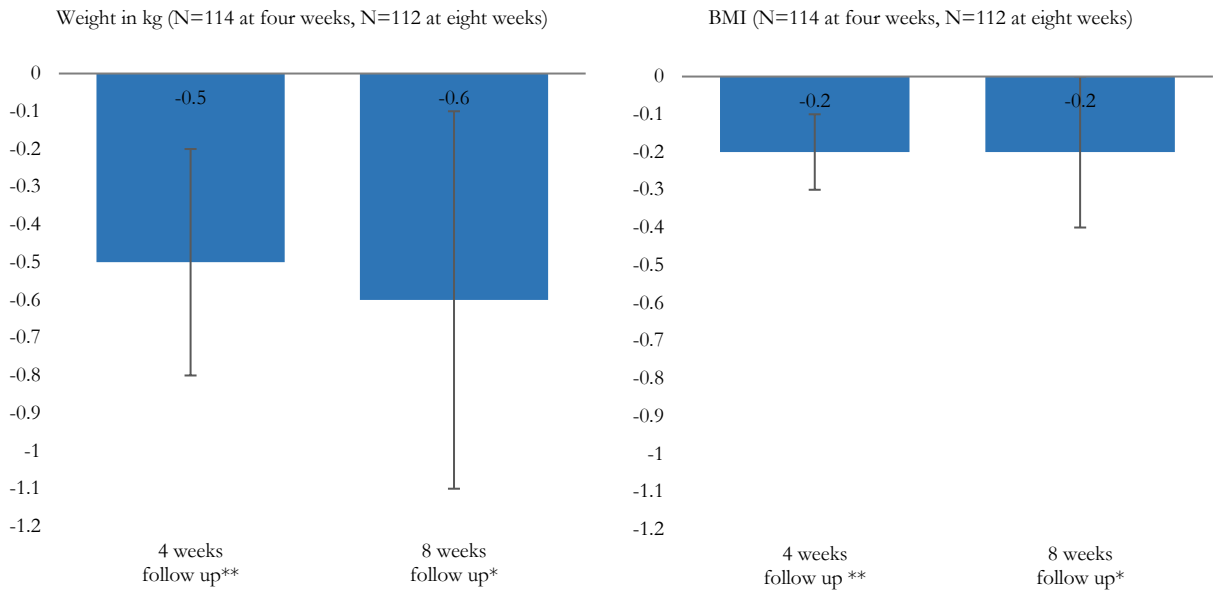
Mixed effect models with fixed effects for randomised group, baseline intake of the respective micronutrient, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

3.5. Intervention impact on biophysical outcomes

3.5.1 Body weight

Participants' baseline BMI was 25.2 (SD=5) in the control group and 25.5 (SD=5.6) in the intervention group. Adjusted weight change in the intervention group relative to the control at the four and eight weeks follow up was -0.5 kg (95% CI -0.2 to -0.9, p=0.0037) and -0.6 kg (95% CI -0.1 to -1.2, p=0.0266), respectively. These effects equate to a 0.2 kg/m^2 reduction in BMI in the intervention relative to the control group at both follow up (Fig. 4.18).

Fig. 4.18: Impact of the intervention on body weight and BMI



Mixed effect models with fixed effects for randomised group, baseline weight or BMI respectively, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

There was no evidence that the intervention significantly affected participants' body composition relative to the control group at either follow up (adjusted differences in body fat percentage: -0.2 pp, 95% CI -0.7 to 0.3, p=0.4245 and -0.8 pp, 95% CI -1.7 to 0.1, p=0.0887, respectively).

3.5.2 Blood lipids and blood pressure

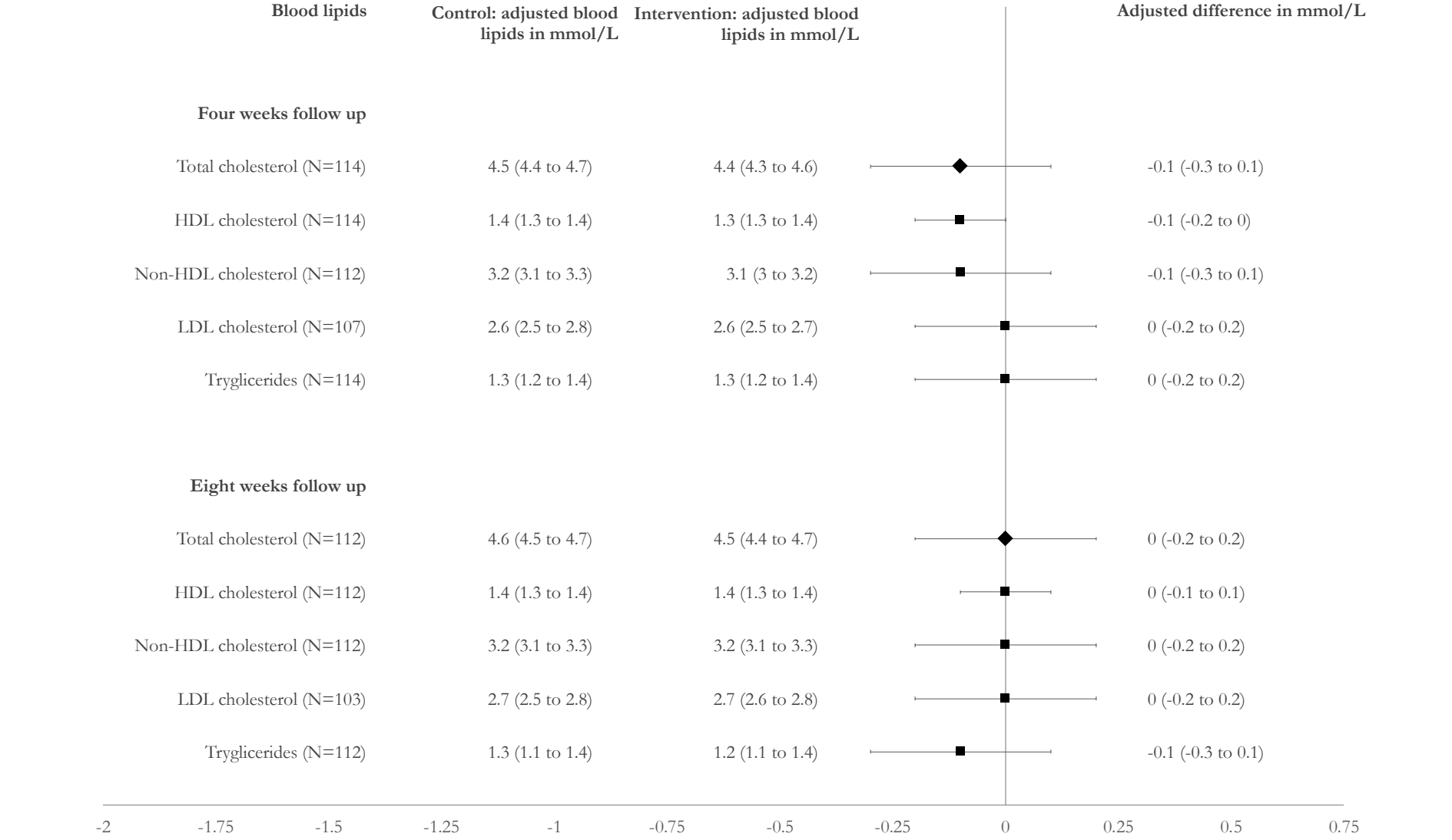
Participants' baseline blood lipids and blood pressure by study group is reported in table 4.7. There was no evidence that the intervention significantly changed blood pressure or any blood lipids fraction relative to the control group at any follow up (Fig. 4.19 and 4.20).

Table 4.7: Baseline blood lipids and blood pressure

	Control	Intervention
Blood lipids in mmoL/L		
Total cholesterol (N=114)	4.47 (0.88)	4.51 (0.92)
HDL cholesterol (N=114)	1.33 (0.39)	1.39 (0.41)
Non-HDL cholesterol (N=114)	3.14 (0.93)	3.12 (0.92)
LDL cholesterol (N=109)	2.6 (0.79)	2.54 (0.86)
Tryglycerides (N=114)	1.25 (0.71)	1.32 (0.82)
Blood pressure in mmHg		
Systolic blood pressure (N=115)	116.96 (13.53)	116.97 (12.09)
Diastolic blood pressure (N=115)	79.04 (9.12)	79.22 (7.59)

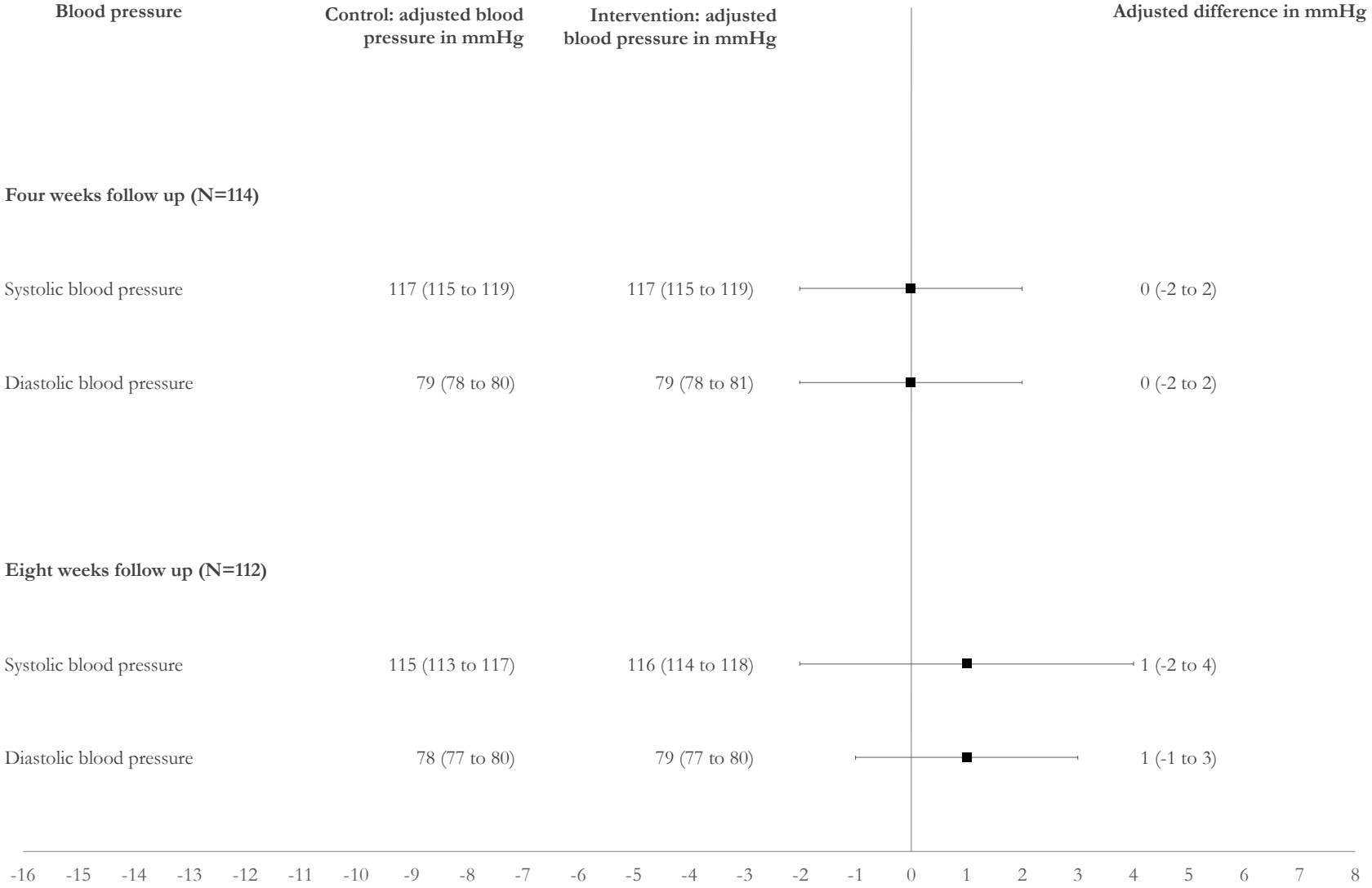
Data are mean and standard deviations

Fig. 4.19: Impact of the intervention on blood lipids in mmoL/L



Mixed effect models with fixed effects for randomised group, baseline levels of the respective blood lipid fraction, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Fig. 4.20: Impact of the intervention on blood pressure in mmHg



Mixed effect models with fixed effects for randomised group, baseline blood pressure, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

3.6. Psychosocial outcomes

Participants' baseline values on all psychosocial variables collected in this trial are reported in table 4.8. The intervention significantly increased participants' intentions, positive attitudes, perceived control, and subjective social norms of eating a low meat diet and of using meat substitutes, while it decreased their attachment to meat. The intervention also significantly encouraged participants to shift towards eating identities associated with reduced intake of meat. The results for each psychosocial outcome are reported below in more detail.

Table 4.8: Participants' baseline scores on psychosocial variables

	Control (N=57)	Intervention (N=58)
Intentions		
to eat a low meat diet	4 (1.4)	4.3 (1.3)
to use meat substitutes	4 (1.3)	4.2 (1.2)
Attitudes		
towards eating a low meat diet	5.1 (1.2)	5.4 (1)
towards using meat substitutes	4.9 (1.1)	5 (1)
Perceived control		
to eat a low meat diet	4.8 (1.1)	5.2 (1.1)
to use meat substitutes	4.9 (1)	5.2 (1)
Subjective social norms		
of eating a low meat diet	4 (1.4)	3.9 (1.5)
of using meat substitutes	3.7 (1.5)	3.7 (1.4)
Eating identity		
Meat eating identity	53 (93%)	53 (91%)
Meat reducing identity	4 (7%)	5 (9%)
Non meat eating identity	0 (0%)	0 (0%)
Attachment to meat	4.4 (0.9)	4.4 (0.7)

Data are means and standard deviations or number and percentage. Higher values represent higher/more favourable levels on each variable. A value of 4 on a seven points scale therefore represents 'indifference' on the relevant variable.

3.6.1 Intentions to eat a low meat diet and to use meat substitutes

Relative to the control, the intervention increased participants' intention to eat a low meat diet by 1.1 units on a seven points scale (95% CI 1.5 to 0.7, $p<0.0001$) at the four weeks follow up and by 1.5 units (95% CI 1.1 to 1.9, $p<0.0001$) at the eight weeks follow up. The intervention also increased participants' intention to use meat substitutes at the four and eight weeks follow up, relative to the control (adjusted differences: 1.7 units, 95% CI 2.1 to 1.3, $p<0.0001$ and 1.3, 95% CI 0.9 to 1.7, $p<0.0001$, respectively) (Fig. 4.21 and 4.22).

3.6.2 Attitudes towards eating a low meat diet and using meat substitutes

Relative to the control, the intervention increased positive attitudes towards eating a low meat diet by 0.5 units on a seven points scale (95% CI 0.2 to 0.9, p=0.0016) at the four weeks follow up and by 0.8 units (95% CI 0.5 to 1.1, p<0.0001) at the eight weeks follow up. The intervention also increased participants' positive attitudes towards using meat substitutes at the four and eight weeks follow up, relative to the control (adjusted differences: 0.9, 95% CI 0.6 to 1.2, p<0.0001 and 0.8, 95% CI 0.5 to 1.1, p<0.0001, respectively) (Fig. 4.21 and 4.22).

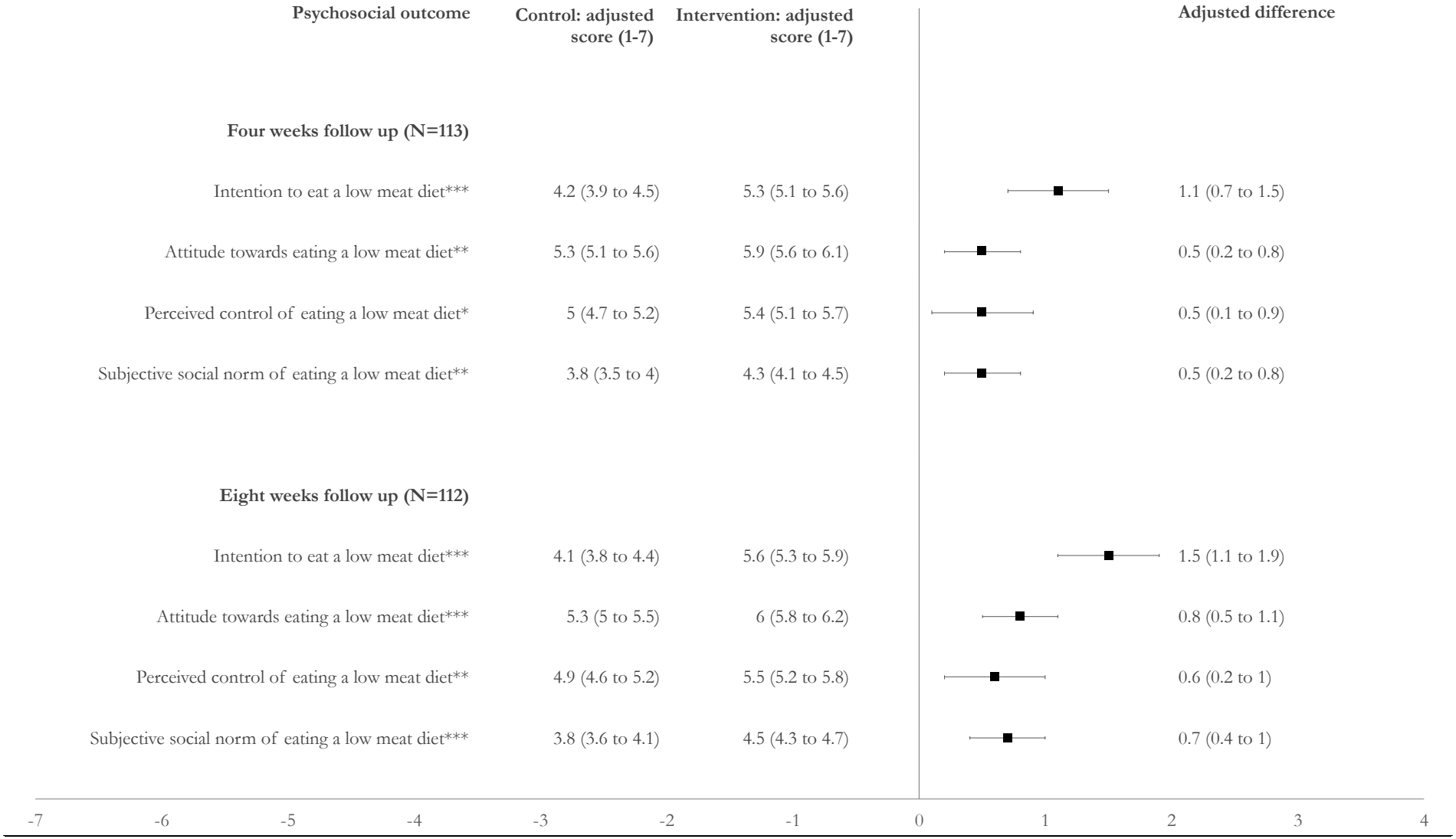
3.6.3 Perceived control of eating a low meat diet and using meat substitutes

Relative to the control, the intervention increased participants' perceived control of eating a low meat diet by 0.5 units on a seven points scale (95% CI 0.1 to 0.8, p=0.0209) at the four weeks follow up and by 0.6 units (95% CI 0.2 to 1, p=0.0037) at the eight weeks follow up. Receiving the intervention also increased participants' perceived control of using meat substitutes at the four and eight weeks follow up, relative to the control (adjusted differences: 0.6, 95% CI 0.3 to 1, p=0.0004 and 0.4, 95% CI 0 to 0.8, p=0.0335, respectively) (Fig. 4.21 and 4.22).

3.6.4 Perceived social norms of eating a low meat diet and using meat substitutes

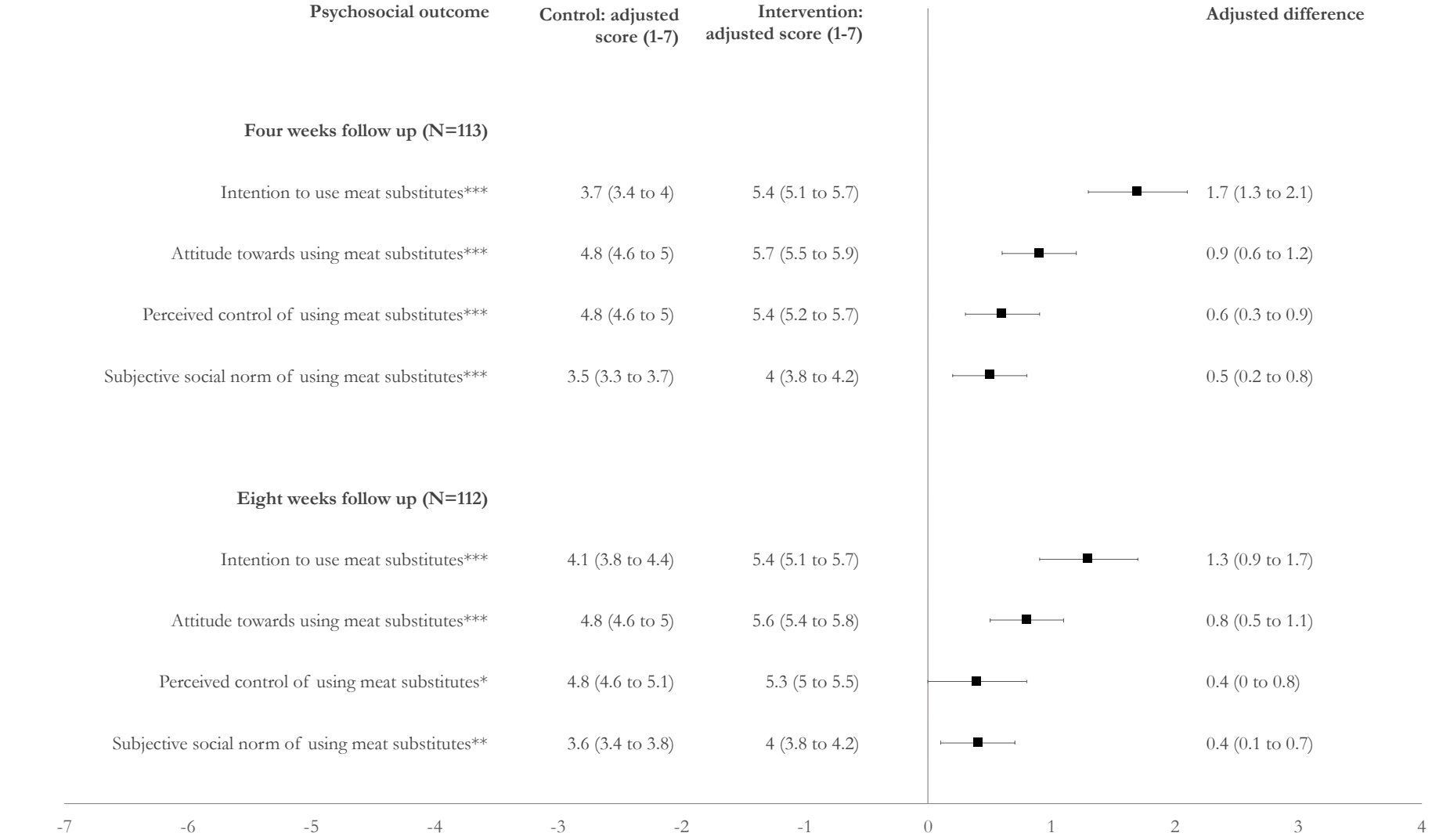
Relative to the control, the intervention increased participants' subjective social norm of eating a low meat diet by 0.5 units on a seven points scale (95% CI 0.2 to 0.9, p=0.0025) at the four weeks follow up and by 0.7 units (95% CI 0.4 to 1, p<0.0001) at the eight weeks follow up. The intervention also increased subjective social norms of using meat substitutes at the four and eight weeks follow up, relative to the control (adjusted differences: 0.54, 95% CI 0.2 to 0.8, p=0.0004 and 0.4, 95% CI 0.2 to 0.7, p=0.0025, respectively) (Fig. 4.21 and 4.22).

Fig. 4.21: Impact of the intervention on intention, attitude, perceived control, and perceived social norm of eating a low meat diet



Mixed effect models with fixed effects for randomised group, baseline levels of the respective psychosocial outcome, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Lower values indicate lower/less favourable levels in the psychosocial outcome and higher values indicate higher/more favourable levels in the psychosocial outcome. A value of 4 represent 'indifference' on the relevant variable. Stars refer to the adjusted differences and represent * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Fig. 4.22: Impact of the intervention on intention, attitude, perceived control, and perceived social norm of using meat substitutes



Mixed effect models with fixed effects for randomised group, baseline levels of the respective psychosocial outcome, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Lower values indicate lower/less favourable levels in the psychosocial outcome and higher values indicate higher/more favourable levels in the psychosocial outcome. A value of 4 represent 'indifference' on the relevant variable. Stars refer to the adjusted differences and represent * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

3.6.5 Dietary identity

At the four weeks follow up, the proportion of participants adopting a meat-reducing identity in the control group was 9%, while among participants who were exposed to the intervention 27% had adopted a meat-reducing or a non-meat eating identity. At the eight weeks follow up this discrepancy further increased: 11% of participants in the control group had adopted a meat-reducing identity compared to 45% of participants who had adopted a meat-reducing or a non-meat eating identity in the intervention group (Fig. 4.23).

Fig. 4.23: Percentage of participants adopting different eating identities



Data are percentages of the group total at each measurement time point

Ordinal logistic regression suggested that compared to the control group, participants in the intervention group had significantly greater odds of shifting towards an eating identity associated with reduced meat consumption at the four and eight weeks follow up (OR=5.1, 95% CI 1.4 to 18.8, p= 0.014 and OR=9.7, 95% CI 3 to 31.1, p=0.0001, respectively).

3.6.6 Attachment to meat

Relative to the control, the intervention reduced participants' attachment to meat by 0.4 units on a seven points scale (95% CI -0.6 to -0.2, p<0.0001) at the four and eight weeks follow up. When

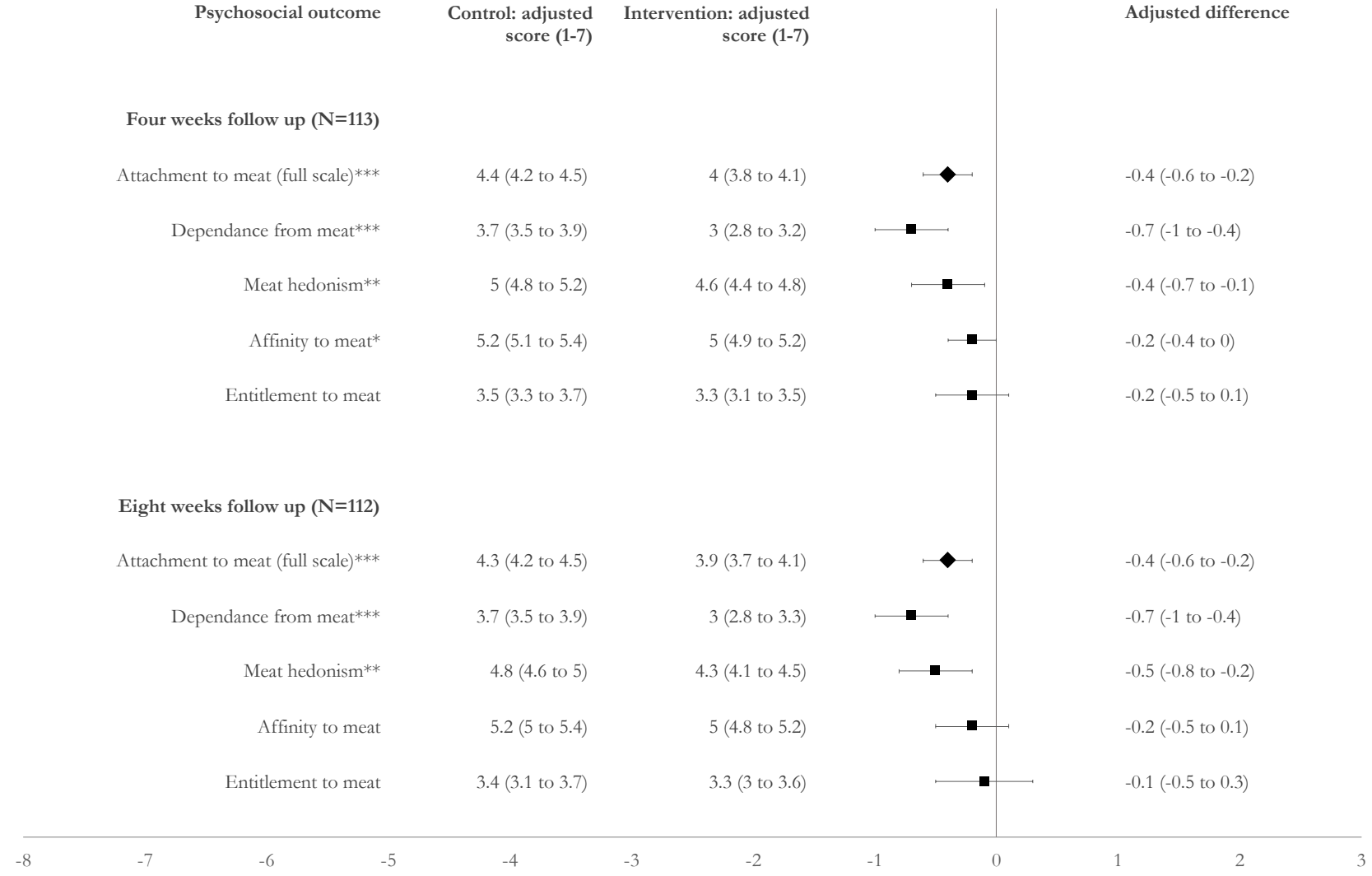
separately considering the sub-constructs of meat attachment, the intervention significantly reduced participants dependence from meat ($p<0.0001$), meat hedonism ($p=0.004$), and affinity to meat ($p=0.0326$) at the four weeks follow up relative to the control. These effects remained statistically significant at the eight weeks follow up, except for those pertaining to meat affinity. There was no evidence that the intervention changed participants' perception of being entitled to eat meat relative to the control at either follow up ($ps>0.05$) (Fig. 4.24).

3.6.7 Desire for similarity between meat and meat substitutes

Overall, participants slightly disagreed or felt ambivalent about wanting meat substitutes to be as similar as possible to meat at every measurement time point. Relative to the control, being exposed to the intervention did not significantly change the extent to which participants desired meat substitutes to be as similar as possible to meat at either follow up.

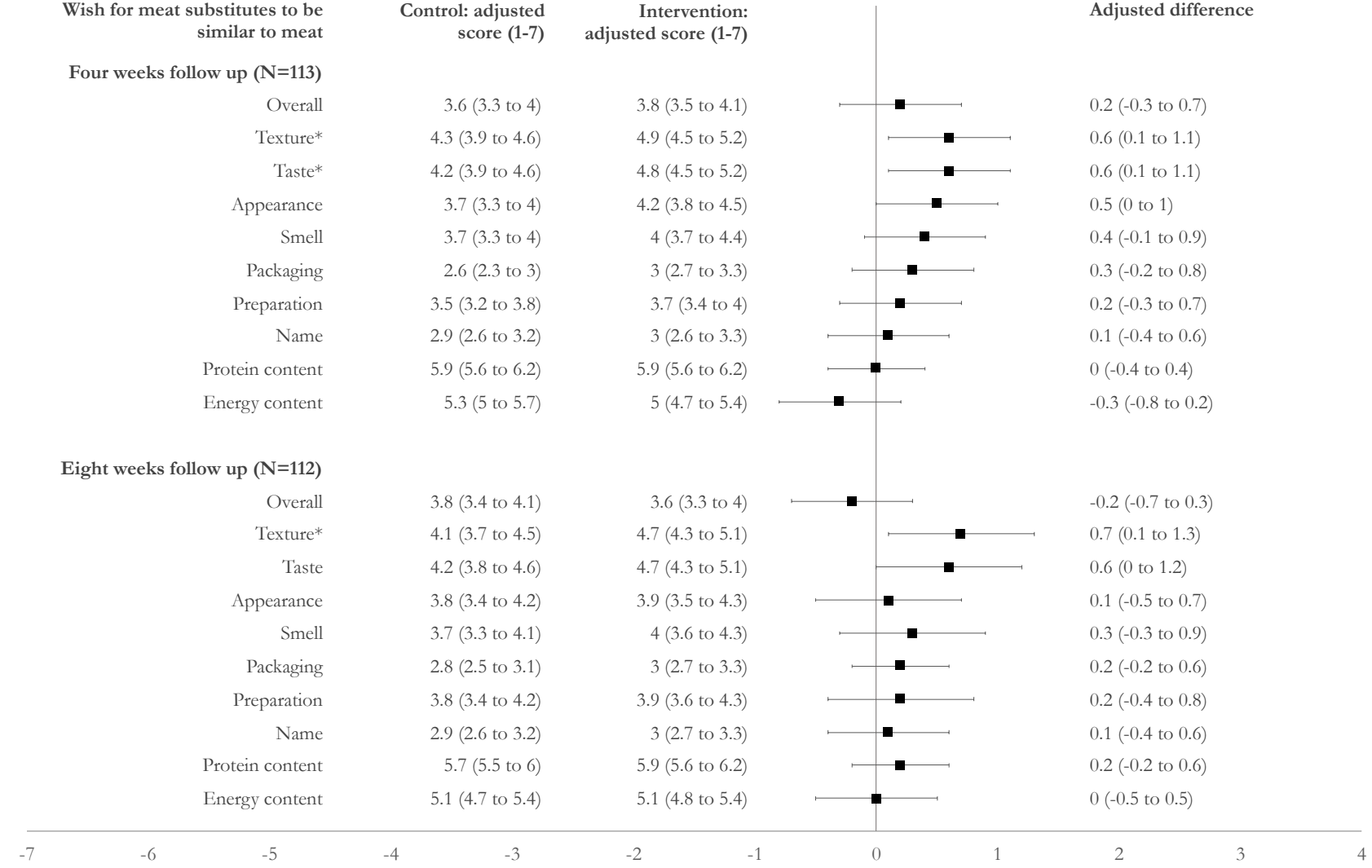
When investigating different aspects of meat substitutes, the intervention increased the desire for meat substitutes' taste to be as similar as possible to meat at the four weeks follow up and for meat substitutes' texture to be as similar as possible to meat at both follow up. There was no evidence that the intervention changed participants' desire for meat substitutes to be similar to meat in any other features explored (Fig. 4.25).

Fig. 4.24: Impact of the intervention on attachment to meat



Mixed effect models with fixed effects for randomised group, baseline levels of the respective psychosocial outcome, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Lower values indicate lower/less favourable levels in the psychosocial outcome and higher values indicate higher/more favourable levels in the psychosocial outcome. A value of 4 represent 'indifference' on the relevant variable. Stars refer to the adjusted differences and represent * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Fig. 4.25: Impact of the intervention on participants' desire for meat and meat substitutes to be as similar as possible



Mixed effect models with fixed effects for randomised group, baseline levels of the respective psychosocial outcome, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Lower values indicate lower/less favourable levels in the psychosocial outcome and higher values indicate higher/more favourable levels in the psychosocial outcome. A value of 4 represent 'indifference' on the relevant variable. Stars refer to the adjusted differences and represent * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

3.7 Environmental outcomes

The baseline levels of GHG emissions (in kg of CO_2-eq) and land use (in m^2) associated with participants' weekly diets is reported in Table 4.9.

Table 4.9: Baseline environmental impact of weekly diets

Food groups	CO_2-eq kg per week Control (N=57)	CO_2-eq kg per week Intervention (N=58)	Land use in m^2 per week Control (N=57)	Land use in m^2 per week Intervention (N=58)
Diet	42.7 (16)	39.6 (15.7)	129.1 (70.7)	116.4 (71.6)
Ruminant	16 (14)	13.5 (14)	80 (70.2)	67.5 (69.8)
Poultry	3.8 (2.9)	3.7 (2.8)	4.7 (3.6)	4.5 (3.4)
Pork	3.9 (3.8)	4.1 (4.3)	5.5 (5.3)	5.8 (6.1)
Soy and TVP meat substitutes	0 (0.1)	0 (0.1)	0 (0.2)	0 (0.1)
Mycoprotein meat substitutes	0 (0)	0 (0.1)	0 (0)	0 (0)
Other meat substitutes	0 (0)	0 (0.1)	0 (0.1)	0 (0.2)
Fish	4.4 (3.2)	3.8 (3.3)	1.2 (0.9)	1.1 (0.9)
Cheese	4.1 (2.4)	4.5 (2.8)	15.1 (8.8)	16.6 (10.4)
Milk and yoghurt	4 (2.7)	3.4 (2.3)	11.3 (7.7)	9.6 (6.6)
Starchy foods	2.8 (0.9)	2.9 (0.7)	4.7 (1.5)	4.8 (1.2)
Pulses	0.3 (0.3)	0.3 (0.3)	2.5 (2.4)	2.5 (2.6)
Eggs	0.8 (0.7)	0.8 (0.9)	1.1 (0.9)	1.1 (1.2)
Cheese substitutes	0 (0)	0 (0)	0 (0)	0 (0)
Nuts and seeds	0.1 (0.1)	0.1 (0.1)	0.4 (0.6)	0.4 (0.7)
Soft drinks	0 (0.1)	0 (0.1)	0 (0)	0 (0)
Milk and yoghurt substitutes	0.1 (0.3)	0.2 (0.4)	0.1 (0.2)	0.1 (0.3)
Vegetables	0.7 (0.3)	0.7 (0.2)	0.5 (0.2)	0.4 (0.1)
Fruit	0.5 (0.3)	0.4 (0.3)	0.9 (0.6)	0.8 (0.6)
Alcoholic drinks	1.1 (1.5)	1.1 (1.3)	1.1 (1.5)	1.1 (1.2)

Data are means and standard deviations.

Exploratory analyses suggested that the intervention significantly reduced GHG emissions and land use from recipients' overall diets at both follow up (Fig. 4.26 to 4.29).

Relative to the control, the intervention reduced the GHG emissions from participants' weekly diets by 10.5 kg of CO_2-eq (95% CI -14.8 to -6.2, p< p=0.0001) at the four weeks follow up and by 7.6 kg of CO_2-eq (95% CI -12.6 to -2.6, p=0.0032) at the eight weeks follow up. These effects were primarily driven by reductions in GHG emissions from ruminant meat, which made up for 62% and 55% of the reduction in overall dietary GHG emissions observed at four and eight weeks, respectively. While ruminant meat was the single food group with the largest impact on changes in GHG emissions at both follow up, reductions from ruminant meat only reached statistical significance at four weeks.

The increases in GHG emissions resulting from increased consumption of meat substitutes were all statistically significant but far smaller than the reductions in GHG emissions from reduced intake of all types of meat. Other than meat and meat substitutes, there were no other statistically significant changes in the GHG emissions from any other individual food group (all p>0.05).

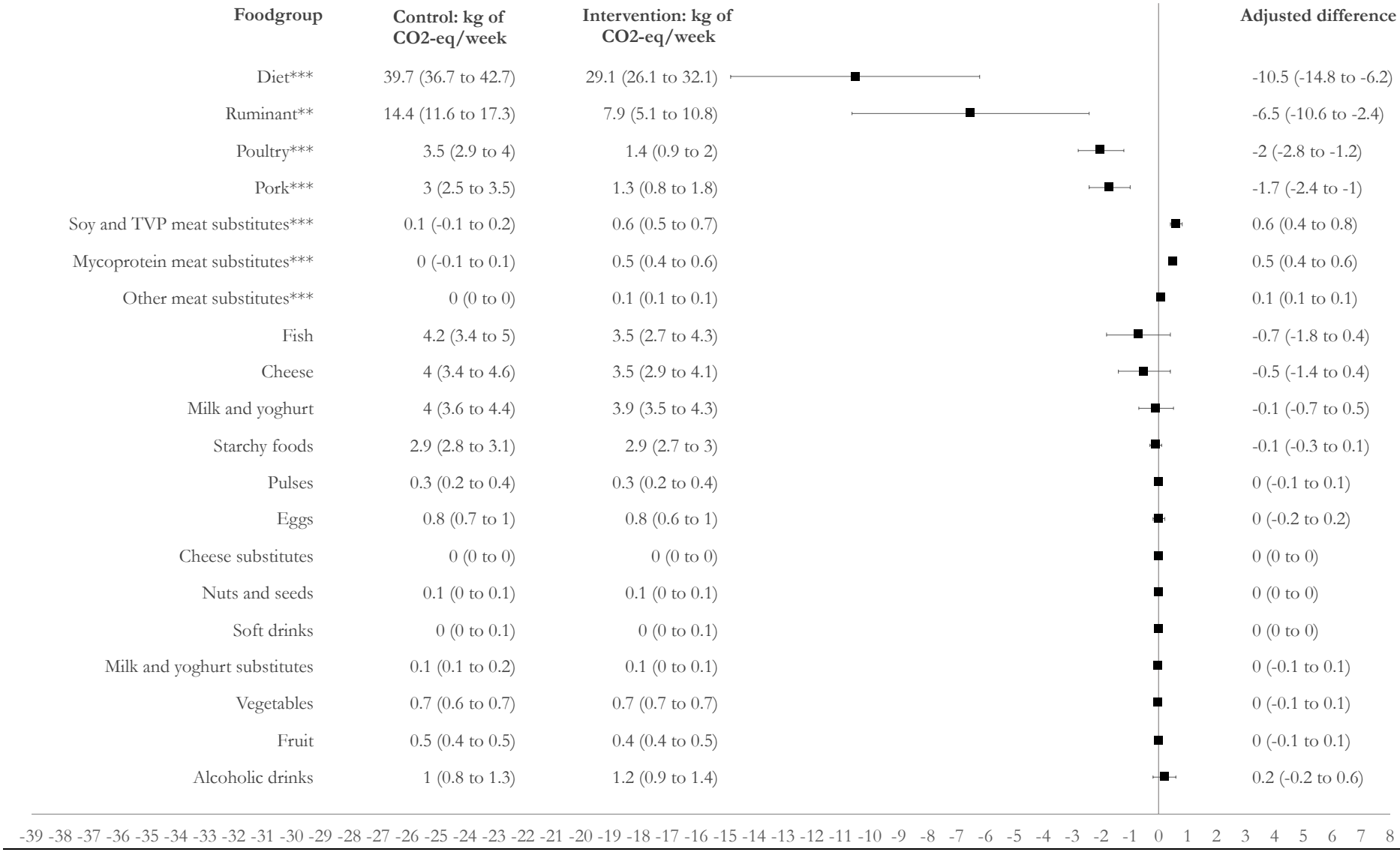
Over the eight weeks study period, RE-MAP saved 4,2 tonnes of CO_2-eq across all intervention recipients (i.e. 57-58 people). This estimates assumes that the diet consumed at the four weeks follow up is representative of participants' diets during weeks one to four and that the diet consumed at the eight weeks follow up is representative of participants' diets during weeks five to eight.

Relative to the control, the intervention reduced the land use associated with participants' weekly diets by 39.4 m^2 (95% CI -59.9 to -18.9, p=0.0002) at four weeks and by 23.6 m^2 (95% CI -45.9 to -1.3, p=0.0382) at the eight weeks. Similar to reductions in GHG emissions, these effects were primarily driven by reductions in land use resulting from reductions in ruminant meat intake, which made up for 83% and 89% of the reduction in land use from participants' overall diets observed at four and eight weeks, respectively. Ruminant meat was the single food group with the largest impact on land use change. However, reductions in the land use from this food group only reached statistical significance at the four weeks follow up.

The increases in land use resulting from increased consumption of meat substitutes were all statistically significant but smaller than the reductions in land use resulting from the reduced intake of meat. Other than meat and meat substitutes, there were no other changes in the intake of specific food groups contributing to statistically significant changes in land use (all $p>0.05$).

Over the eight weeks study period, RE-MAP 'saved' 14.5 km^2 of land across its 57-58 recipients, assuming that the diet consumed at the four weeks follow up is representative of participants' diets during weeks one to four and that the diets consumed at the eight weeks follow up is representative of participants' diets in weeks five to eight.

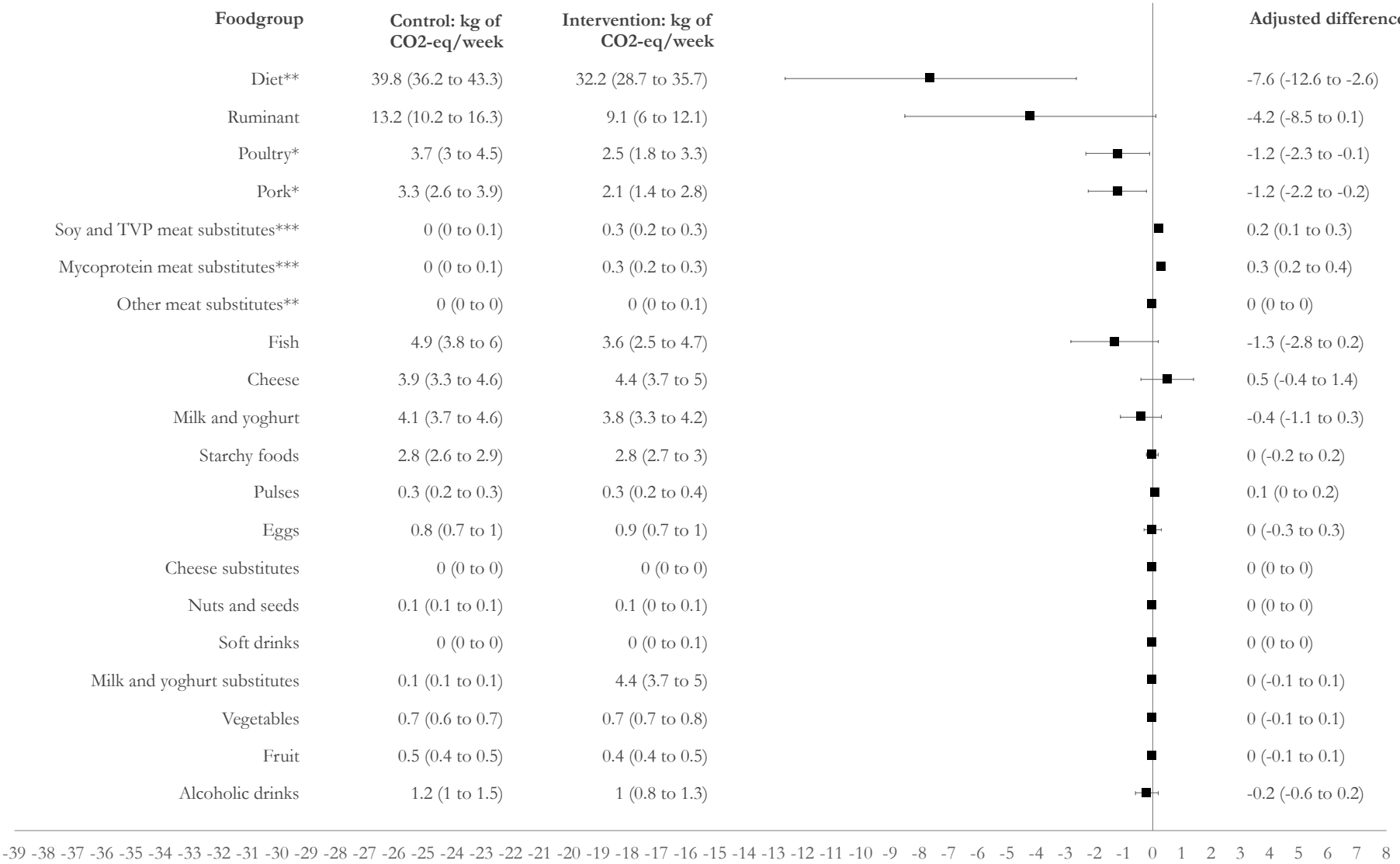
Fig. 4.26: Impact of the intervention on GHG emissions at the four weeks follow up



Mixed effect models with fixed effects for randomised group, baseline levels of the estimated emissions from the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

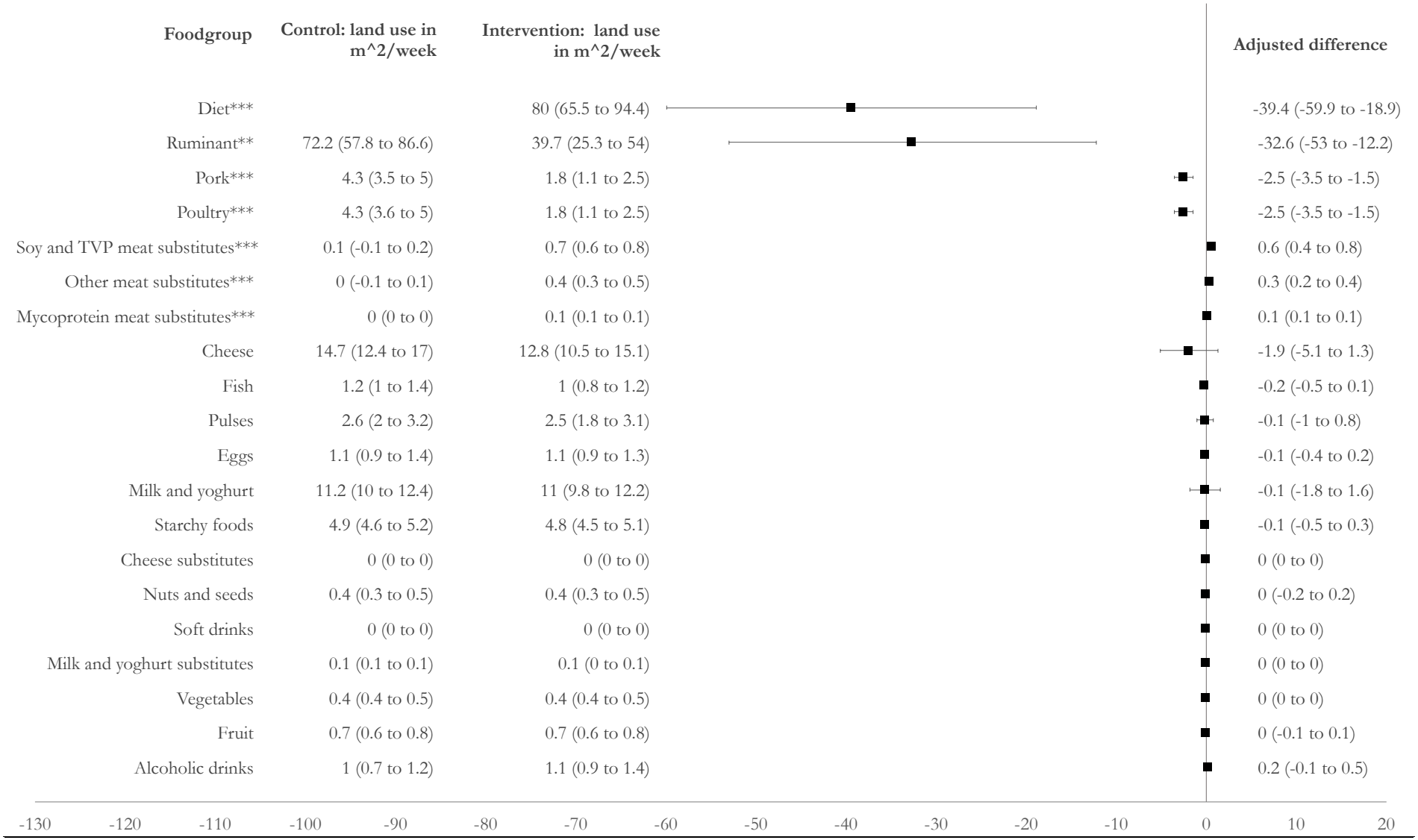
Fig. 4.27: Impact of the intervention on GHG emissions at the eight weeks follow up

Foodgroup	Control: kg of CO2-eq/week	Intervention: kg of CO2-eq/week	Adjusted difference
Diet**	39.8 (36.2 to 43.3)	32.2 (28.7 to 35.7)	-7.6 (-12.6 to -2.6)
Ruminant	13.2 (10.2 to 16.3)	9.1 (6 to 12.1)	-4.2 (-8.5 to 0.1)
Poultry*	3.7 (3 to 4.5)	2.5 (1.8 to 3.3)	-1.2 (-2.3 to -0.1)
Pork*	3.3 (2.6 to 3.9)	2.1 (1.4 to 2.8)	-1.2 (-2.2 to -0.2)
Soy and TVP meat substitutes***	0 (0 to 0.1)	0.3 (0.2 to 0.3)	0.2 (0.1 to 0.3)
Mycoprotein meat substitutes***	0 (0 to 0.1)	0.3 (0.2 to 0.3)	0.3 (0.2 to 0.4)
Other meat substitutes**	0 (0 to 0)	0 (0 to 0.1)	0 (0 to 0)
Fish	4.9 (3.8 to 6)	3.6 (2.5 to 4.7)	-1.3 (-2.8 to 0.2)
Cheese	3.9 (3.3 to 4.6)	4.4 (3.7 to 5)	0.5 (-0.4 to 1.4)
Milk and yoghurt	4.1 (3.7 to 4.6)	3.8 (3.3 to 4.2)	-0.4 (-1.1 to 0.3)
Starchy foods	2.8 (2.6 to 2.9)	2.8 (2.7 to 3)	0 (-0.2 to 0.2)
Pulses	0.3 (0.2 to 0.3)	0.3 (0.2 to 0.4)	0.1 (0 to 0.2)
Eggs	0.8 (0.7 to 1)	0.9 (0.7 to 1)	0 (-0.3 to 0.3)
Cheese substitutes	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)
Nuts and seeds	0.1 (0.1 to 0.1)	0.1 (0 to 0.1)	0 (0 to 0)
Soft drinks	0 (0 to 0)	0 (0 to 0.1)	0 (0 to 0)
Milk and yoghurt substitutes	0.1 (0.1 to 0.1)	4.4 (3.7 to 5)	0 (-0.1 to 0.1)
Vegetables	0.7 (0.6 to 0.7)	0.7 (0.7 to 0.8)	0 (-0.1 to 0.1)
Fruit	0.5 (0.4 to 0.5)	0.4 (0.4 to 0.5)	0 (-0.1 to 0.1)
Alcoholic drinks	1.2 (1 to 1.5)	1 (0.8 to 1.3)	-0.2 (-0.6 to 0.2)



Mixed effect models with fixed effects for randomised group, baseline levels of the estimated emissions from the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

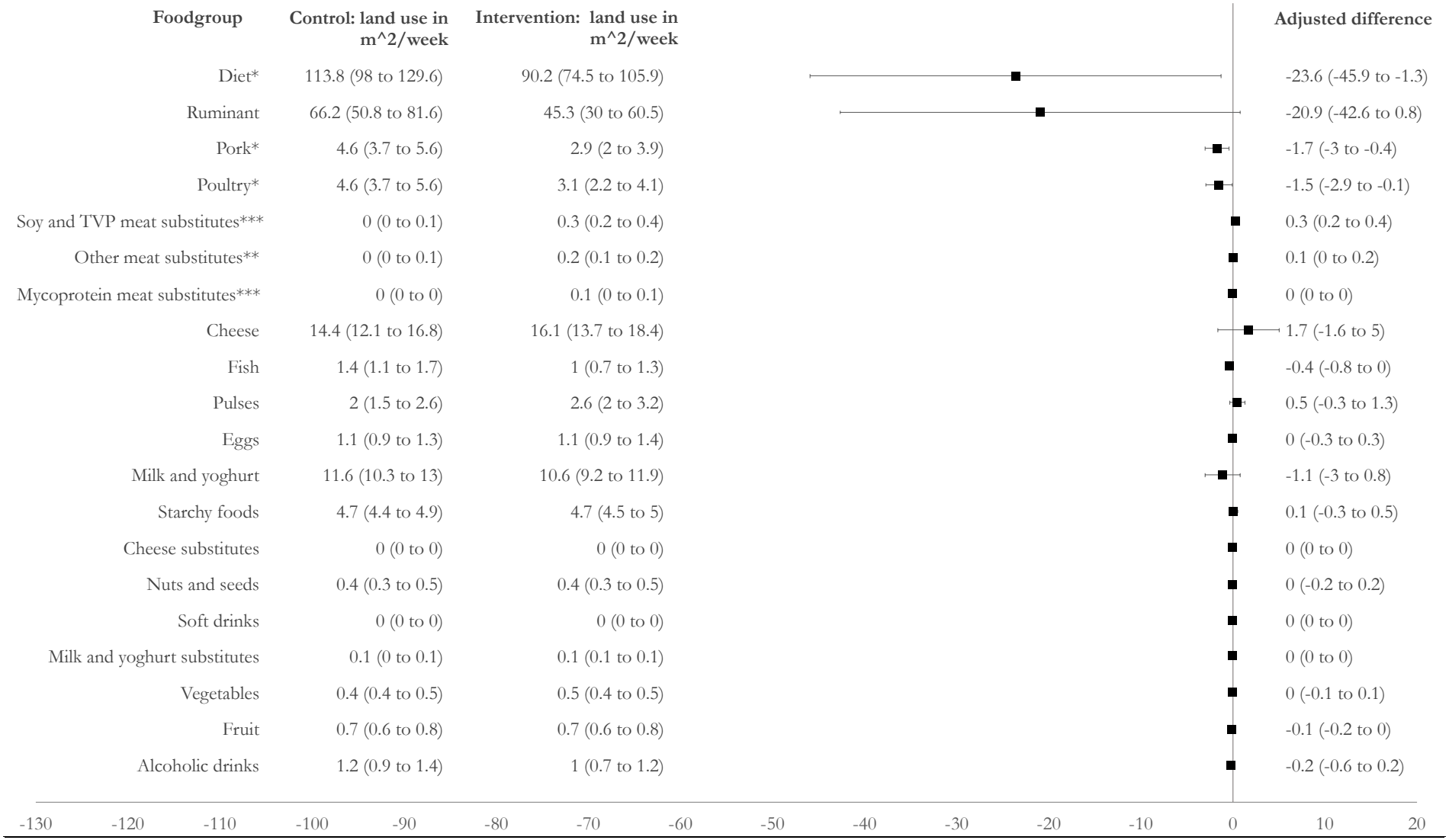
Fig. 4.28: Impact of the intervention on land use at the four weeks follow up



Mixed effect models with fixed effects for randomised group, baseline levels of the estimated land use from the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

Fig. 4.29: Impact of the intervention on land use at the eight weeks follow up

Foodgroup	Control: land use in m^2/week	Intervention: land use in m^2/week	Adjusted difference
Diet*	113.8 (98 to 129.6)	90.2 (74.5 to 105.9)	-23.6 (-45.9 to -1.3)
Ruminant	66.2 (50.8 to 81.6)	45.3 (30 to 60.5)	-20.9 (-42.6 to 0.8)
Pork*	4.6 (3.7 to 5.6)	2.9 (2 to 3.9)	-1.7 (-3 to -0.4)
Poultry*	4.6 (3.7 to 5.6)	3.1 (2.2 to 4.1)	-1.5 (-2.9 to -0.1)
Soy and TVP meat substitutes***	0 (0 to 0.1)	0.3 (0.2 to 0.4)	0.3 (0.2 to 0.4)
Other meat substitutes**	0 (0 to 0.1)	0.2 (0.1 to 0.2)	0.1 (0 to 0.2)
Mycoprotein meat substitutes***	0 (0 to 0)	0.1 (0 to 0.1)	0 (0 to 0)
Cheese	14.4 (12.1 to 16.8)	16.1 (13.7 to 18.4)	1.7 (-1.6 to 5)
Fish	1.4 (1.1 to 1.7)	1 (0.7 to 1.3)	-0.4 (-0.8 to 0)
Pulses	2 (1.5 to 2.6)	2.6 (2 to 3.2)	0.5 (-0.3 to 1.3)
Eggs	1.1 (0.9 to 1.3)	1.1 (0.9 to 1.4)	0 (-0.3 to 0.3)
Milk and yoghurt	11.6 (10.3 to 13)	10.6 (9.2 to 11.9)	-1.1 (-3 to 0.8)
Starchy foods	4.7 (4.4 to 4.9)	4.7 (4.5 to 5)	0.1 (-0.3 to 0.5)
Cheese substitutes	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)
Nuts and seeds	0.4 (0.3 to 0.5)	0.4 (0.3 to 0.5)	0 (-0.2 to 0.2)
Soft drinks	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)
Milk and yoghurt substitutes	0.1 (0 to 0.1)	0.1 (0.1 to 0.1)	0 (0 to 0)
Vegetables	0.4 (0.4 to 0.5)	0.5 (0.4 to 0.5)	0 (-0.1 to 0.1)
Fruit	0.7 (0.6 to 0.8)	0.7 (0.6 to 0.8)	-0.1 (-0.2 to 0)
Alcoholic drinks	1.2 (0.9 to 1.4)	1 (0.7 to 1.2)	-0.2 (-0.6 to 0.2)



Mixed effect models with fixed effects for randomised group, baseline levels of the estimated land use from the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

4. Discussion

4.1 Summary of results

Overall the RE-MAP intervention significantly reduced meat consumption during and after the intervention delivery, while it increased the consumption of meat substitutes. Conversely there was no evidence that it changed the consumption of other main food groups or that it significantly changed participants' energy, macro- or micronutrient intake. The intervention increased participants' intentions, attitudes, perceived social norms, and perceived control to eat a low meat diet and to use meat substitutes, it increased the likelihood of taking up a meat-reducing or non-meat eating identity, and it reduced attachment to meat at both follow up. The intervention led to significant weight loss at both follow up but there was no evidence that it affected blood pressure, blood lipid profiles, or body fat percentage. Finally, the intervention led to significant reductions in the GHG emissions and land use from participants' diets. Taken together these results suggest that the intervention encouraged replacement of meat for meat substitutes without changing other aspects of the diet, improved predispositions to eat less meat, and led to some weight loss and some positive impact on environmental outcomes.

4.2 Trial strengths

This trial had several strengths. It was the first trial assessing the behavioural, nutritional, psychosocial, health, and environmental impact of a four weeks intervention aiming to reduce meat consumption through replacement with meat substitutes. As such, it substantially contributed to the existing evidence on the effectiveness of such interventions.

By employing a randomised controlled trial, the RE-MAP study made it possible to determine the causal impact of the intervention because it ensured that all observable and unobservable confounders were non-systematically distributed between the study groups and that the only systematic difference between the groups was the intervention itself. Additionally, measuring

outcomes during and after the intervention completion provided some early evidence on the sustained impact of the interventions and measuring changes in putative psychosocial determinants of meat and meat substitutes consumption provided early evidence on the potential mechanisms through which the intervention might have changed diets.

Measuring dietary intake is difficult, but I used gold standard methods to measure meat consumption. The food diaries allowed participants to record their eating behaviour prospectively thus reducing the error variance associated with retrospective dietary assessments. Measuring meat consumption over seven days with the diaries, provided a better approximation of habitual meat intakes compared to studies assessing meat consumption over single meal occasions or over fewer days. The diaries also allowed me to assess meat intake both in terms of consumption frequency and portion size. I used daily text messages to remind participants to complete their diaries, which resulted in the food diaries containing 6.9/7 days at the baseline and 6.8/7 days at both follow up that were considered to be 'valid' estimates of intake.

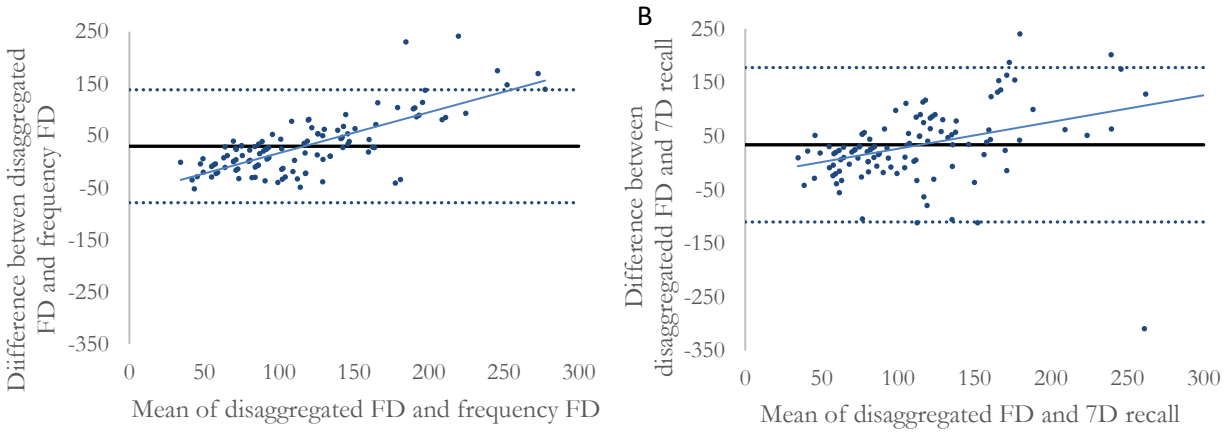
This was the first evaluation of a behavioural intervention using disaggregated meat consumption as the primary outcome, generating very detailed insights on the changes in participants' meat intakes. Contrarily to many other published studies, I also reported the results for different sub-types of meat, such as processed and unprocessed red ruminant, pork, white, and game meat. This represents an important strength of my study, considering the large variations in the health and environmental impact of different meat types.(312)

However, disaggregating food diaries represented an extremely resource intensive method to measure meat consumption and there might be other ways to estimate meat consumption in grams per day with less participant and investigator burden. For example, this could involve (i) asking participants to use a food diary only to note how many meals containing meat they consumed and multiplying

this frequency measure by a standard portion size of meat or (ii) asking participants to retrospectively estimate how many times they ate meat and multiply this frequency measure by a standard portion size of meat. Using the baseline data from food diaries and retrospective questionnaires of RE-MAP, I worked with colleagues to estimate participants' meat consumption in grams per day using these alternative methods and compared their agreements with the fully disaggregated food diaries through Bland-Altman plots (Fig. 4.30).

Overall, both frequency-based measures slightly underestimated the amount of meat intake compared to food diaries and this underestimation was significantly greater at higher levels of meat intake. Compared to fully disaggregated food diaries, the frequency method based on the prospective food diary had a mean absolute bias in estimating meat intake of -29.8 g/day (95% limits of agreement: from -138 to 78 g/day) and the frequency measure based on the retrospective dietary questionnaire had a mean absolute bias in estimating meat intake of -33.8 g/day (95% limits of agreement: from -178 to 110 g/day).

Fig. 4.30: Bland Altman plot comparing estimated meat consumption in g/d from fully disaggregated food diaries and meat consumption estimated through prospective or retrospective frequency measures multiplied by a standard portion size of meat



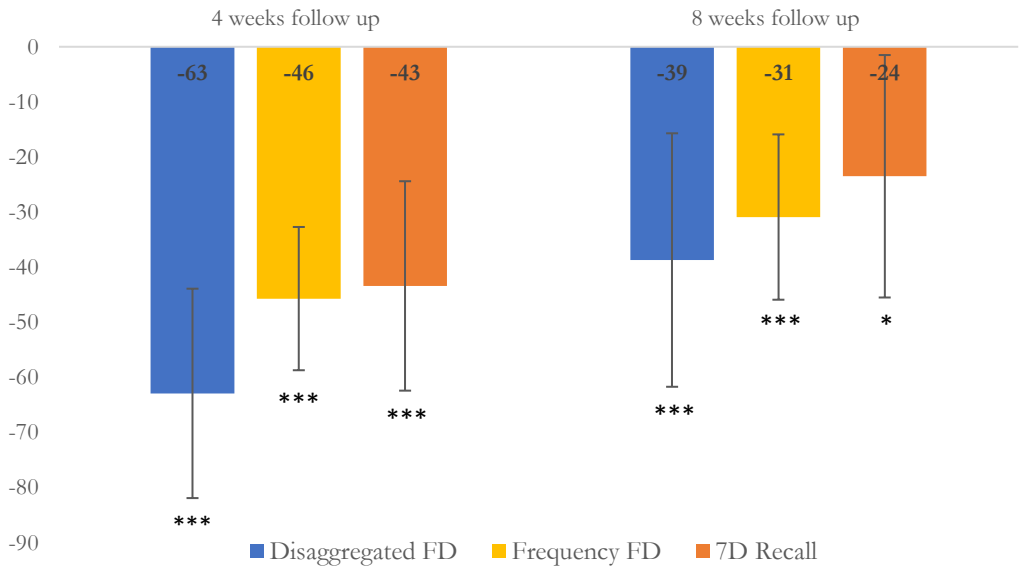
1. Disaggregated FD: Disaggregated meat from 7-day food diaries
2. Frequency FD : number of meals containing meat from food diaries multiplied by a standard portion size of meat
3. 7DDR: Retrospective dietary recall of how many times participants consumed meat over the previous seven days multiplied by a standard portion size of meat

Repeating the primary analysis of RE-MAP using the alternative frequency-based measures produced comparable results in terms of relative reductions in meat intake: relative to the control group, at the four weeks follow up meat consumption declined by 55% when assessed with disaggregated food diaries, by 52% when assessed through the prospective frequency measure, and by 50% when assessed with the retrospective frequency measure.

In absolute terms, reductions in meat intake were underestimated by frequency-based measures: relative to the control group, at the four weeks follow up meat consumption declined by 63 g/d when assessed with disaggregated food diaries, by 46 g/d when assessed with the prospective frequency measure, and by 43 g/d when assessed with the retrospective frequency measure.

However, the interpretation that the intervention significantly reduced meat intake remained unchanged regardless of the method employed to measure meat consumption. A similar pattern was observed for the eight weeks follow up (Fig. 4.31).

Fig. 4.31: RE-MAP impact on meat consumption in g/d relative to the control based on three different methods to estimate meat consumption



Legend and figure adapted from original paper: Mixed effect models with fixed effects for randomised group, baseline meat consumption and gender, and random effects for the intercept and slope. Values are mean and 95% confidence intervals. N=114 at four weeks and N=113 at eight weeks. Disaggregated FD: disaggregating the quantity of meat from meat-containing composite products recorded in 7-day food diaries; Frequency FD: counting the frequency of meals containing meat recorded in 7-day food diaries*standard portion size; 7D Recall: asking participants to retrospectively recall how many they consumed meat in the last 7 days*standard portion size. *P≤0.05, **P≤0.01, ***P≤0.001

The assessment of the intervention impact on nutritional intakes and selected biomarkers of health represents a further strength of this study, as it provides early evidence to address some public concerns on the healthfulness of using meat substitutes.(313,314) Instead of modelling the health impact of using meat substitutes based on theoretical assumptions of how using these foods would change people's diets, my study empirically measured how an intervention promoting the replacement of meat for meat substitutes affected nutritional intakes and some biomarkers of health risk. Similarly, my analysis of the environmental impact of recipients' diets was based on empirically collected data on participants' consumption of a wide range of food groups – rather than theoretically modelling how diets might change following the introduction of an intervention.

The study had a very high retention rate, having only lost one participant in each study group. This might have been the result of (i) the flexible appointment times spanning from 7 am to 8 pm allowing participants to attend their visit outside working hours, (ii) the reminder text messages on the day before the study visit and on the day of the visit itself, (iii) and the financial incentives being staggered across the three assessment visits. This high retention ensured that adequate statistical power was achieved and that the intervention effect was not inflated by a disproportional loss of participants with greater difficulties in reducing their meat intakes or for whom the intervention was not working.(315) Baseline observation carried forward analyses supported the claim that participants' attrition did not affect the main results.

Finally, blinding myself to the randomisation sequence reduced the risk of allocation bias and blinding the researchers coding the food diaries and entering the data in the database to participants' group allocation reduced the risk of detection bias.

4.3 Trial limitations

The results of the RE-MAP trial should be interpreted in light of some methodological limitations.

First, I recruited a convenience sample limiting the generalisability of the results. Participants were only recruited among adult-only households within Oxford, they were highly educated, predominantly white, and had a greater proportion of female participants compared to the British population. Additionally, volunteers who took part in public engagement activities to inform the development of the intervention, where also highly educated and had an interest in science and the impact of meat consumption. The intervention effect observed in the present trial might therefore not generalise to people from less privileged backgrounds or other hard-to-reach populations. Future research should aim to involve more such people during the design and the evaluation of interventions aiming to reduce meat consumption. This would increase the likelihood of study results replicating when delivered at scale and it would help to ensure that interventions do not exacerbate existing health inequities among the population. Within the RE-MAP trial, future exploratory analyses might investigate whether the intervention effect differed according to relevant demographic characteristics of recipients, such as income and highest educational achievement. By design, I only recruited participants with high meat intakes. As such, the intervention effect might also not apply to populations with lower habitual meat intakes.

Second, the study was prone to several sources of bias. Neither participants nor I were blind to the study group allocation after randomisation. This might have consciously or unconsciously led me to treat participants in the two groups differently and might have introduced or increased the extent to which social desirability bias affected participants' questionnaire responses and food diaries.

The food diaries themselves might have influenced participants' meat consumption. In the context of a randomised controlled trial, this would only affect the validity of the results if the diaries

disproportionally affected those receiving the intervention. While there is no evidence that this was the case, it is possible that participants receiving the intervention felt particularly uncomfortable recording high levels of meat consumption. This might have encouraged participants in the intervention group to reduce their meat intakes or to underreport their meat intakes.

Another important limitation of the study is the error variance affecting many of the outcome measures. The outcomes recorded with the food diaries were likely to be affected by errors both during the recording process and the analyses. During the food recording process measurement errors might have occurred due to participants' difficulties estimating portion sizes, forgetfulness to record their food intakes, or technical difficulties interacting with the electronic food diaries. Additionally, asking participants to record their food intake over seven days might have led to participant fatigue and subsequent declining accuracy in their dietary reporting over the seven days. During the analysis of food diaries measurement error might have also occurred due to the numerous assumptions required to estimate portion size, estimate the proportion of edible meat, convert the raw weights of meat to cooked weights, and estimate the ingredients of composite dishes when these were not specified. Additionally, since the disaggregation of meat products and the count of meals containing other food groups was done manually on approximately 2,394 food diary days, it is likely that human error affected these measures. To overcome these challenges, I had considered using urinary biomarkers of meat consumption as a more objective measure of meat intakes. However, this strategy proved unfeasible due to the lack of a reliable biomarker, the participant burden associated with collecting and storing urine samples, and the technical challenges pertaining to the storage and transport of the urinary samples that had to remain frozen from the moment they were collected to the moment they were analysed. However, because RE-MAP was a randomised controlled trial and food diaries were disaggregated without knowing the study condition of participants, these measurement errors are likely to have occurred in equal measures in both study groups.

Additional measurement errors might have affected the retrospective food questionnaire that I used in sensitivity analyses. Specifically, participants might have had difficulties remembering their food intakes and correctly categorising different foods in the pre-specified groups. The nutritional outcomes might also be affected by errors resulting from participants' difficulty in correctly reporting their food intake and from inaccuracies in the nutritional information of the Myfitnesspal database. It is plausible that measurement errors of nutritional outcomes differentially affected people in the intervention and control group. Specifically, meat substitutes are often sold as ready meals and contrarily to many meat products they require little to no addition of salt for their preparation. Considering that participants almost never reported added salt in their diaries it is possible that those in the control group (i.e. eating more meat and fewer meat substitutes) had greater underreporting of sodium than those in the intervention. The lack of a significant reduction in sodium following the intervention is therefore likely to be a conservative estimate of the intervention effect.

The energy intake for both study groups and at all measurement time points was low and likely to indicate a degree of underreporting. To mitigate this problem, I decided a-priori to exclude food diary days with <1000 kcal, as I considered these days unlikely to accurately represent habitual food intakes among adults. Error variance might have affected biomarkers of health risk, too. In particular, it was impossible to ensure that participants attended all of their visits at the same time and in a fasted state and some participants walked or cycled to the visit, which might have affected their blood pressure. A last source of measurement error might have occurred through data entry. All data was manually inserted in a bespoke database. This task involved transcribing many thousands data points and is likely to have introduced some human error. To mitigate these errors I used range checks and other diagnostic tests before locking the database. Despite some exceptions highlighted above, measurement errors should have affected the intervention and the control group in equal measure. As such, the relative difference in outcomes between the study groups should still represents a reliable estimate of the intervention effect.

Some psychosocial outcomes included in my study were not measured with validated scales and should therefore be interpreted with caution. However, these scales had strong face validity and were considered easy to understand by a panel of people participating to the patient and public involvement focus group described in the previous chapter.

The analysis of the environmental impact of RE-MAP should also be interpreted cautiously. I only had disaggregated data for meat consumption, which meant that I had to estimate the consumption of other food groups based on self-reported consumption frequency data and standard portion sizes of food groups. This approach might have introduced substantive imprecision, since standard portion sizes might not have accurately represented those consumed by participants. However, disaggregating every food group would not have been feasible within the constraints of this DPhil. Additionally, environmental impact data were not available for every food group included in the analysis. When these data were lacking, I relied on reasonable proxies. For example, I used the environmental impact of Tofu as a proxy for all soy-based and TVP meat substitutes, although Tofu is only one of many such products..

Where possible, I used Poore and Nemecek's database to estimate the environmental impact of producing different food groups.(24) This was to promote consistency in the methodology underlying the estimates of environmental impact. However, Poore and Nemecek's database did not report an estimate for the environmental impact of mycoprotein. As such, I extrapolated this value from a separate lifecycle analysis.(311) The changes in the environmental impact associated with the increased consumption of mycoprotein products might therefore not be directly comparable with the changes in the environmental impact of other food groups included in the analysis.

Because of the multicomponent nature of the intervention it was impossible to quantitatively assess which intervention component(s) causally influenced the different outcomes. Additionally, due to the very high number of outcomes, significant results of secondary and exploratory analyses should be interpreted with caution.

Finally, because many of the meat substitutes were frozen or suitable for home freezing it was impossible to ensure that the substitutes consumed at the second follow up were not those provided during the intervention. Anecdotal evidence from the qualitative interviews suggested that some participants did not purchase new meat substitutes and still had sufficient supplies from the intervention four weeks after the intervention completion while others finished the supply from the study at the end or shortly after the intervention completion and only consumed independently purchased substitutes at the eight weeks follow up.

While the trial provided evidence on the intervention impact several weeks after the intervention completion, future work is needed to reliably assess the long term impact of behavioural interventions to reduce meat consumption.

4.4 Results in context of other studies and policy implications

While RE-MAP is the first randomised trial of its kind, two similar interventions were previously evaluated in pre-post studies.(247,249) RE-MAP broadly supported the findings of these earlier studies suggesting that providing free access to meat substitutes and supporting motivational materials can reduce (or is associated with reductions in) meat consumption both during the intervention and after the intervention completion. The RE-MAP study contributed to this existing literature by corroborating the causal role of interventions providing meat substitutes and supporting material in reducing meat consumption.

However, the aforementioned pre-post studies found that providing free meat substitutes and motivational materials was associated with some positive changes in participants' blood lipids, which is in contrast with my trial results. (247,249) There are four possible explanations to this discrepancy:

- First, the RE-MAP study was shorter than one of the aforementioned studies and it is possible that longer follow ups would have detected an effect
- Second, the aforementioned studies assessed blood lipids though venepuncture blood samples that might have delivered more precise measures of blood lipids than the finger prick samples used in RE-MAP
- Third, the interventions previously tested might have been more effective than RE-MAP at improving blood lipids
- Fourth, it is possible that the changes detected in previous pre-post studies were not causally linked to the interventions and would have occurred regardless of the intervention. Since meat contributes to a significant proportion of saturated fatty acids in the British diet and that my intervention reduced the intake of saturated fatty acids at both follow ups, it is at least plausible that over time RE-MAP would have resulted in improved blood lipids.(93)

My systematic reviews found that providing information on the health and environmental benefits of eating less meat led to greater intentions to consume a low meat diet but did not lead to actual changes in participants meat consumption.(184) In RE-MAP, I delivered infographics on the benefits of eating less meat and, in line with previous research, participants intentions to eat less meat increased. However, since information alone was not found to affect actual meat consumption in previous studies, the changes in meat consumption generated by RE-MAP are likely to be the result of other intervention components or the interaction between the infographics and other components.

None of the behavioural interventions identified in my systematic reviews directly assessed the impact of recipe books and success stories. However, these intervention components were in line with

general principles from the behavioural science literature, suggesting that people's capability of performing a behaviour and the perception that other people are engaging in a behaviour can have a strong impact on human behaviour.(316,317)

While the RE-MAP intervention delivered promising results, it was also very costly: Excluding the personnel costs of developing and delivering the intervention, the cost of RE-MAP was on average £115.2 per participant, meaning that for every £1 spent on the intervention, RE-MAP reduced meat consumption by 4.2 grams per week at the first follow up (Table 4.10). While some of these intervention costs could be lower if RE-MAP was delivered at scale, the intervention in its current form is too costly to represent a scalable policy option.

Table 4.10: Estimated intervention costs per participant

Component	Material	Estimated cost
Meat substitutes	Free meat substitutes for the household for four weeks	£75 Source: RE-MAP data
Infographics	Six A4 double-sided colour printed sheets	£10 Source: ryman.co.uk
Cookbooks	Nine A4 double-sided colour printed sheets	£14 Source: ryman.co.uk
	'A girl called Jack'	£10 Source: amazon.com
Success stories	Two A4 double-sided colour printed sheets	£3 Source: ryman.co.uk
Deliveries	3 second class stamps	£2 Source: postoffice.co.uk
	3 envelopes	£1 Source: ryman.co.uk
	Total materials cost per participant	**£115**

The most directly applicable policy implications of RE-MAP were (i) that exposure to meat substitutes can be an acceptable and effective way to reduce meat consumption, (ii) that people using meat substitutes are likely to swap meat for substitutes without changing other aspect of their diet, (iii) that replacing meat for meat substitutes does not detrimentally affect nutritional intakes or biomarkers of cardiovascular health, (iv) that using meat substitutes can help people lose weight, (v) and that replacing meat for meat substitutes can lead to significant reduction in the GHG emissions and land requirements of people's diets.

4.5 Conclusions and next steps

In conclusion, RE-MAP reduced meat consumption by encouraging swaps with meat substitutes and without changing other aspects of participants' diets or substantially affecting nutritional intakes. RE-

MAP increased participants' intentions, attitudes, perceived control, and perceived norms of eating a low meat diet and using meat substitutes and reduced attachment to meat. The intervention also increased participants' likelihood to adopt reduced- or non-meat eating identities, it led to weight loss, and reduced the GHG emissions and land requirements of recipients' diets. Despite the promising results, the costs of RE-MAP are too high for this intervention to represent a scalable policy option in its current form. The qualitative research presented in the next chapter provides some insights for how to design a more cost-effective version of the RE-MAP intervention.

Chapter 5: Qualitative Results of the RE-MAP Trial

1. Chapter summary

This chapter presents the findings from twenty semi-structured qualitative interviews conducted with participants who received the RE-MAP intervention. The insights generated by this research complement the quantitative evaluation in four domains: First, the interviews contributed towards developing a better understanding of the mechanisms through which the RE-MAP intervention affected recipients' meat consumption. Second, the qualitative interviews highlighted how recipients perceived the four intervention components of the RE-MAP intervention, highlighting opportunities to further enhance the effectiveness of each component. Third, while the interviews revealed a few mild unintended consequences experienced by participants, in general this qualitative work confirmed that the intervention did not lead to substantive backfire effects. Fourth, this qualitative workstream helped to interpret the findings from the quantitative analyses, suggesting (i) that the results of the quantitative trial might underestimate the impact that the intervention could have on meat consumption, (ii) that the findings of the trial might generalise beyond people who are pre-motivated to eat less meat, and (iii) that the increased consumption of meat substitutes does not provide conclusive evidence that the intervention increased recipients' *independent purchase* of these products.

2. Methods

2.1 Study objectives

The randomised controlled trial presented in chapter 4 generated empirical evidence that the RE-MAP intervention effectively reduced recipients' meat consumption, changed their perspectives on eating meat and meat substitutes, promoted weight loss, and reduced some markers of environmental impact from recipients' diets. However, this evidence did not provide insights into participants' personal experiences of the intervention and of the wider study. I, therefore, embedded a qualitative workstream within the trial to explore participants' (i) perspectives on how the intervention affected their meat consumption, (ii) opinions of the four intervention components, and (iii) experiences of the operational study processes, such as recruitment and data collection.

2.2 Recruitment and ethics

To meet the aforementioned objectives, I conducted twenty semi-structured interviews with participants who received the RE-MAP intervention and completed the study protocol. The Medical Sciences Interdivisional Research Ethics Committee (IDREC) of the University of Oxford provided the ethical approval to conduct these qualitative interviews (Ref: R54329/RE001). A written information sheet explained the procedure and aim of the interviews and participants gave their written informed consent to be interviewed when enrolling in the RE-MAP trial (Appendices 2 to 4). Before interviewing consenting participants, I reminded them that the interviews would be audio recorded and transcribed, that the results would be included in my thesis and other academic outputs, and that anonymous quotes might be used to support the claims made throughout the qualitative analysis. I also reminded participants that they were not obliged to take part in the interviews.

2.3 Sampling strategy

I initially planned to employ a purposeful sampling technique to achieve a sex balance. However, this proved unfeasible, as the majority of participants in the intervention group were female and it was

logistically difficult for many participants to prolong their last study visit to stay for the interview. I, therefore, asked every participant who received the intervention, completed the study protocol, and for whom it was logistically possible to prolong their last study visit to take part in the interviews until I reached the pre-specified sample size of 20 participants.

2.4 Sample size

To determine the required sample size, I considered various factors affecting information power. Information power is a metric describing how effectively the data generated through each interview is expected to contribute towards meeting the objectives of a qualitative study.(318) The higher the information power, the smaller the number of interviews required. Malterud and colleagues suggest that greater information power is achieved by projects with (i) highly specific samples, (ii) clear research aims, (iii) use of theory, (iv) and greater data quality.(1) Based on these criteria, I considered the information power for my interviews to be medium-low. This was because the semi-structured nature of my interviews allowed for new research questions to develop organically, the planned data analyses were predominantly data-driven rather than theory-driven, and it was impossible to meaningfully estimate the quality of collected data a-priori. I, therefore, deemed a sample of 20 participants to be appropriate, as this equalled 40% of the sample I planned to recruit for the intervention group. To retain flexibility, I also pre-specified that recruitment could be extended should new themes continue to emerge during the interview process. However, this was not the case and recruitment was terminated after the 20th interview.

2.5 Topic guides

To structure the interviews, I developed a topic guide including four main sections (Appendix 8):

- **Rapport building:** The first section served to build rapport with participants and remind them that I was interested in their own personal experiences and that there were no right or wrong answers to my questions.

- **Motivation to enrol:** The second section asked participants to reflect upon their initial motivation to enrol in the study.

- **Overall study experience:** The third section asked participants to elaborate on their experiences with the overall study and with the intervention as a whole.

- **Intervention components:** The last and most substantive section asked participants to elaborate on whether and how each intervention component affected their meat consumption or other aspects of their diets and life.

While broadly following this structure, I also explored themes that emerged organically during the interviews. Whenever possible, I used open questions to encourage participants to elaborate on their thoughts and feelings freely. I also avoided questions of evaluative nature to minimise the risk of social desirability bias.

2.6 Data analysis

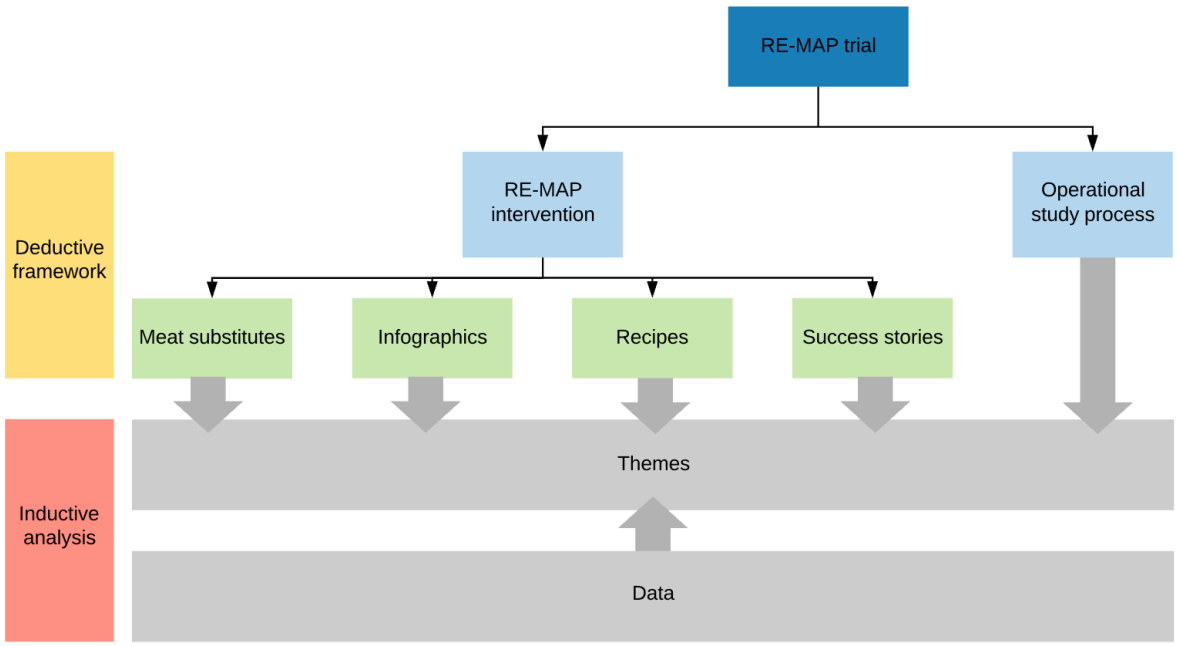
The audio recorded interviews were transcribed verbatim. Non-verbal utterances were only transcribed when they had a semantic meaning (e.g. a cough to indicate an ironic statement) but not otherwise (e.g. just a cough). I analysed the data using thematic analysis in NVivo 12.0 following the six steps outlined in the 2006 methodological paper by Braun and Clarke:(319)

- First, I familiarised myself with the data by reading the transcribed interviews multiple times and making notes about initial thoughts on potential codes and patterns.

- Second, I coded the data in NVivo. Data can primarily be coded in two ways: A deductive approach, in which the coding follows a pre-specified framework and an inductive data-

driven approach, in which the data is coded 'without trying to fit it into a pre-existing coding frame'. I employed both techniques at different stages of my analysis. I initially used a deductive approach to identify data pertaining to each of the four RE-MAP intervention components and to operational study processes (e.g. data collection or recruitment). Within this framework I then used an inductive data-driven approach to analyse the data (Fig. 5.1).

Fig. 5.1: analytical approach



- Third, I grouped the different codes into broader themes. Throughout this work I aimed to develop groups of codes that were mutually exclusive and collectively exhaustive while also retaining the complexity of the data. As outlined by Braun and Clarke, and by Boyatzis, groups of codes can be identified at the semantic level or at the interpretative level.(319,320) The former approach aims to identify themes descriptively without aiming to go beyond what participants say, while the latter aims to identify the ideologies, conceptualisations, ideas, and assumptions that underlie what participants said. I elected to employ a semantic approach, as the main aim of this study was to describe the range of stated experiences with the intervention and the wider study.

- Fourth, I redefined themes through an iterative process of checking consistency between the data, the codes, and the themes. This process resulted in the development of new themes, the discounting of other themes, and the merger of some existing themes.

- The fifth and the sixth steps involved naming the themes to accurately capture their essence and writing up the analysis.

The process described above is presented as linear, however in practice it was conducted iteratively with later steps frequently resulting in amendments to previous parts of the analysis. Due to practical constraints of this DPhil, I was the only researcher conducting the interviews and analysing the resulting qualitative data. Throughout this chapter I discuss the findings from the analysis often referring to how the data corroborated or disputed the way in which I had originally hypothesised the intervention would work (see logic model in chapter 3). In the discussion of this chapter I present a fully updated logic model, which integrates the insights generated by this qualitative workstream.

3. Results

3.1 Sample characteristics

The demographic characteristics of interviewed participants are reported in Table 5.1. Overall, this sample reflected the demographic characteristics of the intervention group, in that participants were highly educated, predominantly white and female, and generally in their thirties.

Table 5.1: Baseline demographic characteristics

	Interviewed (N=20)	Overall intervention (N=57)
Age in years	34 (11)	33 (11)
Gender		
female	14 (70%)	38 (66%)
male	5 (25%)	19 (33%)
Other or prefer not to say	1 (5%)	1 (2%)
Ethnic origin		
White	19 (95%)	50 (86%)
Chinese	0 (0%)	4 (7%)
Black Caribbean	0 (0%)	1 (2%)
Black African	0 (0%)	0 (0%)
Other or prefer not to say	1 (5%)	3 (5%)
Household income		
£0-£9,999	1 (5%)	1 (2%)
£10,000 - £19,999	2 (10%)	7 (12%)
£20,000 - £29,999	5 (25%)	8 (14%)
£30,000 - £39,999	3 (15%)	10 (17%)
£40,000 - £49,999	0 (0%)	3 (5%)
£50,000 - £59,999	2 (10%)	8 (14%)
£60,000 - £69,999	1 (5%)	5 (9%)
£70,000+	5 (25%)	10 (17%)
Do not know or prefer not to say	1 (5%)	6 (10%)
Highest educational degree		
GCSE or equivalent	1 (5%)	4 (7%)
A-level or equivalent	1 (5%)	7 (12%)
BSc or equivalent	9 (45%)	28 (48%)
Higher degree (MSc, PhD or equivalent)	9 (45%)	19 (33%)

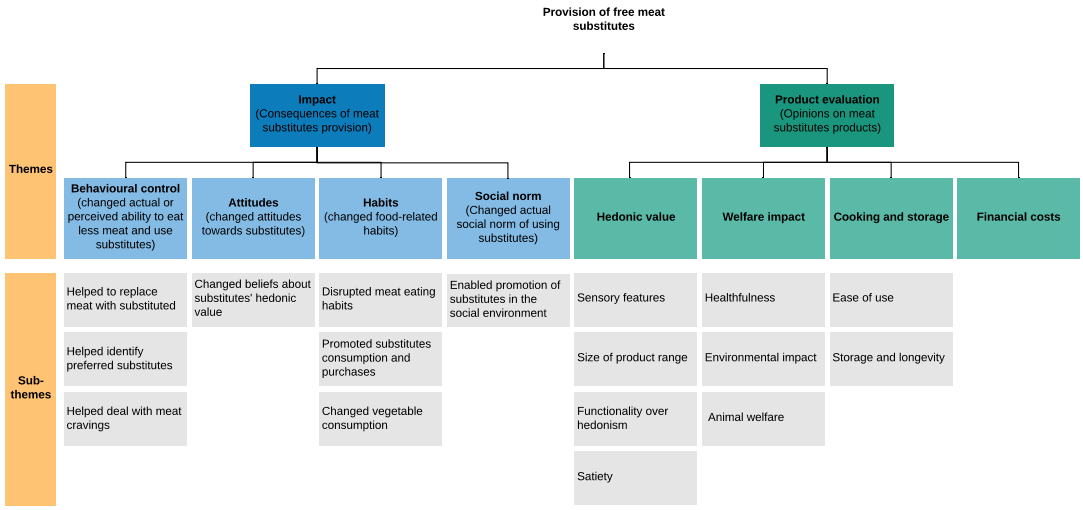
Data are mean and standard deviation or number and percentage

The sections below outline the results of the qualitative analysis organised into the four RE-MAP intervention components and the operational study processes of the trial.

3.2 Meat substitutes

As part of the intervention, participants received a supply of meat substitutes, which they could select from a catalogue of commercially available products. The interviews captured heterogeneous and contrasting views about many aspects of this intervention component and the exposure to meat substitutes was polarising, usually increasing positive perceptions of these products but occasionally reinforcing negative opinions. However, in general participants perceived meat substitutes as a helpful aid to eat less meat and many viewed substitutes as the main intervention component, while infographics, recipes, and success stories were often perceived as supporting resources of secondary importance. Below, I provide a detailed account of how meat substitutes affected participants (section 3.2.1) and of participants' opinions about various features of meat substitute products (section 3.2.2, Fig. 5.2).

Fig. 5.2: Meat substitutes themes



3.2.1 Impact of meat substitutes

According to the interviews, meat substitutes changed participants' behaviours, thoughts, and feelings in numerous ways and through multiple mechanisms. Specifically, meat substitutes were perceived to affect participants' behavioural control of eating a low meat diet (section 3.2.1.1), attitudes towards meat substitutes (section 3.2.1.2), eating habits (section 3.2.1.3), and the social norms around using meat substitutes in recipients' social environments (section 3.2.1.4).

3.2.1.1 Behavioural control

My initial logic model hypothesised that meat substitutes would enhance recipients' behavioural control of eating a low meat diet by enabling 'like for like' swaps and by making plant-based substitutes available. The interviews supported these hypotheses (Quote 1, 2), but also highlighted other mechanisms through which this intervention component affected behavioural control. First, the substitutes provided a concrete guidance for what to replace meat with, which was particularly helpful for participants who were unaware of these products or who disliked traditional vegetarian alternatives, such as pulses or mushrooms (Quote 3). Second, trying a large number of different meat substitutes enabled some participants to identify the ones that they enjoyed and that they would consider integrating in their routine diets (Quote 4). Finally, meat substitutes were considered a helpful aid for dealing with meat cravings, which was presented as important for supporting longer term transitions to plant-based diets (Quote 5).



Quote 1: "A lot of [meat substitutes] were like a sausage or a pie. So where you would have had meat in your meal you can just have something that is an alternative. It functions in the same way within your meal but it's not got meat in it. Makes it a very easy swap." Participant 15 (male, 34)

Quote 2: "Because the [meat substitute] products were there I didn't have to think 'Oh where will I go? what am I going to need to get?' and it made me try different things whereas if I had to go out and buy them myself I probably would have tried one or two and then maybe given up and gone 'Well this is too difficult to figure out, I can't do it'. But having those options available was a lot easier." Participant 5 (female, 30)

Quote 3: "I've always said 'Oh I could never be a vegetarian because I didn't like cheese and I didn't like mushrooms' and if you go to a restaurant anywhere most vegetarian meals are mushrooms stuffed with cheese [...] so this has opened my eyes to the fact that I could actually eat less meat and eat stuff that I do like without having to eat cheese or mushrooms." Participant 2 (female, 27)

Quote 4: "The opportunity to try a whole range of it made me realise that actually there was stuff in the range that I really, really liked and would chose over meat and stuff that I might not try again" Participant 8 (female, 23)

Quote 5: "I think in the long run having meat substitutes would help in terms of if I was having a meat craving I would probably have that instead." Participant 1 (female, 22)

3.2.1.2 Attitudes

My initial logic model hypothesised that providing meat substitutes would increase positive attitudes towards these products through a process of mere exposure, which describes people's tendency to develop a preference for things as they become more familiar with them.(287,288,321) While many participants elaborated on how their attitudes were affected by the provision of substitutes, there was

no evidence that mere exposure played an important role, as it was only alluded to in one interview (Quote 6). Instead, this intervention component changed recipients' attitudes by challenging negative pre-existing beliefs about the hedonic value of meat substitutes and by showcasing the extent to which these products improved since participants last tried them (Quote 7, 8). The exposure to a wide range of substitutes, also allowed participants to swiftly identify those that they enjoyed (see above), which might have contributed towards promoting positive attitudes toward some of these products.



Quote 6: "if you're a meat eater sometimes you feel like eating meat, you know […] isn't exactly the same but [um] I find [that like] with anything the more you eat something the more you want it, the less you eat something the less you want it" Participant 20 (female, 32)

Quote 7: "For me the most critical [intervention component] personally was having the meat replacements that I probably wouldn't have bought otherwise and having [them] actually changed my mind, my prejudice that they weren't going to be good. I actually think some of them are quite good." Participant 16 (female, 31)

Quote 8: "I thought they were good [um] I haven't had meat substitutes in like 10 or 15 years and it made me realise how far along they'd come." Participant 8 (female, 23)

3.2.1.3 Eating and food purchasing habits

The impact of meat substitutes on eating habits and food purchasing habits emerged as a recurrent theme. The provision of meat substitutes disrupted meat eating habits by prompting some participants to consider using these products where they would otherwise have used meat (Quote 9) and led some participants to start purchasing meat substitutes during their routine shopping trips and when eating out (Quote 10).

In this context, some participants indicated that they had continued to consume meat substitutes several weeks after the intervention completion but that they had not started purchasing these products independently because they still had sufficient supplies left from the intervention. Some participants highlighted that meat substitutes also changed dietary habits unrelated to meat consumption, including increasing the consumption of frozen foods, ready meals, processed foods, and meals that followed the traditional 'one meat(substitute) two veggies' format (Quote 11).

Meat substitutes were sometimes perceived to affect vegetable consumption too, with some participants saying that this intervention component increased their vegetable intake by facilitating a gradual transition to a natural plant-based diet (Quote 12), while others said that it inhibited their proactive planning and procurement of meals containing vegetables (Quote 13).



Quote 9: "there were some days when I had some jackfruit or whatever it was, but if I hadn't had that I probably would have cooked chicken instead." Participant 11 (male, 39)

Quote 10: "I think by [the end of the intervention month] it had become a habit. I[…] I didn't think I would, but I would be in Sainsbury's and I would just pick up… I'd naturally gravitate towards that vegetarian section." Participant 3 (female, 23)

Quote 11: "[…] most of the option like burgers or sausages tended to force me a bit more back to the kind of typical British like 'one meat and two veg'. So I don't think there were recipes they created that were as varied as they might have been otherwise, but that's partly to do with the [meat substitutes] that I selected." Participant 6 (female, 30)

Quote 12: "I started off swapping meat for meat [substitute] so Quorn mince for normal mince, and things like that. But then as I went on I thought well let's try some Tofu, let's do almost what I would do for a meat dish but add in Tofu, or more vegetables quite often as well" Participant 5 (female, 30)

Quote 13: "if I was cooking meat I would normally cook two or three vegetables to go with it just because that's habitual. I found myself a lot of times just having the Quorn product for some reason […] it was very convenient to have them delivered and also to have them in the freezer. I'm normally very regimented with knowing what I'm going to cook, I plan out my meals on the weekend and cook them and […] I found I was less likely to do that with the meat replacements study. I would just go and see what was in the freezer and just grab something out and cook that. So perhaps that explains the previous point about the vegetables and the lack of them." Participant 12 (male, 33)

3.2.1.4 Social norms

Another unanticipated mechanism through which the provision of meat substitutes affected participants' diets was by helping them promote meat substitutes among members of their social environment. This social influence occurred in three different ways.

First, meat substitutes sparked conversations between intervention recipients and members of their social environment, who subsequently decided to purchase substitutes themselves (Quote 14).

Second, some participants used meat substitutes to prepare meals for their families and friends to introduce their social networks to these plant-based foods (Quote 15). However, not all participants felt sufficiently comfortable to use substitutes when cooking for others, as they thought that their guests would prefer meat or perceive substitutes to be a poor offer for a social meal (Quote 16).

Finally, one participant reported replacing meat with meat substitutes when cooking for her family without explicitly specifying that she had done so (Quote 17).



Quote 14: "I told [my brother] about the Quorn and he sent me a picture on WhatsApp of his local supermarket and they had a freezer full of Quorn things that were 40% off and so he bought a lot of them because I told him they were really good. So I guess just sharing stories, I mean we're humans we copy each other and [um] you could see that." Participant 12 (male, 33)

Quote 15: "I had dinner with my dad and I was like 'Oh why don't we try these [meat substitutes] maybe you'll like to try a veggie burger?' He quite enjoyed it." Participant 1 (female, 22)

Quote 16: "[meat substitutes were] slightly antisocial […] just a lot of friends wouldn't want to, to eat them. […] I think if people come over and expect to be entertained they would want either a delicious vegetarian meal or meat and I think the meat substitutes […] they would certainly turn their nose at that, I wouldn't serve a vegetarian roast to friends. […] if you said here's a meat substitute I think people might feel a little bit short changed." Participant 14 (female, 40)

Quote 17: "I did share the [meat substitutes] with my partner, a couple of times by telling him what he was getting and others by simply cooking something and just not really specifying what it was." Participant 5 (female, 30)

3.2.2 Evaluation of meat substitutes

This section elaborates on participants' opinions of meat substitutes. Views were heterogeneous and the value participants' attributed to specific product features was determined by their underlying values and objectives. For example, participants generally perceived meat substitutes to be less energy dense than meat. This characteristic was presented as favourable among those who valued weight loss and as unfavourable among those who were concerned they might not reach their targets for energy intake. Participants discussed four aspects of meat substitutes, including (i) hedonic value, (ii) welfare, (iii) cooking and storage requirements, and (iv) financial cost. In this section, I give voice to participants' opinions without aiming to question the evidence underlying their views.

3.2.2.1 Hedonic value of meat substitutes

Participants frequently discussed the hedonic value of meat substitutes, specifically focussing on (i) sensory features, (ii) product range, (iii) functionality, and (iv) sense of satiety. Opinions about meat substitutes' sensory features were contrasting. Some participants reported that substitutes had a pleasantly lighter taste, nice texture, and good smell, while others thought they were bland, smelly, and with an unpleasant, unfamiliar texture. The extent to which meat substitutes replicated the

sensory features of meat also generated conflicting views. Some participants were pleased when they were unable to distinguish these products from meat (Quote 18), while others thought that by mimicking meat, these products failed to celebrate natural vegetarian flavours, were unimaginative, and induced false expectations about their taste and texture (Quote 19). Finally, one participant thought that the sensory features of some substitutes were not coherent, as some products 'looked like fish but tasted like chicken', which represented an initial barrier to consumption (Quote 20).

The product range was another factor contributing to participants' hedonic experiences. Some participants perceived the range of substitutes to be sufficiently large and varied to keep them interested in these products (Quote 21) while others quickly became bored of the similarity among substitutes despite the high number of products available (Quote 22).

Some participants commented that they did not view meat substitutes as pleasure foods. Instead they viewed these products as functional products, which enabled them to 'get fuel' without having to eat meat (Quote 23). Finally, one participant thought that meat substitutes did not deliver the same sense of satiety as meat.



Quote 18: "I honestly didn't expect them to taste as good as real meat but the majority of them I found I couldn't notice the difference in the taste so that was a real positive." Participant 19 (male, 33)

Quote 19: "The thing that frustrated me about vegetarian products was when they were trying to be meat because […] they just should try and embrace that they're vegetarian as like there's so many great flavours out there." Participant 8 (female, 23)

Quote 20: "With the [specific meat substitute] I had to kind of get around the fact that it looks like tuna but it tastes like chicken so it was a bit of visual things to get over." Participant 2 (female, 27)

Quote 21: I thought [meat substitutes] were great because they were varied enough to be interesting: everything from Kiev to burgers to mince to this and that, you know. […] I've never tried Jack fruit before for example, so they were varied enough to be interesting […]" Participant 20 (female, 32)

Quote 22: "I did get a little bit maybe sick of, they seems to be fairly repetitive within say the [meat substitute brand] products as they were quite similar, I mean there were some differences on the surface but they're quite similar. It's made of the same thing." Participant 12 (male, 33)

Quote 23: "I mean like you eat things and then normally I have a very good time and I think this is great I'm loving this. But [eating with meat substitutes] was just eating to eat." Participant 7 (male, 22)

3.2.2.2 Welfare impact of meat substitutes

Participants frequently discussed the impact of consuming meat substitutes on various welfare issues, including health, the environment, and animal welfare.

There were mixed views about the healthfulness of substitutes. The perceived food safety and easy digestion of meat substitutes contributed towards a perception of healthfulness (Quotes 24, 25), while the processed nature of these products contributed towards a perception of unhealthfulness (Quote 26). There were mixed views about the healthfulness of meat substitutes' nutritional profiles, which were sometimes described as low in fat and high in fibre and sometimes as high in fat, sodium, and sugar, and low in protein and vitamins. These discrepancies might be due to different participants assessing meat substitutes' nutritional profiles against different foods. Those assessing the nutritional profiles of meat substitutes against comparable meat products (e.g. a vegetarian sausage vs a meat sausage) might have developed favourable opinions about the healthfulness of meat substitutes' nutritional content. Conversely, those assessing the nutritional profiles of meat substitutes against very different meat products (e.g. a vegetarian sausage vs a lean chicken breast) or other natural plant-based foods (e.g. pulses) might have developed unfavourable opinions about the healthfulness of meat substitutes.

Participants generally perceived meat substitutes to be less energy dense than meat, yet this characteristic was presented as favourable among those who valued weight loss (Quote 27) and as unfavourable among those who worried they might not reach their targets for energy intake (Quote 28).

Regarding the natural environment, some participants perceived the production of substitutes to result in fewer greenhouse gas emissions and land use. However, one participant perceived meat substitutes to also detrimentally affect the natural environment and was unclear about the

environmental benefits of substitutes over meat. Some participants also alluded to reduced animal suffering as a positive by-product of replacing meat with substitutes.



Quote 24: "You didn't have to worry so much about safety of the meat going off and getting salmonella or something" Participant 11 (male, 39)

Quote 25: "I enjoyed the eating of [meat substitutes] as much and then consequently found that what happened afterwards was nicer as well. I think the digestion, with the digesting meat takes a lot longer and it's a lot harder" Participant 20 (female, 32)

Quote 26: "[…] so like the ham and whatever, turkey type things [um] that just felt like I was eating paper which made me feel again it's not healthy because it's kind of processed and I don't even know what I'm eating." Participant 16 (female, 31)

Quote 27: "I've been trying to lose some weight and I've been on a calorie restricted diet. One of the advantages of having a Linda McCartney kind of beef roast versus, you know, a joint of beef, is that the calorie content is really limited. So for me it's just about, you know, calorie restriction. That was the biggest kind of advantage that I saw." Participant 14 (female, 40)

Quote 28: "I did often wonder am I missing out on vitamins or on my like caloric requirements? Because the vegetarian food is often lower." Participant 12 (male, 33)

3.2.2.3 Cooking and storage requirements of meat substitutes

Meat substitutes were often perceived as easy to use as they (i) did not require learning new recipes or cooking techniques, (ii) were quick to prepare, and (iii) allowed sharing cooking utensils with vegetarian household members (Quote 29).

Some participants thought that storing meat substitutes also presented fewer challenges compared to meat. This was mainly because these products were perceived to last for longer than meat and because they were perceived to pose fewer food safety risks when going through the freeze-thaw cycle (Quote 30). However, participants also highlighted a small number of challenges related to using meat substitutes. Specifically, integrating substitutes in composite dishes was sometimes challenging, as these products often came as ready meals or stand-alone items.

Other participants struggled to understand when substitutes were cooked, since many of them did not change colour during the cooking process (Quote 31).



Quote 29: "[meat substitutes] were definitely easier to cook you just bung it in really, and quicker as well, definitely. I think the Quorn pieces in particular are much quicker to cook than chicken." Participant 3 (female, 23)

Quote 30: "the ease with which you could freeze things was something I hadn't appreciated before the month of having so many substitutes. If I'd bought chicken or beef mince instead of Quorn pieces or Quorn mince I would have been so much more fussed about defrosting them perfectly and having to remember to take them out of the freezer into the fridge two days before I want to cook with them and I think that was a lot easier for me […]" Participant 4 (female, 28)

Quote 31: "The [meat substitute] mince starts off kind of red and then it doesn't change colour and so I wasn't quite sure when it was cooked, whereas your normal mince is pink and then it goes brown." Participant 2 (female, 27)

3.2.2.4 Financial cost of meat substitutes

Views on the costs of meat substitutes were also mixed. Some participants perceived meat substitutes to be cheaper than meat products while others perceived them as more expensive. However, the perceived higher costs were not always discussed in a negative context. For example, one participant thought that the animal welfare benefits of meat substitutes were worth the financial premium of these products (Quote 32).

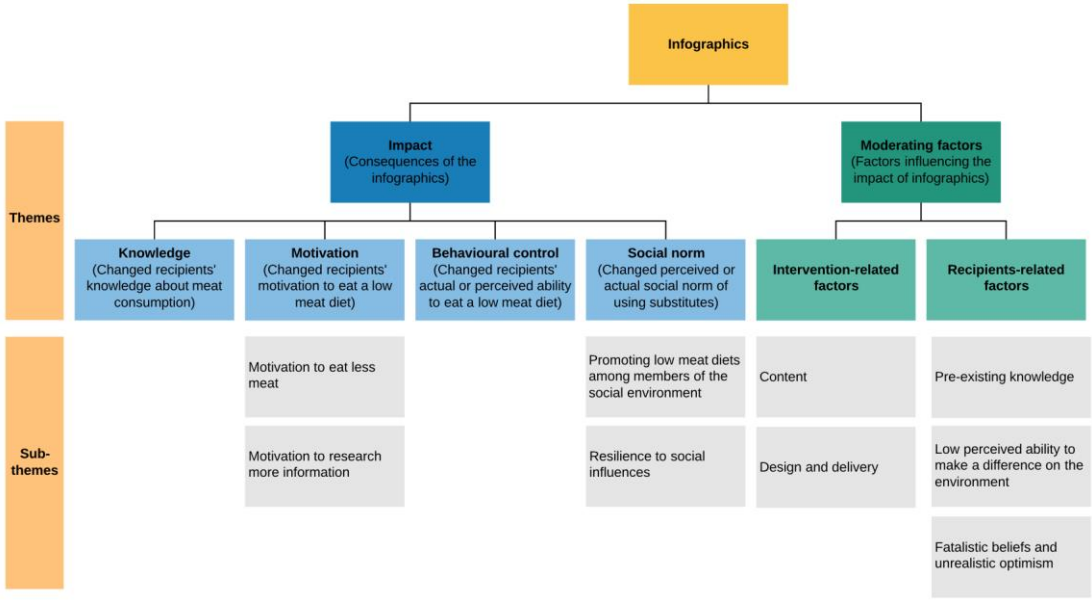


Quote 32: "I was thinking about having chicken nuggets versus Quorn nuggets… Actually Quorn nuggets are nice so that's a vital point …but if they were the same taste, you know how much is a chicken's life worth? And I decided it's probably worth the 30p difference in my moral compass and I should probably get Quorn." Participant 8 (female, 23)

3.3 Infographics

The RE-MAP intervention involved the provision of infographics outlining some health and environmental benefits of eating a low meat diet. During the interviews, participants outlined how the infographics affected them (section 3.3.1) and discussed factors moderating this impact (section 3.3.2, Fig. 5.3). Despite some heterogeneity in participants' views, the infographics were generally perceived as acceptable and motivating, albeit of secondary importance compared to meat substitutes.

Fig. 5.3: Infographics themes



3.3.1 Impact of infographics

According to the interviews, the infographics worked through multiple mechanisms involving recipients' knowledge (section 3.3.1.1), motivation (section 3.3.1.2), and behavioural control of eating a low meat diet (section 3.3.1.3). Additionally, recipients used the infographics to encourage members of their social environment to eat less meat and to explain why they reduced their own meat intake (section 3.3.1.3).

3.3.1.1 Knowledge

Participants often described how the infographics enhanced – or failed to enhance - their knowledge about the health and environmental benefits of eating less meat. For some participants the

infographics provided new knowledge about the consequences of eating meat, which made them feel more positive about reducing their own meat consumption (Quote 33). Other participants thought that the infographics did not directly add to their existing knowledge but were helpful at corroborating existing notions and increasing the saliency of this knowledge.

Conversely, some participants felt that the infographics did not meaningfully improve their understanding of how eating less meat can benefit human health and protect the environment (Quote 34).



Quote 33: "[…]what was most interesting to me and was quite shocking was about the water required to produce meat because honestly that is something that never crossed my mind and that kind of spurred me on to eat less." Participant 6 (female, 30)

Quote 34: "For me [the infographic] wasn't giving me a message that was of any interest to me because I already know that I'm not going to get type 2 diabetes." Participant 10 (female, 62)

3.3.1.2 Motivation

Some participants thought that the infographics motivated them to eat less meat (Quote 35). In this context, some highlighted how providing the infographics at the start of the intervention represented a timely aid to eat less meat during a time when this dietary transition still required conscious motivational efforts.

Some participants also felt that the infographics motivated them to conduct their own research on the impact of eating and producing meat (Quote 36). This independent research might have further increased recipients' knowledge about the benefits of eating less meat (see section 3.3.1.1), which might in turn have contributed towards generating positive attitudes towards eating a low meat diet.



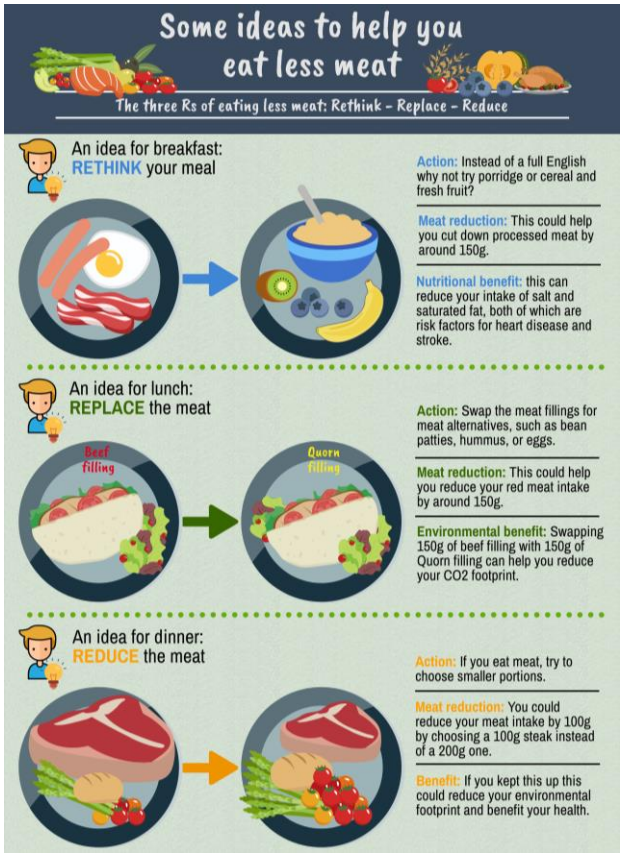
Quote 35: "I mean it's hard to separate it from the whole package in a way, but I did think that [the infographics] kind of gave me an extra layer of motivation to reduce my meat consumption and it made me feel more comfortable trying to introduce that diet into my household" Participant 13 (female, 31)

Quote 36: "because I'd looked at the infographics I then watched quite a few Netflix documentaries like cancer obviously and about the impact on the environment and one's health […] my view changed significantly in terms of the environmental impact that meat eating has and how easy it would be to limit the impact." Participant 20 (female, 32)

3.3.1.3 Behavioural control

In my initial logic model, I had not hypothesised that the infographics would enhance behavioural control to eat less meat, even if they outlined a few practical strategies for how to do so (Fig. 5.4). This was because I did not perceive this small number of practical suggestions to represent a sufficiently relevant component of the infographics. However, the interviews provided some evidence to suggest that these practical strategies did increase some recipients' ability to eat less meat. In particular, one participant explained how reading about the 'Rethink-Reduce-Replace' strategy in the infographics helped her to reduce her meat consumption and led her to replace her meat-based breakfast with porridge.

Fig. 5.4: Practical strategies outlined in the infographics



3.3.1.4 Social norms

Some participants used the infographics to encourage members of their social environment to eat less meat by sharing insights on the benefits of eating less meat with them (Quote 37). Additionally, some participants highlighted how the information provided in the infographics helped them to

justify their decision to eat less meat to people who questioned this dietary choice (Quote 38). The infographics might, therefore, have helped recipients to become more confident in their choice to eat less meat and more resilient to social pressures to eat meat-rich diets.



Quote 37: "my friends and family were like 'Oh why are you doing this?' and if they were round my house I'd show them the leaflets or I'd remembered a couple of the stats about the environment and I'd kind of share those figures with people, so I think they definitely did help" Participant 3 (female, 23)

Quote 38: "I also again showed them to some people so that was quite good [um] like I spoke to my sister about it and she was kind of a bit shocked about some of the like statistics." Participant 1 (female, 23)

3.3.2 Factors moderating the impact of infographics

The interviews also shed light on factors influencing the extent to which the infographics effectively delivered impact. These factors related to the infographics themselves and to characteristics of the intervention recipients.

3.3.2.1 Infographics-related factors

The impact of the infographics was affected by their content, design, and delivery mode. On the infographics' content, the aspects contributing towards increasing their effectiveness included (i) the use of routine experiences to convey meat's impact on the environment, (ii) the use of absolute rather than relative risk increases to communicate the health risks associated with meat consumption, (iii) the perceived credibility of the information provided and messenger, (iv) and the lack of animal welfare infographics, which would have been perceived as patronising (Quote 39).

Conversely, content-related aspects inhibiting the infographics' impact included the lack of information about the health and environmental impact of replacing meat with meat substitutes (Quote 40), and the fact that the information was not sufficiently tailored to the UK context or to recipients' personal circumstances. For example, some participants thought that global statistics on the environmental impact of meat consumption were not relevant to the UK or that general information on the health impact of eating meat did not apply to them personally (Quote 41). One

participant also considered the information on the environmental consequences of eating meat to be inaccurate, discrediting the overall credibility of the infographics (Quote 42).

On the design and delivery mode, participants praised the aesthetically pleasing and easy to understand graphics, while they critiqued the fact that the infographics were delivered as colour printed resources, which was perceived as incongruent with the messages on safeguarding the environment and made it harder for participants to access the information remotely (Quote 43, 44).



Quote 41: "I was quite happy not to be given a lecture on how animals deserve as much right as us because that's very intellectual and there's a lot of disagreements. So I think I would have just switched off at that point." Participant 4 (female, 28)

Quote 42: "[it would have been helpful to have] information about health benefits of eating meat replacements specifically as opposed to eating plant versus meat. A kind of comparison between eating plants, meat and meat replacements." Participant 16 (female, 31)

Quote 43: "Essentially I've been told that my blood levels in terms of sugar are such that I will never ever have type 2 diabetes […] So for me [the infographic] wasn't giving me a message that was of any interest to me because I already know that I'm not going to get type 2 diabetes." Participant 10 (female, 62)

Quote 44: "the [environmental] information was wrong, so essentially when you say that you're giving me incorrect information I start questioning all the information in the infographics." Participant 10 (female, 62)

Quote 45: "[…] you could send it by e-mail because like we're talking about the environment and then you get the paper through." Participant 3 (female, 23)

Quote 46: "I don't carry the [um] booklet around of your infographics but I do have a phone that I read when I get bored in the middle of the day, if I'm reading an article on BBC News I may as well read one that's relevant to the study I'm on" Participant 4 (female, 28)

3.3.2.2 Recipients-related factors

The impact of the infographics was also influenced by characteristics of the intervention recipients. Specifically, some participants thought that the infographics did not have a strong impact on them because they had a high level of pre-existing knowledge about the health and environmental implications of eating meat (Quote 47). Other participants thought that changing their own individual diet would not be sufficient to make a discernible positive impact on the natural environment, which inhibited the extent to which the environmental infographics could motivate them to change behaviour (Quote 48). Similarly, the potential impact of the health infographics was limited by some participants' fatalistic beliefs and unrealistic optimism about their health. These

beliefs describe people's perceived lack of control over their own health and the perception that they are personally not at risk of developing adverse health conditions in the first place (Quote 49).



Quote 47: "[the infographics] probably didn't make a difference to me because a lot of the material I knew already just because of my family. One set of my cousins being vegetarians, I've heard a lot of the arguments and the statistics beforehand." Participant 19 (male, 33)

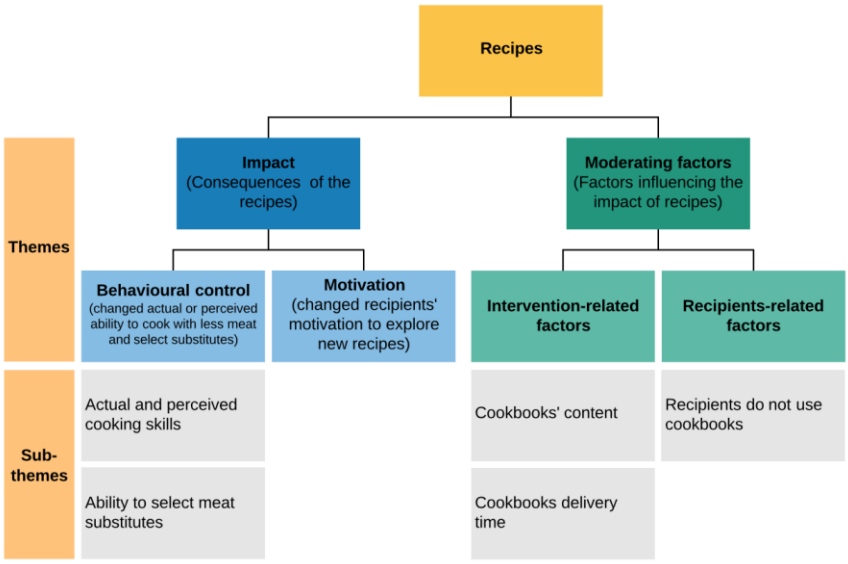
Quote 48: "[…] the environment, I can take that into consideration but I don't personally feel like I can do anything about that. […] I don't actually think it impacted me as much as the health infographic." Participant 17 (female, 42)

Quote 49: "I felt more motivated by the environmental [infographics] to be honest […] because I would like to be healthy but in a way I care slightly more about the environmental stuff because I think most people feel the same to some extent with yourself: You're kind of like 'I feel like I'll be fine', you kind of think you're slightly invincible so you're like 'oh so what if I'm like unhealthy'" Participant 1 (female, 22)

3.4 Recipes

The intervention also included the provision of two cookbooks: a meat substitutes recipe booklet delivered when the intervention started and '*A Girl Called Jack'* delivered during the last intervention week. During the interviews, participants discussed how the recipes affected them (section 3.4.1) and the factors influencing whether or not this intervention component delivered impact (section 3.4.2, Fig. 5.5).

Fig. 5.5: Recipes themes



3.4.1 Impact of recipes

In my initial logic model, I hypothesised that recipes would reduce meat consumption by providing recipients with the cooking skills required to prepare appetising plant-based meals. However, the interviews did not provide evidence that this mechanism played an important role (section 3.4.1.1). Instead, recipes were primarily viewed as a motivational component of the intervention, which inspired recipients to explore new plant-based foods (section 3.4.1.2).

3.4.1.1 Behavioural control

As mentioned above, participants did not generally use the recipes to learn 'how to cook' meat substitutes and other plant-based meals (Quote 50, 51). Instead, the way in which recipes enhanced

recipients' behavioural control was by increasing their ability to effectively identify and select their preferred meat substitutes during the intervention. Specifically, these recipes provided guidance on how specific meat substitutes could be integrated in different types of dishes, which in turn helped participants to identify the ones that they liked to try in their diets (Quote 52).



Quote 50: "[… the recipes] in the book I felt were sometimes a bit simple […] not all of them but some of them I probably could have thought of myself." Participant 11 (male, 39)

Quote 51: "I just never follow any cook books anyway so it's not, you know, it's nothing wrong with those cook books it's just me like I prefer to go for […] my own thing" Participant 13 (female, 31)

Quote 52: "[…] the handmade written recipes came much earlier. I thought they were useful […] because they were at the beginning and I was trying to think which substitute products I should buy, what am I gonna cook with them, what new recipes should I be looking into." Participant 4 (female, 28)

3.4.1.2 Motivation

Participants often described the recipes as a motivational component of the intervention rather than a training component. Specifically, some participants outlined how receiving recipes inspired and motivated them to explore new plant-based meals and to independently search for more plant-based recipes (Quote 53).



Quote 53: "[the recipes] certainly helped with after the sort of first or second week to be eating less meat and trying to think of new recipes and so it was really good and then it inspired me to go and look at other recipes that I could possibly find that would actually work." Participant 5 (female, 30)

3.4.2 Factors moderating the impact of recipes

Participants discussed various factors influencing whether or not the recipes effectively delivered impact. These factors related to the intervention itself and to recipients' characteristics.

3.4.2.1 Intervention-related factors

The impact of the recipes was affected by the content of the cookbooks and as well as by their delivery time. On the recipes' content, some participants liked that these resources focussed on how to prepare convenient and healthy meat-free meals rather than on 'how not to eat meat' (Quote 54). Conversely, some participants thought that the recipes were unappealing (Quote 55) and that the content of *'A Girl Called Jack'* was not aligned with the broader intervention aim, as it primarily

focussed on eating on a budget and included a few meat-containing recipes, which failed to motivate reductions in meat consumption (Quote 56).

On the delivery time, some participants challenged the decision to deliver *'A Girl Called Jack'* during the last intervention week. Specifically, they thought that it would have been helpful to provide more natural plant-based recipes at the start of the intervention rather than waiting until the last intervention week, as this would have highlighted early in the programme that eating less meat does not necessarily require the use of meat substitutes (Quote 57).



Quote 54: "I liked the fact that it wasn't just here are a group of recipes. It was the story about how she came up with these recipes and what really struck me was that it wasn't about *'I am choosing not to eat meat'*. It was about '*this was a situation I was in'* […] I think that can sometimes be the problem. if you're taking something out of your diet it can make you panic and think *'Oh how am I ever going to find ways to cook with this? I can't just chuck things together from the fridge'* when actually her recipes show that you could do" Participant 5 (female, 30)

Quote 55: "None of [the recipes] particularly appealed to me so I sort of just did my own thing and ended up cooking things that I would usually cook anyway." Participant 13 (male, 31)

Quote 56: "[…] the book itself specifically is kind of 'eating on a budget' and things like that. I didn't find it particularly motivating regarding meat consumption because there were still meat recipes in there and I was like *'oh'* " Participant 1 (female, 22)

Quote 57: "I would have found it helpful to, just specifically thinking about the recipes, […] from the beginning to have more kind of just plant-based options in that first cook book to remind me that they're an option as well, that reducing your meat consumption doesn't necessarily just mean with meat substitutes. It might just mean a lentil curry instead of a chicken curry and rice." Participant 13 (female, 31)

3.4.2.2 Recipients-related characteristics

The interviews also highlighted two characteristics of recipients, which diminished the potential for recipes to deliver impact. First, some participants explained that they did not benefit from the recipes because they do not habitually use recipes when cooking and subsequently did not engage with these materials (Quote 58).

Second, some participants perceived the recipes to be too simple to meaningfully contribute towards enhancing their cooking skills. Additionally, participants often perceived meat substitutes to be very easy foods to prepare, which contributed towards further reducing their perceived need for recipes (Quote 59).



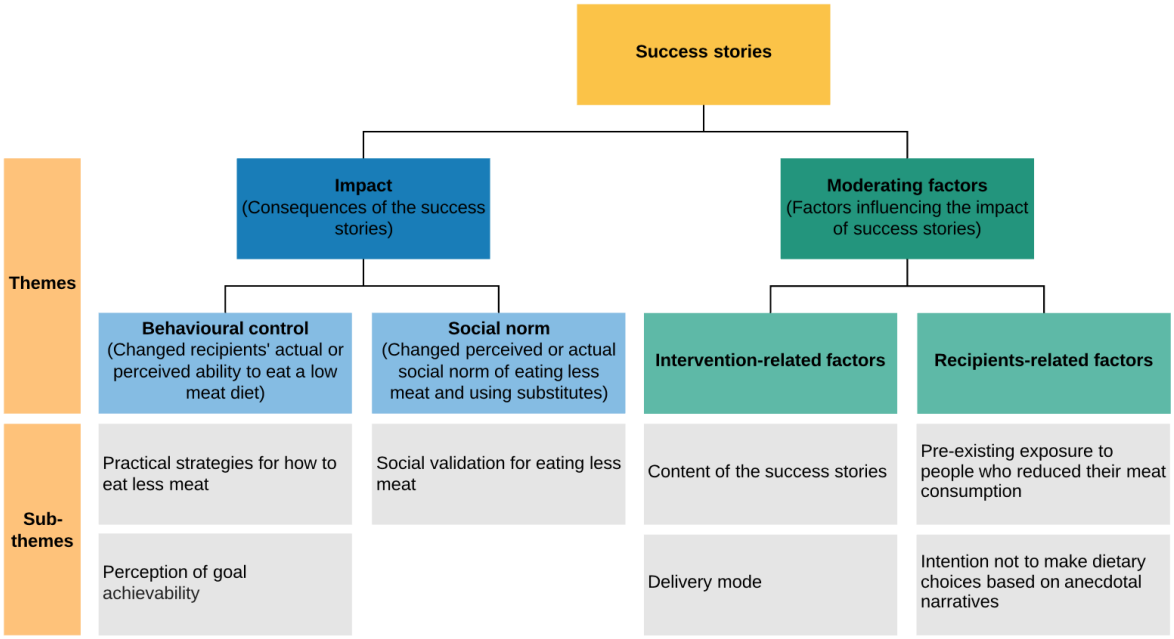
Quote 58: "The [cookbooks] didn't [influence what I eat] because I tend not to use cook books. Like when I was making broth I just chucked it in the pot and cooked it, I didn't go 'oh I need this amount, I need that amount and I need that amount.' I just chucked things in a pot and go for it and see what I get. And it usually comes out okay." Participant 10 (female, 62)

Quote 59: "[With meat substitutes] I was cooking what I would cook anyway so I'd cook my own spaghetti bolognese recipe or chilli […] and instead of using meat I would just put in substitutes. So I didn't necessarily feel as though I needed the recipes." Participant 3 (female, 23)

3.5 Success stories

The final intervention component was success stories that outlined how other people had reduced their meat intake. Similar to other intervention components, participants discussed the impact of receiving these stories (section 3.5.1) and the factors affecting their impact (section 3.5.1, Fig. 5.6).

Fig. 5.6: Success stories



3.5.1 Impact of success stories

While there were mixed views about the impact of success stories, this intervention component was generally considered less impactful than other elements of the intervention. However, there was some evidence to suggest that the success stories increased participants' actual or perceived ability to eat less meat (section 3.5.1.1) and that they socially validated participants' decision to eat less meat for animal welfare reasons, without completely giving up meat (section 3.5.1.2).

3.5.1.1 Behavioural control

The role models in the success stories outlined some practical strategies for how to eat less meat and some participants reported benefitting from these strategies when trying to reduce their meat intake. For example, one participant followed the practical advice to use spices to compensate for the lack

of meat flavours in plant-based dishes and another followed the advice to not order meat when eating out. The success stories therefore helped to increase some recipients' behavioural control to eat less meat. Additionally, these stories led some participants to perceive meat reduction as more achievable by highlighting that other people successfully managed to implement this dietary change (Quote 60).



Quote 60: "I liked [the success stories], I think they're useful because they're real life examples […] just explaining 'look, it's not as hard as you think. It is it's not as hard to persuade your family to do this either. Just do it.' It wasn't to me the most impactful part of [the intervention] but I think it will be for some people." Participant 20 (female, 32)

3.5.1.2 Social norm

The success stories also delivered impact through a mechanism involving social norms. In particular, one participant struggled to reconcile her decision to 'only reduce' meat consumption and her awareness of the animal welfare implications of eating any meat. Reading about other people who decided to 'only reduce' their meat intake for animal welfare reasons socially validated her decision to continue doing the same (Quote 61).



Quote 61: "it was interesting to see somebody specifically saying that they were concerned about animal welfare. That is a motivation for me but it's the one that makes me the most uncomfortable […] because I feel like if I agree that that's an issue I really should be a vegan and I know that that's at the moment not a realistic option […] so I was glad that you didn't focus on it in the infographics. But it was nice to slightly remind me that is an issue […] I think it reassured me that there was someone who had acknowledged that anxiety but still hadn't completely removed meat products from their diet. It made me feel like that's okay to kind of acknowledge it without cutting [meat] out entirely." Participant 13 (female, 31)

3.5.2 Factors moderating the impact of success stories

Despite the effects outlined above, participants repeatedly highlighted that the success stories did not have a major impact and provided numerous reasons for why this might be. As for other intervention components, these reasons related to the intervention itself or to characteristics of the recipients.

3.5.2.1 Intervention-related factors

Participants highlighted three aspects related to the content and delivery mode of the success stories, which diminished their impact. First, some participants did not relate to the experiences described in the success stories, either because their demographic group was not represented by any of the role

models or because the practical tips provided in the success stories were incompatible with their lifestyles or dietary needs (Quote 62). Second, some participants thought that the success stories failed to motivate reductions in meat consumption because they outlined the stories of 'unknown strangers'. While participants generally acknowledged that their dietary choices can be influenced by members of their immediate social environment, reading about the experience of strangers failed to replicate this social influence (Quote 63). Finally, participants believed that presenting the success stories as printed leaflets made this intervention component less compelling than it could have been if it was delivered in a more engaging video or interview format.



Quote 62: "you see this is the problem because the likelihood is she was using soya mince and I've got to restrict my soya because of my thyroid. So this wasn't fitting in with what my needs were, in terms of I needed a meat substitute that wasn't soya. It wasn't relevant for me personally and none of the rest of them really were relevant for me personally." Participant 10 (female, 62)

Quote 63: "For me personally some random person I don't know telling their story doesn't particularly influence me to be honest. […] I mean it's always interesting to read but I wouldn't say that those particularly persuaded me. […] But I think the people that I actually know around me do have an impact […]" Participant 1 (female, 22)

3.5.2.2 Recipients' characteristics moderating the impact of success stories

The interviews also highlighted two characteristics of intervention recipients, which prevented success stories from delivering meaningful impact. First, some participants were already exposed to people who consciously reduced their meat intake, which prevented the success stories from generating additional social influence (Quote 64). Second, some participants considered meat consumption to be a personal choice, which was not (and should not) be influenced by other people's behaviour (Quote 65).



Quote 64: "I think because I'm already in this context were I know people who are eating less meat or who are vegetarian or vegan I didn't necessarily need any more convincing." Participant 06 (female, 30)

Quote 65: "[The success stories were] useful to read but I wouldn't say it contributed in any way to what I was doing, I wouldn't say it helped me kind of stick to it to be honest with you […] I think it's much more of a personal thing, you either want to do it for yourself and hearing someone else has done it might not necessarily change […]" Participant 03 (female, 23)

3.6 Study process

So far, the results section of this chapter outlined participants' perceptions of the four intervention components. This final section will focus on participants' experiences of the operational study processes, i.e. all their experiences related to taking part in the trial other than those related to receiving the intervention. Specifically, participants elaborated on:

- their motivation for enrolling into the study,
- how taking part in the trial affected their eating behaviour independently from receiving the intervention, and
- some adverse consequences experienced during the study.

3.6.1 Reason for enrolling

The interviews highlighted seven drivers that motivated participants to take part in the study. Four of these drivers were related to participants' desire to receive the intervention or to change their eating habits. Specifically, some participants were seeking support to eat less meat (Quote 66), wanted to learn more about the impact of meat consumption (Quote 67), wanted to try meat substituted and to learn more about the health and environmental impact of replacing meat with these products (Quote 68), or wanted to explore whether the intervention would help them improve the nutritional composition of their diets (Quote 69).



Quote 66: "I'd been interested in trying to eat less meat for a while […] I've been tempted to do so a few times but never really been able to stick with it and I thought this might be an opportunity to do it in a bit more regimented way" Participant 12 (male, 33)

Quote 67: "In the media there was loads of talk about how cutting out meat is basically essential for the environment and also the health impacts as well, so I just thought it would be really interesting to learn more about that" Participant 3 (female, 23)

Quote 68: "I always wanted to try some of the substitute but I always had a little bit of prejudice about that, so I thought that it was a good idea to go into the study" Participant 17 (female, 42)

Quote 69: "I've had a long term thyroid problem […] so I've got to be very careful about what I eat so I was quite interested if the intervention would give me lower calorie food and equal amounts of protein" Participant 10 (female, 62)

The interviews also highlighted three drivers for taking part in the study that were unrelated to receiving the intervention or changing one's diet. Specifically, some participants took part because

the study provided an economic incentive (Quote 70), some were interested in learning their score on specific health metrics measured as part of the study (Quote 71), and some were interested in taking part in a research project either to get involved with the University's research community or to contribute to scientific progress (Quote 72).



Quote 70: "[Taking part is] a good way to earn money […] it's preferable to getting a part time job so I just wanted to find out what the study was about. […] it sounded really interesting and the pay was good […]" Participant 19 (male, 33)

Quote 71: "So being a scientist I'm interested in getting access to analytics that I wouldn't normally have access to […]"Participant 12 (male, 33)

Quote 72: "I'd just moved to the University and had started working in the University I thought well that would be fun to get involved in something to do with a study, so that's what it was." Participant 15 (male, 34)

3.6.2 Study impact on behaviour

The interviews highlighted two operational study processes that influenced eating behaviours and attitudes towards eating less meat. First, the mere fact of being enrolled in a study about meat consumption influenced some participants' meat intake, either by making them feel guilty about consuming meat (Quote 73) or by representing a timely and concrete opportunity to enact their pre-existing intentions to eat less meat (Quote 74). Second, keeping an online food diary also influenced some participants' eating behaviour. Specifically, some felt that keeping food diaries made them become more conscious and deliberate about their food choices (Quote 75) and some felt that having to share their food diaries with the research team influenced their dietary choices by making them feel 'observed' (Quote 76). These mechanisms seemed to apply to people's dietary choices in general, and not just to their consumption of meat. Additionally, these processes presumably applied both to the control group and the intervention group and are, therefore, not further discussed as a limitation.



Quote 73: "I mean the study itself motivated me, I was like 'Oh I'm doing this I kind of feel a bit guilty if I'm' [um] yeah." Participant 01 (female, 22)

Quote 74: "I think part of [the reason for not reducing meat previously] is that there was no moment to decide that. […] the flash point of being involved in this trial affected my actual actions […] Participant 04 (female, 28)

Quote 75: "The monitoring […] I think that encouraged me to think about what I eat and actually be more conscious of what I eat" Participant 16 (female, 31)

Quote 76: "[The food diary] is kind of an intervention in itself because you think about what you're eating and even though I know you're not gonna be judging […] you do think [..] somebody is looking at this information and I do think that kind of makes a difference in itself" Participant 13 (female, 31)

3.6.3 Adverse consequences

The interviews highlighted two operational study processes, which led some participants to experience mild unintended consequences. One participant felt distressed about the nutritional feedback automatically provided by the food diary when exceeding recommended intakes of energy and specific nutrients. This, in turn, made the same participant feel uncomfortable about eating what she wanted. However, this participant acknowledged that keeping a food diary also helped her to become more conscious of her diet, which she perceived as positive (Quote 77, 78). Another participant felt that the biomarkers monitored as part of the study did not cover some key metrics, including iron and B12. This participant reported feeling tired during the study and was unable to state whether it was due to their increased exercise or reduced meat intake. As such, she felt concerned about the lack of objectively collected data on iron and B12 (Quote 79).



Quote 77: "In a way like I kind of wish that there were a way of you gathering that information without all of the calorie […] because I'd find all that a bit stressful […] I probably balance it out to a relatively balanced and healthy diet over a week but when I see a day where I've gone into the red it does kind of […] make me slightly uncomfortable." Participant 13 (female, 31)

Quote 78: "I guess it's a sort of guilt […]. As well as having a positive effect on being more conscious of what I'm eating I think it also made me feel uncomfortable sometimes about eating things I wanted to eat. Not necessarily meat but just in general." Participant 13 (female, 31)

Quote 79: "It would be helpful to have iron or B12 because I did a lot of exercise and I felt like it might be that I'm feeling tired because of the exercise or maybe because I'm not eating meat […] I think that was my concern […] that we did look at the blood pressure, the cholesterol going down […] but I think I would have been reassured to see what happened with iron or any other things." Participant 16 (female, 31)

4. Discussion

In this chapter, I reported the results of twenty semi-structured qualitative interviews conducted with RE-MAP intervention recipients. The interviews explored recipients' thoughts about the four RE-MAP intervention components and the overall study. This qualitative workstream complemented the results of the quantitative evaluation in four key domains:

- First, it contributed to a better understanding of the mechanisms through which the RE-MAP intervention affected recipients' meat consumption, providing some support for the mechanisms hypothesised in my initial logic model (Fig. 7, see chapter 3 for more details) but also challenging some aspects of that logic model and providing evidence for unanticipated mechanisms.
- Second, it explored perceptions of the four RE-MAP intervention components, highlighting opportunities to further enhance the effectiveness of each component.
- Third, it confirmed that the intervention did not lead to substantive backfire effects or unintended consequences, except for a few mild unintended consequences, which mainly pertained to operational study processes.
- Finally, it helped to better understand and more accurately interpret the findings from the quantitative analysis.

These insights are discussed in the four sections below followed by a consideration of the methodological strengths and limitations of this qualitative study.

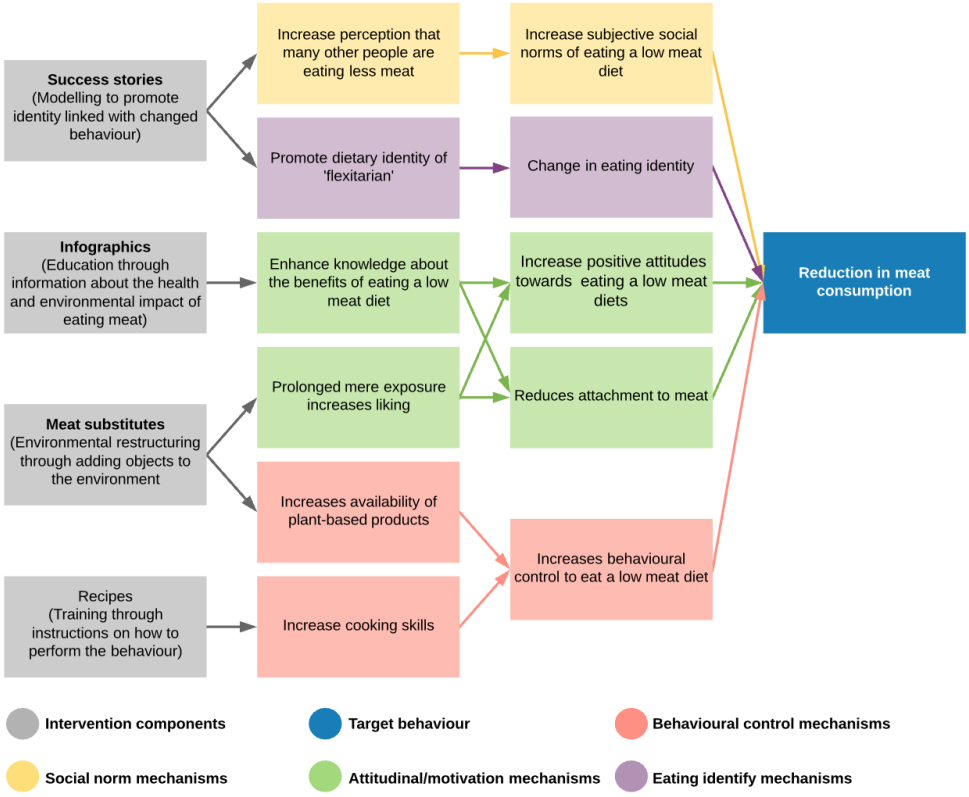
4.1 Mechanisms of action of the RE-MAP intervention

The first key output of my qualitative workstream was to contribute towards a better understanding of the mechanisms through which the RE-MAP intervention influenced meat consumption. This work supported some aspects of my initial logic model (Fig. 5.7, see chapter 3 for more details), including that the intervention worked through processes involving attitudes, behavioural control, and subjective norms.

However, it also challenged many aspects of that logic model by providing evidence for unanticipated mechanisms of action, challenging the relevance of some hypothesised mechanisms, and highlighted the complex interaction between different mechanisms.

In this section, I discuss the congruencies and discrepancies between the mechanisms identified through the interviews and those hypothesised in my initial logic model. Throughout this section, I develop an updated logic model by triangulating insights from the qualitative and quantitative workstreams.

Fig. 5.7: Original logic model developed during the intervention development

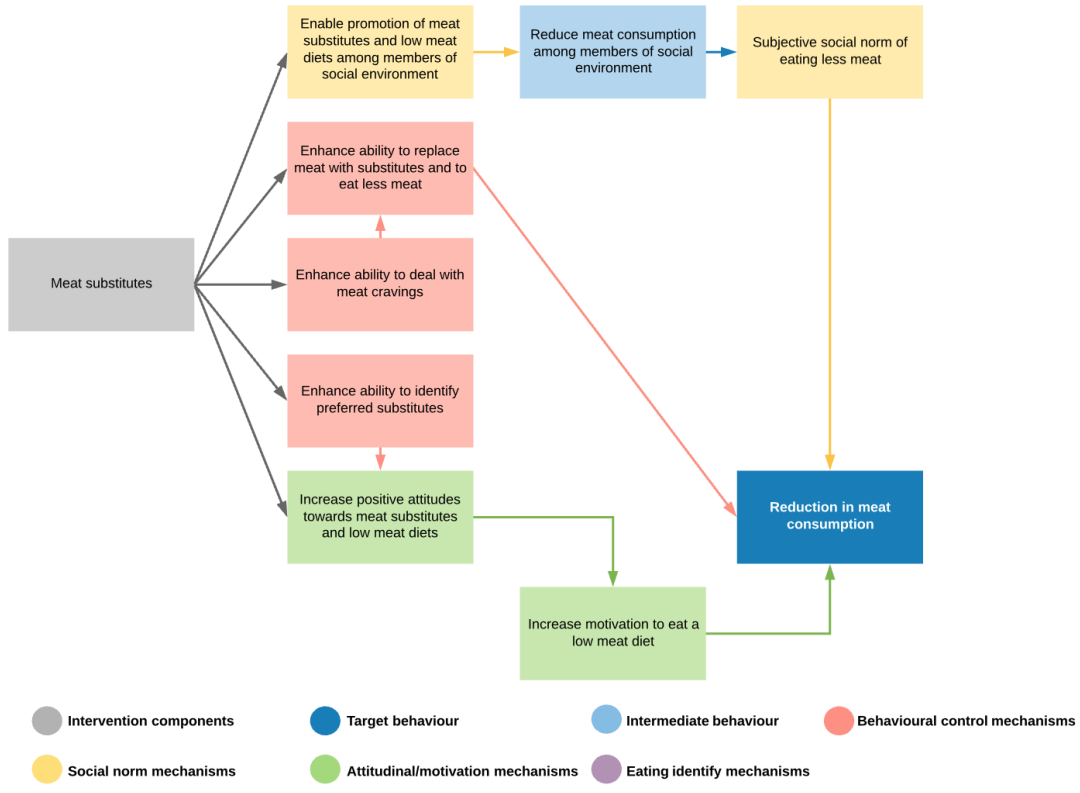


Regarding meat substitutes, my initial logic model hypothesised that supplying these products for an extended period of time would generate more positive attitudes towards replacing meat with meat substitutes and reduce recipients' attachment to meat through a process of mere exposure, i.e. people's tendency to develop a liking for things as they become more familiar with them.(286–288) Additionally, I had hypothesised that the easy access to meat substitutes would enhance recipients' behavioural control to replace meat with these plant-based substitutes (Fig. 5.7).

The interviews supported the insight that the availability of meat substitutes increased recipients' behavioural control of eating less meat and that the provision of substitutes increased positive attitudes towards replacing meat with these products. However, this attitudinal change did not seem to occur as a result of mere exposure. Instead, exposing participants to a vast range of meat substitutes challenged pre-existing negative views of these products and enabled recipients to identify substitutes that they enjoyed, which might have informed their product selection and subsequent experience.

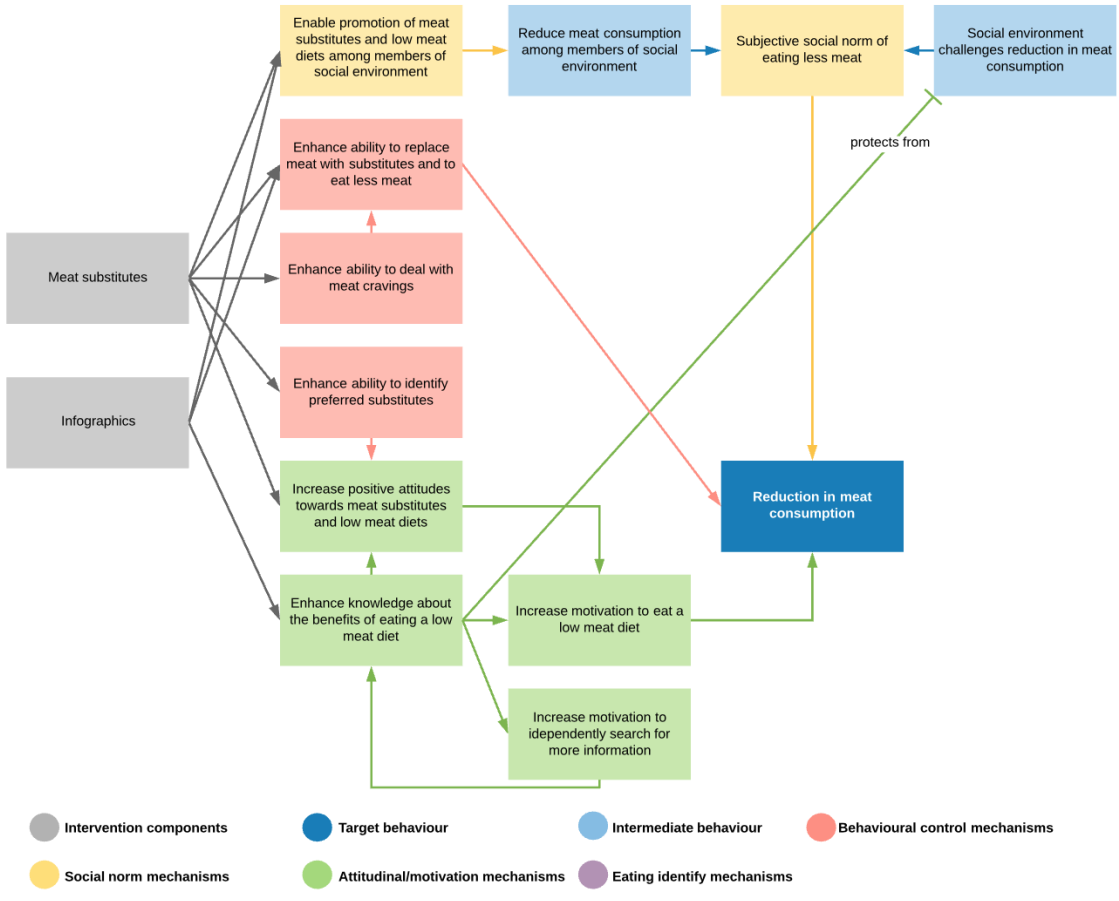
The interviews also identified two mechanisms underlying the impact of meat substitutes, which were not captured by my initial logic model: First, meat substitutes increased recipients' ability to eat less meat by helping them to deal with meat cravings. Second, meat substitutes enabled recipients to promote low meat diets among family and friends. The putative reduction in meat consumption in recipients' social environments might in turn have helped recipients to eat less meat, as people's behaviour is strongly influenced by that of their peers.(322,323) Figure 5.8 presents an updated logic model for how the provision of meat substitutes might have influenced meat intake.

Fig. 5.8: Updated logic model for the provision of meat substitutes



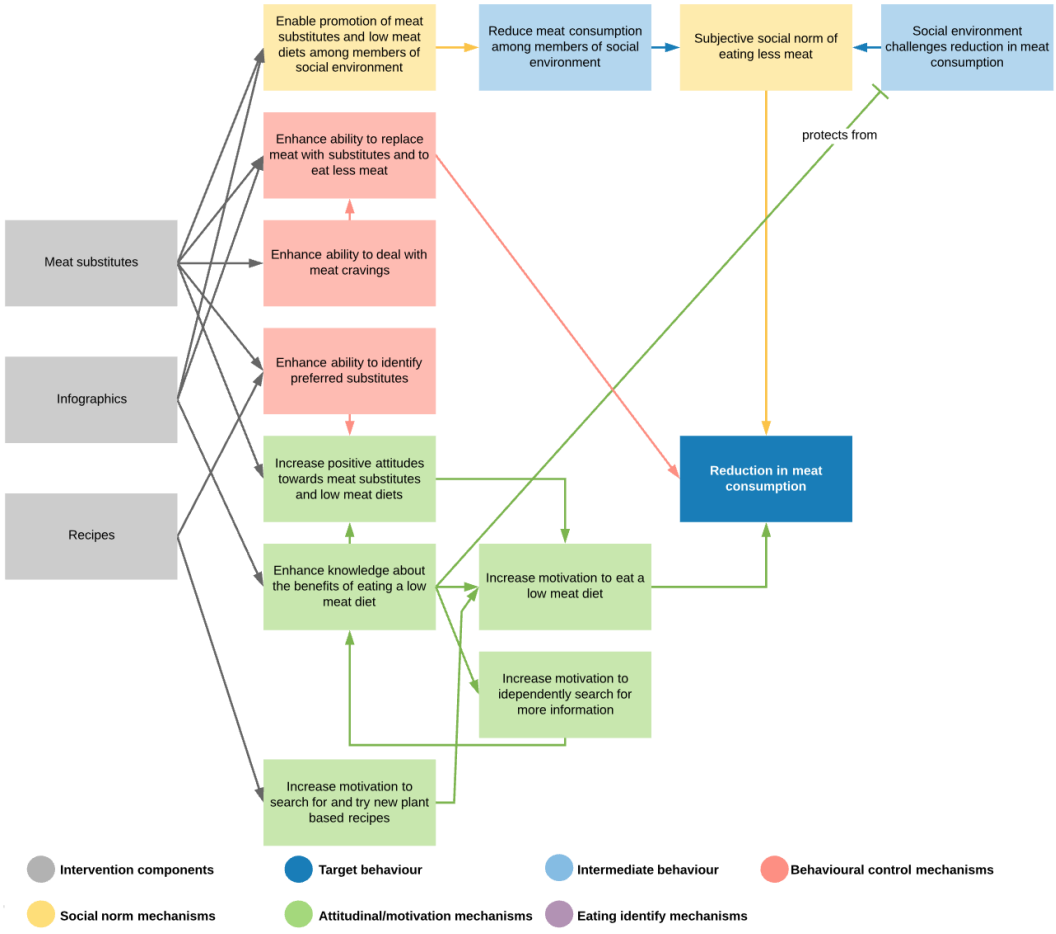
Regarding the infographics, my initial logic model hypothesised that these resources would increase positive attitudes towards eating less meat and reduce meat attachment by increasing recipients' knowledge of the health and environmental implications of meat consumption (Fig. 5.7). The interviews partly supported this mechanism but also highlighted that the infographics did not always increase recipients' knowledge directly. Instead, the infographics sometimes made pre-existing knowledge more salient and prompted independent research on the impact of meat consumption, which might have influenced attitudes and motivation to eat less meat. I also identified two mechanisms underlying the impact of infographics, which were not captured by my initial logic model. First, the infographics enhanced behavioural control of eating less meat by outlining some practical strategies for how to do so. Second, the infographics empowered recipients to explain their choice of eating less meat and enabled them to promote low meat diets among members of their social environment. Figure 5.9 presents an updated logic model for the impact of the infographics in addition to the one for meat substitutes.

Fig. 5.9: Updated logic model for the provision of meat substitutes and infographics



Regarding the impact of recipes, my initial logic model hypothesised that these resources would increase recipients' behavioural control to eat less meat by providing the skills required to prepare appetising plant-based meals (Fig. 5.7). However, I found no evidence to suggest that this mechanism played an important role. Instead, the recipes primarily motivated participants to search and try new plant-based recipes. Additionally, the recipes helped recipients to swiftly identify and select their preferred meat substitutes, which might have contributed towards generating more positive attitudes towards these products. Figure 5.10 presents the updated logic model for the impact of recipes in addition to the one for meat substitutes and the infographics.

Fig. 5.10: Updated logic model for the provision of meat substitutes, infographics, and recipes



Regarding the success stories, my initial logic model hypothesised that these resources would increase subjective social norms of eating a low meat diet and promote the uptake of the 'flexitarian' eating identity, by highlighting that many people were reducing their meat intake and describing the story of individuals identifying as 'flexitarians'.

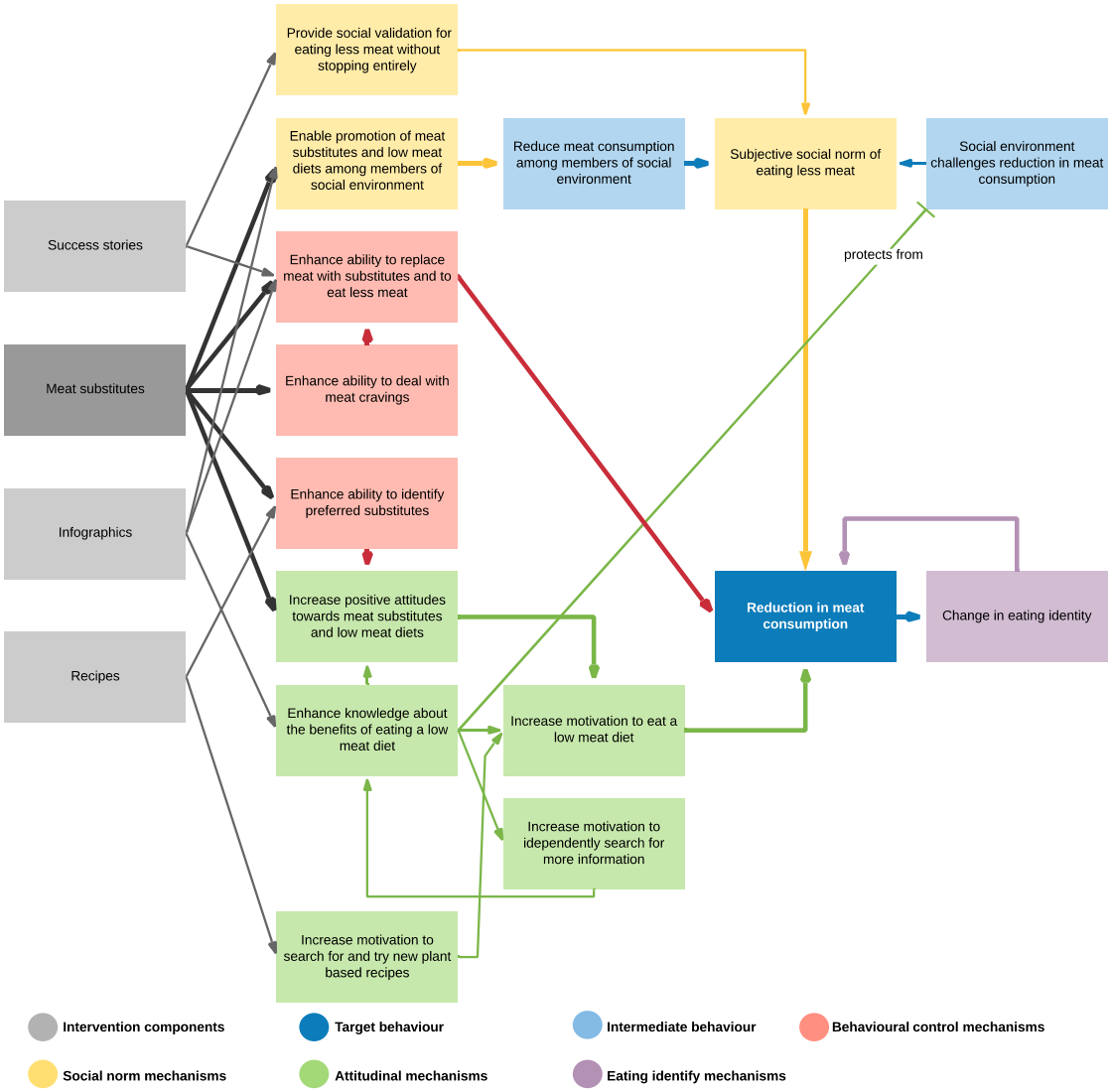
However, the interviews generated no evidence to suggest that these mechanisms played an important role. Instead, the success stories increased recipients' behavioural control of eating less meat by outlining practical strategies for how to cut down and by socially validating recipients' decision to eat less meat for animal welfare reasons without completely giving up meat.

No participant mentioned that the success stories - or any other intervention component - directly affected their eating identity. Yet, the randomised trial provided compelling quantitative evidence that the intervention changed many recipients' dietary identity from 'meat eaters/omnivores' to 'flexitarian or vegetarian'. By triangulating the insights from the quantitative and qualitative analyses, my new logic model therefore hypothesises that the changes in eating identities occurred as a result recipients' actual dietary changes, rather than as a direct result of an intervention component. Participants might, therefore, have started by reducing their meat consumption as a result of the intervention and only subsequently changed their eating identity to be more aligned with their new eating habits. However, from a behavioural science perspective changes in identities can have a strong impact on people's behaviour. (282,324–327) As such, in my updated logic model I hypothesise that the changes in eating identities might in turn reinforce reductions in meat consumption.

Figure 5.11 presents a fully updated logic model. Mechanisms originating from the provision of meat substitutes are depicted in bold to signal recipients' views that the provision of meat substitutes represented the most important intervention component, while infographics, recipes, and success stories were of secondary importance. This is also reflected in the fact that all the core mechanisms influencing meat consumption in the updated logic model are initiated through the provision of meat substitutes, while other intervention components only reinforce these mechanisms (i.e. in figure 5.11 all the arrows directly affecting the 'target behaviour box' would remain if all intervention components except for meat substitutes were removed). Conversely, the original logic model

hypothesised that each intervention component affected meat consumption directly and largely independently (Fig. 5.7).

Fig. 5.11: Updated logic model for the full RE-MAP intervention



In summary, my qualitative study provided a better understanding of the mechanisms through which the RE-MAP intervention reduced recipients' meat consumption and an opportunity to update the logic model accordingly.

4.2 Opportunities to optimise the RE-MAP intervention

My qualitative analysis also explored recipients' perceptions of the four intervention components and highlighted opportunities to further improve their effectiveness. Specifically, the interviews

highlighted three areas in which meat substitutes (or their provision) could improve to promote greater substitution of these products for meat:

- First, it would be important to increase the actual and perceived healthfulness of meat substitutes as well as the positive environmental impact of replacing meat with these products. This is because recipients did not perceive meat substitutes to be necessarily healthier and/or more sustainable than meat.

- Second, it would be important to improve the hedonic experience of meat substitutes, since participants were not uniformly satisfied with commercially available products.

- Third, the interviews suggested that attitudes towards meat substitutes became more positive because recipients could try a wide range of substitutes, which challenged their prejudice towards these products and enabled them to identify the ones that they enjoyed, rather than through mere exposure. As such, enabling recipients to try a wide range of meat substitutes as a one-off (e.g. a wide range of small samples) could deliver similar attitudinal effects but at much lower costs compared to providing a full supply of substitutes for a prolonged period of time. However, providing a 'one-off' exposure to meat substitutes samples would be less effective at enhancing recipients' behavioural control to eat less meat, as it would not provide easy access to plant-based substitutes. Future research could explore he relative cost-effectiveness of different approaches.

Through my qualitative analysis I also identified three opportunities to enhance the impact and scalability of providing information about the health and environmental benefits of eating less meat:

- First, information should be delivered digitally, rather than as colour printed resources. This would (i) increase the extent to which participants might perceive these resources to be congruent with the messages they contain about safeguarding the environment, (ii) it would make it easier for recipients to access these resources remotely, and (iii) it would make it easier

for recipients to share these resources with families, friends, and colleagues. Some recipients already used the infographics to promote plant-based diets among their social environment and delivering these resources digitally could further leverage this mechanism. However, in the context of a randomised trial a digital delivery could also increase the risk of intervention contamination between study groups, since those receiving the infographics could disseminate these resources much more easily and potentially reach participants in the control group.(328,329)

- Second, the information promoting the replacement of meat for meat substitutes should more explicitly outlining the health and environmental benefits of swapping meat with meat substitutes, rather than focussing on the benefits of moving from a meat-based diet to a 'natural' plant-based one. This would help to address some concerns about the health and environmental impact of using meat substitutes. However, to date there have been few studies directly exploring the health benefits of replacing meat with meat substitutes limiting the claims that can be made on the benefits of this dietary change. (330–332)

- Third, some participants thought that they could not make a meaningful difference to the environment simply by changing their diets as individuals. Providing information on the environmental impact achieved by dietary changes existing social units (e.g. families, sport teams, classes) could therefore enhance the impact of these interventions.

My qualitative analysis also highlighted two opportunities to enhance the impact and scalability of providing recipes to promote plant-based diets:

- First, the recipes should exclusively focus on plant-based meals, rather than including meat-containing recipes too. The rationale for including some meat-containing recipes was to reinforce the idea that reducing meat consumption without completely giving it up would help to make a positive difference. However, some recipients thought that the inclusion of

meat-containing recipes was confusing and detrimentally affected the motivational impact of this intervention component.

- Second, the recipes should be provided in digital form rather than as printed cookbooks to ensure that the intervention delivery mode is perceived as congruent with the environmental rationale for eating less meat

Finally, it might be possible to enhance the impact of success stories by enabling intervention recipients to share their own success stories with one another. This might be even more effective if the intervention was delivered to pre-existing groups (e.g. a sports team or a school class), as the interviews highlighted that reading the success stories of strangers was not particularly motivating.

In summary, this section drew from the insights generated by the qualitative interviews to highlight opportunities to enhance the effectiveness of the intervention components featured in RE-MAP.

4.3 Unintended consequences

The third key output of my qualitative workstream was to confirm that the intervention did not lead to substantive backfire effects or unintended consequences. The interviews only identified three negative unintended consequences of the study and the intervention. These unintended consequences and potential mitigation strategies for future research are discussed below.

One participant felt uncomfortable about having to view the nutritional feedback automatically provided by the online food diary when they exceeded recommended intakes of specific nutrients. Due to pragmatic considerations, in the RE-MAP study I used a commercially available food diary app and so I had limited control over specific features of the food diary and the user experience with the app. Additionally, although the app contained some features which might have contributed to the aforementioned adverse consequence, it also included features that made it easier for participants to

generate food records (e.g. the scanning feature, which allows participants to enter foods in their diaries simply by scanning the barcode of these products). Future researchers wishing to use food diaries to measure meat consumption will have to consider the risks and benefits of using a commercially available food diary apps compared to those of developing a new tailored app or using paper pencil food diaries.

Another participant felt concerned about the lack of objective monitoring of iron and B12 during the study. While monitoring these outcomes objectively would have been ideal, I considered it sufficient to estimate intakes of iron and B12 through participants' food diaries, since this trial was not primarily investigating the nutritional and health impact of the intervention.

Finally, one participant thought that the intervention reduced his vegetable consumption. However, the quantitative evidence found no evidence to suggest that – on average - the intervention affected vegetable intake. As such, while the intervention might have reduced the consumption of vegetables among some participants, this is unlikely to represent a systematic backfire effect of the intervention. To mitigate this adverse consequence, future interventions aiming to reduce meat intake with meat substitutes should highlight more explicitly that meat substitutes are not intended to replace vegetables.

Taken together, the qualitative interviews identified only very few unintended adverse consequences of taking part in the RE-MAP study. Most of these adverse consequences were related to operational study processes rather than to the intervention.

4.4 Enhanced understanding of quantitative findings

The last key output of my qualitative workstream was to help better understand and interpret the results from the quantitative intervention evaluation. In particular, the quantitative evaluation

suggested that participants consumed an increased number of meat substitutes four weeks after the intervention completion. Prima facie, this could be interpreted as evidence that participants had started to independently purchase meat substitutes after the intervention. While this was the case for some participants, others reported still having some substitutes left from the intervention four weeks after the intervention completion. The quantitative analysis therefore cannot be interpreted as definitive evidence that participants purchased their own substitutes after the intervention.

The interviews also highlighted that some participants used RE-MAP materials to promote plant-based diets among families and friends, suggesting that for every intervention recipient other people in their social environment might have reduced their meat intake as a consequence of the intervention. As such, the reduction in meat consumption estimated through quantitative analyses might accurately reflect the intervention's impact on individual recipients but might underestimate the impact that the intervention had on meat consumption at the population level.

The interviews suggested that aspects of the trial other than the intervention could have influenced participants' diets (e.g. keeping a food diary). However, these processes applied both to the control group and the intervention group. As such, unless these factors interacted with the intervention, there is no reason to believe that these insights invalidate the findings from the randomised controlled trial.

Finally, the interviews provided some insights into the generalisability of the quantitative results. I initially hypothesised that the trial would recruit people who wished to reduce their meat intake and that findings would only generalise to this population. However, my qualitative analysis highlighted that some participants enrolled in the trial for other reasons too, including wanting to contribute towards scientific progress, getting free diagnostic tests, or receiving the financial compensation. This insight is in line with quantitative analyses showing that at the baseline participants were 'indifferent'

towards intending to eat a low meat diet. Taken together, these insights suggest that the findings of the quantitative study might generalise beyond people who are pre-motivated to eat less meat.

4.5 Methodological strengths and limitations

The qualitative workstream presented in this chapter has several methodological strengths. The semi-structured nature of the interviews allowed participants to elaborate on their thoughts freely and in depth. Additionally, this format allowed me to explore themes that naturally emerged during the research process. Interviewing participants immediately after the study ensured that they remembered their experience of the intervention and the study in detail and could provide a rich account of their thoughts and feelings. Additionally, conducting the interviews individually allowed participants to elaborate on their experiences independently without being influenced by the narratives of others.(333) I recruited a large sample (40% of the eligible population), which might have contributed towards identifying a wide range of experiences and developing a rich picture of how the intervention might have worked and might be improved going in the future. Finally, all interviews were audio recorded and transcribed verbatim, which facilitated an in depth and iterative analysis of this material.

However, the results of the interviews should also be interpreted in the context of some methodological limitations. As with many other types of qualitative research, the interviews were effective at identifying the range of thoughts and experiences but were not designed to estimate how prevalent these experiences were in the underlying population. As such, it is possible that some of the themes presented in this chapter only affected a small sub-sample of intervention recipients, while others might have been much more prevalent. However, I conducted this qualitative study mainly to generate hypotheses about how the intervention worked and about opportunities to enhance its effectiveness. It was, therefore, not imperative to generate a detailed account on the prevalence of different experiences and views.

Another study limitation is that I led both on the RE-MAP intervention development and the qualitative interviews underlying this chapter. While participants were not told this explicitly, most participants might have assumed this and some might have consciously or unconsciously tried to please me by focussing on their positive views of the intervention while being less vocal about their negative opinions. To reduce the risk of this social desirability bias, I repeatedly reminded participants that there were no right or wrong answers and I encouraged them to elaborate on their negative views of the intervention as well.(334,335) Ideally, it would have been preferable to let an independent researcher conduct these qualitative interviews. However, this was not possible within the constraints of my DPhil.

It is also possible that I unconsciously conducted the interviews in a way that promoted positive narratives about the intervention while inhibiting negative ones. I took specific steps to minimise this risk, including asking open ended questions, avoiding questions of evaluative nature, and consciously encouraging participants to elaborate on their negative views. While the semi-structured nature of the interviews allowed me to explore unsolicited themes, in practice most of the questions I asked focussed on better understanding how the four intervention components affected participants' meat consumption. As such, another limitation of these interviews is that they might have failed to capture how the intervention affected participants' lives more broadly.

As previously mentioned, many participants could not stay for an interview after their last follow-up visit, which made it difficult to implement the purposeful sampling strategy I had planned. Instead, I interviewed any intervention participant who agreed to be interviewed until I reached the required sample size. This convenience sample might have increased the risk of bias, as those who agreed to be interviewed might have done so because they felt particularly positively or negatively about the intervention or they might have been systematically different from those who could not stay for an interview in respect to other characteristics (e.g. less busy lifestyles). However, the interviewed sample

was broadly representative of other participants receiving the intervention in regard to the baseline characteristics measured. Meat intake reduced by 63 g/d (SD=71) at four weeks and by 28 g/d (SD=49) at 8 weeks among the 20 interviewed participants, representing smaller reductions that those observed among the overall intervention group (77g/d, SD=84 at four weeks and 48 g/d, SD=72). As such, the intervention might have worked even better among non-interviewed participants.

The generalisability of my qualitative interviews is limited. The sample of participants taking part in my study and in the interviews was very homogeneous and comprised primarily white and well-educated volunteers who lived in adult-only households in Oxford. The range of perceptions captured in my interviews might therefore not be representative of how the intervention would be perceived (or how it might work) among people from other social or cultural backgrounds. It is also likely that some intervention component might need to flexibly adapt depending on the needs of different recipients. For example, the relevance and acceptability of some RE-MAP components, such as the recipes and success stories, might be strongly influenced by the characteristics of recipients. To ensure that this intervention material is relevant for a wide range of people, it might be possible to redesign these components as 'bottom up' features, whereby intervention recipients are encouraged to share their own success stories or plant-based recipes with their social environment. Taking this grassroot approach, rather than designing and delivering the same material to all recipients, might help to ensure that the intervention material is relevant and appropriate across a wider range of socioeconomic and cultural backgrounds. In sum, it is important to carefully adapt and test the impact of RE-MAP on recipients from a wider range of backgrounds before considering strategies for scaling.

Finally, I made the pragmatic decision to analyse the interviews without a second researcher duplicating my work. This prevented me from comparing my analysis with that of a second researcher and the findings presented in this chapter might therefore be unduly influenced by my personal

interpretation of the data. This limitation is of particular importance considering that I developed the RE-MAP intervention and thus commenced the data analysis with clear pre-existing hypotheses of how the intervention might have worked. To address this limitation, I have repeatedly cross checked the consistency between the results of my analysis and the qualitative data and iteratively amended my analysis to ensure it accurately reflected the data.(319) Additionally, I aimed to address this limitation by frequently discussing emerging themes and the underlying data with my supervisory group.

4.6 Conclusion

In conclusion, the insights generated by my twenty semi-structured qualitative interviews complemented the quantitative evaluation by (i) contributing better understanding the mechanisms through which the RE-MAP intervention affected meat consumption, (ii) highlighting perceptions of the four intervention components and opportunities for improving each component, (iii) identifying a small number of unintended adverse consequences of taking part in the study, and (iv) generating insights to better interpret the findings of the quantitative analyses.

Chapter 6: Discussion

1. Chapter summary

In this chapter, I discuss the main findings of my DPhil, which has contributed new evidence on the effectiveness of behavioural interventions to reduce meat consumption through:

1. Two systematic reviews synthesising the evidence on the effectiveness of interventions targeting conscious behavioural determinants or restructuring physical micro-environments;(268,269)

2. The development of a behavioural intervention (RE-MAP) to reduce meat consumption through the provision of meat substitutes, infographics, success stories, and recipes;(267)

3. A RCT evaluating the impact of RE-MAP on meat consumption, wider dietary changes, markers of health risk, markers of environmental degradation, and psychosocial factors related to the intake of meat and meat substitutes; and

4. Twenty qualitative interviews exploring the mechanisms through which the intervention might have delivered impact and recipients' experiences of the intervention.

This discussion summarises the findings of the aforementioned studies in the context of the wider policy landscape on meat reduction, highlights the key strengths and limitations of my DPhil, and offers suggestions for future research and practice.

2. Summary and implications of research findings

Over the past decade, reducing meat consumption to protect human health and the natural environment has developed from an emerging topic of academic interest to a 'hot' topic among researchers, policy makers, the food industry, and members of the general public.

The past years have seen a steep increase in the number of retailers, food outlets, and restaurants investing in promoting vegetarian foods and plant-based meat substitutes. Tesco recently committed to a 300% increase in sales of plant-based meat substitutes by 2025, Sainsbury's launched several new lines of vegetarian and hybrid products, and retailers including LEON and Burger King have introduced - and loudly advertised - new plant-based options on their menus.(336–339)

The impact of meat consumption on people's health and on the environment started to feature more prominently in the press too.(340–342) The 2019 Intergovernmental Panel on Climate Change report received widespread attention on mainstream media and social networks, the Guardian introduced an 'Animals Farmed' index collating articles about the environmental impact of meat production, Carbon Brief published a series on the impact of human diets and climate change, and the popular 2020 Attenborough documentary *'A Life On Our Planet'* featured a whole section on the impact of meat consumption on biodiversity.(340,343,344)

The past decade has also seen a surge of policy papers and academic reports explicitly setting targets to reduce meat consumption in the UK and globally. The UK Committee on Climate Change called for a 20% reduction in the consumption of red ruminant meat by 2050, the Scientific Advisory Committee on Nutrition (SACN) recommended that adults in the UK eating more than 90 g/day of red and processed meat should reduce their daily intake to a maximum of 70g, the EAT-Lancet Commission suggested that global red meat consumption should fall by more than 50% to achieve sustainable and healthy food systems, and scientific analyses suggest that food systems will only keep

within planetary boundaries if global diets did not exceed 97g/w of red meat and 169g/w of poultry.(1,11,76,77)

Following the rise in the availability of plant-based products, the increased media coverage of meat consumption's impact, and the release of dietary targets for meat, some emerging evidence seems to provide reason for optimism: A recent survey in the UK indicated that compared to 2017, 23% more people now understand the environmental impact of consuming meat, almost 40% of people are willing to consider reducing their meat intake, and approximately 14% of people have started to pursue a flexitarian diet.(345–347) In 2016, the President of Unilever Foods published a prominent blogpost entitled *'The rise of the flexitarian'* where she described her enthusiasm for how "eating for ethical, environmental or health reasons is no longer the behaviour of a niche of consumers".(348)

But does the increased public interest for sustainable diets really set us on the right trajectory to achieve meat consumption targets? Have claims of - and hopes for - rising numbers of people adopting reduced meat diets translated to sufficient reductions in actual meat consumption to keep food systems within planetary boundaries? An analysis of data from the National Diet and Nutrition Survey conducted by my colleagues at Oxford has shown that between 2008/09 and 2016/17 average daily meat consumption per capita decreased only by 12g, 40% of people in the UK still do not meet SACN recommendations to limit daily red and processed meat to 70g, and the proportion of people consuming meat did not change over time (Stewart et al., in preparation, personal communication). In the most recent NDNS only 3.7% of people report following a vegetarian or vegan diet.(93,349) If current trends continue, the UK is likely to achieve the 20% reduction target for ruminant meat by 2050 suggested by the Committee on Climate Change. However, based on current trajectories the UK is far from meeting the more ambitious meat reduction targets required to keep food systems within planetary boundaries.(11,76,349)

My DPhil offers possible explanations for why there may only be moderate reductions in meat consumption despite substantive increases in public awareness initiatives. My first systematic review - and subsequent studies - suggest that among interventions targeting conscious behavioural determinants those involving self-monitoring and lifestyle counselling for people with pre-existing conditions offered the most promise to reduce meat consumption.(269,350,351) However, these interventions have not been implemented widely: smartphone applications or similar, personalised support to facilitate self-monitoring of meat intake is still lacking and lifestyle counselling intervention might reduce meat intake among people recovering from conditions linked with meat intake but are unlikely to represent a feasible population-wide strategy to promote plant-based diets. Conversely, most public initiatives implemented over the past few years have focussed on providing information about the benefits of eating less meat, be that through documentaries, newspaper articles, and dietary recommendations.

Based on my systematic reviews, providing information can effectively increase *intentions* to eat less meat but offers less promise when it comes to promoting substantive changes in actual meat intakes. Similarly, studies published after my review found that interventions exclusively providing information were associated with null results or very small effects on actual meat consumption.(352–356) Beyond experimental studies, observational analyses also find no consistent associations between the media coverage of the detrimental consequences of animal sourced foods and subsequent purchases.(357) In line with this evidence, the surge of information over the past few years was followed by an increase in the public's understanding of meat consumption's impact on health and the environment and by conscious intentions to eat less meat, but only modest reductions in actual meat intake followed.(345,349)

Acknowledging that information provision may not directly lead to substantial reductions in meat consumption, informing the public about the benefits of eating less meat might still play an important role to promote a transition to plant-based diets:

- First, as mentioned before information can affect people's conscious intentions to eat less meat. Interventions that are only effective at promoting conscious intentions to change one's dietary behaviour are of limited value for promoting other dietary habits, as most people do not 'consciously intend' to be overweight or to consume high amounts of saturated fatty acids, sugar, or salt. As such, there is little scope to promote such behaviours by tackling their intentions. However, 47% of people are currently not interested in eating less meat and – if delivered in combination with other initiatives - interventions promoting conscious intentions to cut down might play an important role for reducing meat consumption specifically.(262,345)

- Second, there are many misconceptions about the impact of meat consumption on health and the natural environment. For example, extensively reared meat is often perceived as (more) sustainable, producing meat locally is perceived as a powerful way to mitigate meat's environmental impact, and eating less meat is not perceived as necessary to ensure a sustainable global development if other human activities are tackled. Providing information to address some of these misconception might help people who wish to eat a sustainable diet – or in fact live sustainable lives – to do so effectively.

- Third, information provision might increase people's understanding of the necessity to reduce meat consumption and subsequently increase their support for stronger and more restrictive policy options aiming to promote this dietary change.

Taken together, my systematic reviews and the wider literature suggest that, while information provision can be important on many levels, it is essential to also consider other strategies to promote substantial reductions in meat consumption at the population level. This insight is in line with broader principles from behavioural sciences, suggesting that food choices are often automatic responses to the physical environments in which people live rather than being the exclusive result of conscious considerations about what we know to be the consequences of eating different foods.(202–208)

An intervention approach that takes into account the largely automatic nature of people's food choices consists of restructuring the physical micro-environments in which people live and set up the architecture of food choices in a way that could promote reductions in meat consumption. These interventions largely work by targeting unconscious determinants of human behaviour and their effectiveness generally does not rely on recipients' intentions to eat less meat. My second systematic review evaluated the effectiveness of these approaches and confirmed that some interventions restructuring physical micro-environments (e.g. supermarkets, food courts, and canteens) effectively reduced meat intake. Research published after this review corroborated these conclusions and provided more evidence on the effectiveness of interventions restructuring micro-environments, including repositioning vegetarian options to be more prominent at point of purchase,(358–361) increasing the relative availability of vegetarian options in cafeterias,(362) setting vegetarian options as the default choice on menus,(356,363) and reducing portion sizes of meat products in various out of home settings.(364)

However, choice architecture interventions are not always effective (365,366) and more research is needed to understand the conditions under which they work best. There is also an outstanding question on how to encourage more food industry stakeholders to implement choice architecture interventions that effectively reduce meat sales, as these initiatives are likely to be perceived as detrimental for their financial success. Regulatory measures from government could help to create a

level playing field in which choice architecture interventions no longer translate into competitive disadvantages to businesses. However, a recent survey found that only 35% of adults in the UK would support government action to reduce meat consumption, suggesting that ambitious regulatory measures might not be an appealing policy option for governments in the near future.(367) Public awareness campaigns on the need to reduce meat consumption could help to increase public demand for government action, but this process is likely to take time and action to promote healthier and more sustainable food systems should not be delayed.(173,368,369) As such, identifying interventions that effectively reduce meat consumption, while also offering financially advantageous opportunities to food businesses represents a promising, pragmatic first step in the right direction.

Encouraging people to replace meat for plant-based meat substitutes might represent such an opportunity. Since 2014 the market value of meat substitutes has grown from less than £600M to £816M in 2019 and is expected to reach £1,120M by 2024.(262) Between 2017 and 2018 the value sales of meat substitutes increased by 22% for ready meals, by 33% for chilled products, and by 59% for frozen products. The market penetration of meat substitutes is also on the rise with 65% of adults in the UK having consumed a meat alternative in the six months leading up to September 2019, up from 56% in 2018.(262) The growing popularity of meat substitutes has encouraged many food businesses to invest in these products: In 2018 ad-spend for meat substitutes increased by 90%, supermarkets continued to add new lines of meat substitutes, and various popular and high-profile restaurants have added meat substitutes on their menus.(262)

Despite these relative increases, in absolute terms the consumption of meat substitutes remains low compared to the consumption of meat.(73,93,169–171,262) This is partly due to people's suboptimal perception of and lack of familiarity with meat substitutes.(262,370–372) Interventions restructuring physical micro-environments to promote substitutions of meat for meat substitutes might reduce meat consumption while also being acceptable to some food industry stakeholders. My systematic

reviews identified an interesting intervention approach that did this by providing recipients with free meat substitutes for a prolonged period of time. This approach emerged as promising because it was one of the few interventions for which there was evidence of sustained effects and early evidence suggested that it might also have improved blood lipid profiles.(373–376) However, the studies evaluating this intervention employed pre-post designs, precluding causal inferences on its impact. I therefore decided to use the provision of meat-substitutes as the centrepiece of a novel intervention, which I developed and tested in a RCT.

I used the BCW framework to identify five putative barriers preventing meat eaters from eating less meat and structured the intervention content to tackle these barriers using behavioural science frameworks, findings from my systematic reviews, consultations with psychology and nutrition experts, and co-design activities with members of the general public. The final intervention was named RE-MAP and featured four intervention components, including (i) the provision of free meat substitutes for the household for four consecutive weeks, (ii) plant-based recipes, (iii) infographics about the health and environmental benefits of eating less meat, and (iv) success stories of people who reduced their meat intake and identified as flexitarians.

Relative to a no-intervention control, the RE-MAP intervention led to a 63 g/d reduction in meat consumption at four weeks and to a 39g/d reduction at eight weeks. This represents one of the largest effect sizes currently captured in the academic literature on behavioural interventions to reduced meat consumption. The intervention also increased the frequency with which meat substitutes were consumed, without significantly changing the consumption of other main food groups, energy, or nutrients, with the exception of saturated fatty acids that decreased at both follow up, fibre that increased at the first follow up, and monounsaturated fatty acids that decreased at the second follow up.

Encouragingly, RE-MAP also reduced meat attachment and increased intentions, attitudes, perceived social norms, and perceived control of eating a low meat diet and of using meat substitutes. Initially, I had hypothesised that RE-MAP would promote replacement of meat with meat substitutes through a process of mere exposure, i.e. people's tendency to develop a liking for things as they become more familiar with them.(4–6) Rather than mere exposure, my qualitative interviews suggested that predispositions to use meat substitutes became more positive because recipients were given the opportunity to try a range of meat substitutes, which challenged their prejudice towards these foods and enabled them to identify the ones they enjoyed.

At the end of the intervention 27% of recipients identified as flexitarians or vegetarians (vs 9% among controls) and four weeks after the intervention had ended, this proportion further increased to 45% (vs 11% among controls). My initial logic model hypothesised that RE-MAP would change recipients' eating identity through the success stories and that these changes in eating identities would translate to dietary changes. However, according to my qualitative interviews it is more likely that the intervention changed recipients' diets first, and that these dietary changes – in turn – prompted shifts in recipients' eating identities, which might then have promoted longer-term reductions in meat consumption.(9–13) This process is in line with some existing psychology theories suggesting that behavioural habits provide a source of information through which people construct their personal identities. In other words, it is suggested that through the perception of frequently performed behaviours, people infer that these behaviours are important to them and build their (eating) identities around these behaviours.(377–380) The learning for future intervention development efforts is that it might not always be necessary to change 'hearts and minds' in order to change behaviour. Instead, an effective approach could be to develop interventions that focus on changing behaviour through any available (and acceptable) means and hearts and minds are likely to follow.

The effects on eating identities observed in RE-MAP were predominantly driven by people shifting from a meat-eating identity to a flexitarian identity, while only one recipient started to identify as fully vegetarian. So what are the promises and risks of promoting this relatively novel eating identity? Flexitarianism is a portmanteau of "flexible" and "vegetarian" and was added to the Oxford Dictionary only two years before I started my DPhil in 2016. This eating identity refers to people who follow primarily - *but not strictly* - a vegetarian diet.(381) Contrary to vegetarianism or veganism there is no set amount of meat that one should eat to be considered flexitarian. Previous literature suggests that the prospect of being labelled a vegetarian or a vegan can prevent people from changing their diets, as adopting these eating identities can sometimes lead to negative stigmatisation.(382) Additionally, some meat eaters may simply not be ready to give up meat entirely. An eating identity that describes a commitment to eat less meat whilst circumventing the perceived risk of being stigmatised as a vegetarian (or vegan) and the challenges associated with giving up meat completely might therefore help some people to sustainably reduce their meat intake.(341,342) (9–13)

However, there are outstanding questions about whether flexitarianism allows people to present themselves as virtuous and sustainable people (to others and themselves), whilst making little changes to their actual diet. RE-MAP partly supported and partly disputed this potential risk: participants identifying as flexitarians in my trial consumed on average 84.9 g/d of meat (SD= 51.6, N=9) at the baseline, 43.6 g/d (SD= 44.5, N=19) at four weeks, and 63.4 g/d (SD=61.1 N=30) at the eight weeks. While this is probably more than one would expect from somebody claiming to eat a 'predominantly plant-based diet with occasional consumption of meat', it is still substantially less than the average meat consumption among those identifying as omnivores or meat eaters, which was 135.3 g/d (SD= 76.2, N= 105) at the baseline, 92.2 g/d (SD= 65.5, N=93) at four weeks, and 113.4 g/d (SD=73, N= 81) at eight weeks. Taken together these findings suggest that promoting a flexitarian eating identity could help people to reduce their meat intake but that caution needs to be exercised to ensure that this dietary identity remains associated with meaningful reductions in meat consumption.

Some of my qualitative interviews and the wider literature on the perception of meat substitutes highlight that these foods are not necessarily perceived as healthy and/or environmentally sustainable foods.(370,371) While in absolute terms replacing meat with more 'natural' plant-based products is likely to result in greater health and environmental benefits, in RE-MAP replacing meat with meat substitutes led to significant weight loss and reduced the estimated GHG emissions and land use associated with recipients' diets at both follow up.(4,374,376)

The results of my thesis provide encouraging results on the potential of using meat substitutes to reduce meat consumption. However, further research is required to consider how exposure to meat substitutes can be implemented at scale and outside the confines of a research studies. Some preliminary ideas for how this could be achieved were generated through my qualitative interviews and are outlined in Chapter 5 and in the sections below.

Other than generating insights for how to apply learnings from RE-MAP to develop more scalable interventions, my qualitative interviews complemented my quantitative findings in four key domains: First, they helped to better understand how RE-MAP affected meat consumption. This work supported some of the mechanisms I originally hypothesised, but it also challenged the relevance of some other hypothesised mechanisms (e.g. that mere exposure was not the main mechanism through which recipients' perceptions of meat substitutes improved), identified some unanticipated mechanisms (e.g. that recipients used RE-MAP intervention materials to encourage reductions in meat consumption among members of their social environment), and highlighted the complex interaction between mechanisms. Second, they provided evidence on how participants felt about RE-MAP, highlighting opportunities for how to further improve the intervention or enhance its cost-effectiveness. Third, they confirmed that the RE-MAP intervention did not lead to substantial unintended consequences. Fourth, they helped to more accurately interpret the findings from the quantitative workstream. For example, the interviews highlighted that participants enrolled in the trial

for many reasons other than the desire to eat less meat, suggesting that the findings of the RCT are likely to generalise beyond populations who are pre-motivated to reduce their meat intake.

3. Strengths and limitations

One of the main strengths of my DPhil is the novelty of my research. My reviews were the first papers to systematically synthesise the effectiveness of behavioural interventions to reduce meat consumption. Since their publication, my reviews have informed important new research and policies, including the development of new interventions,(364) the scope of other systematic reviews,(383–385) and various practical recommendations outlined in policy reports.(20,386) RE-MAP was also the first intervention of its kind to be evaluated in a RCT and emerged as one of the most effective interventions to reduce meat consumption evaluated to date. Prior to RE-MAP no other study evaluated a behavioural intervention to reduce meat intake by manually disaggregating meat products from more than 2,300 days of food diaries. My RCT therefore measured its primary outcome with a level of granularity and precision that has not been achieved by any other study evaluating a behavioural intervention to date. My DPhil therefore makes an important and novel contribution to the literature on the role that behavioural interventions in general - and the provision of meat-substitutes in particular - might have in promoting healthy diets and sustainable food systems.

My DPhil aimed to establish the short- and long-term impact of behavioural interventions to reduce meat consumption. My systematic reviews synthesised data on the interventions' impact measured during or immediately after the intervention delivery as well as data collected at the longest available follow up. Similarly, in RE-MAP I measured all outcomes at the end of the intervention as well as four weeks after the intervention completion. Although the existing evidence on sustained effects of behavioural interventions to reduce meat consumption is extremely limited, my DPhil contributed to develop the 'best available' evidence on the long-term impact of such interventions.

The mixed methods approach underlying my DPhil constitutes a further strength of my thesis. Across my studies, this DPhil drew from insights generated through systematic reviews of experimental evidence, qualitative comparative analyses, reviews of behaviour change theories, public engagement initiatives, a randomised controlled trial, and semi-structured qualitative interviews. Drawing insights from multiple sources enabled me to better understand the determinants of meat intake and the mechanisms through which behavioural interventions could help people eat less meat. For example, triangulating the findings from my RCT and my qualitative interviews allowed me to better understand how RE-MAP delivered impact and to update my logic model accordingly.(387)

Despite the many strengths, my research should be interpreted in light of some overarching limitations. To date, there is only a small number of high quality studies evaluating the effectiveness of behavioural interventions to reduce meat consumption. My DPhil therefore only delivers early insights into how this particular intervention approach might work to reduce meat consumption. Encouragingly, studies published after my reviews and after the completion of RE-MAP generally support the conclusions presented in my thesis. As such, the findings presented in this manuscript still provide valid preliminary conclusions to inform policy and future research. The rapid increase in the number of studies evaluating behavioural interventions to reduce meat consumption is contributing towards developing a more robust evidence base and future research should attempt to synthesise this evidence through formal meta-analyses to help determine what strategies might lead to the greatest relative impact.

That said, experimental studies evaluating the effectiveness of behavioural interventions are intrinsically limited in the amount and type of insights they can provide about what works to reduce meat consumption in the 'real world'. While experimental studies isolate single interventions to test their impact on meat consumption, in the real world interventions are normally delivered by numerous different actors and are generally extremely complex – and often not coordinated -

combinations of numerous initiatives. It is possible that some interventions fail to work when delivered in isolation within experimental studies but might contribute to promote plant-based diets in the real world when delivered as part of a wider and more complex portfolio of initiatives. By analogy, if we wanted to know whether an airplane can fly, testing if its wings can take off in isolation will only provide very limited insights. Yet this analogy resembles what commonly happens in experimental studies of behavioural interventions to reduce meat consumption. This is often the best that can be feasibly achieved within the realm of experimental research studies.

In my DPhil, I aimed to mitigate the aforementioned limitations of experimental studies by augmenting my systematic reviews with a QCA (which explored the effectiveness of combinations of intervention characteristics rather than the impact of individual intervention components) and by designing and evaluating an intervention that combined many strategies resembling and amplifying real world trends, such as the increased availability of meat substitutes (in RE-MAP: provision of free meat substitutes), the increased awareness of the health and environmental impact of eating meat (in RE-MAP: infographics), and the increased perception that other people are reducing their meat intake (in RE-MAP: success stories). Even so, it is important to acknowledge that experimental research only offers one of many lenses through which one can determine the likely impact of behavioural interventions and caution should be exercised when designing policies based on this evidence. Other approaches, including observational research, qualitative research, professional expertise, and even anecdotal case studies need to be considered to draw a more accurate and fuller picture of the most promising avenues to promote lower meat diets.

A further limitation spanning across my DPhil is that experimental studies of interventions to reduce meat consumption are commonly evaluated in silos, i.e. they only assess whether they successfully reduce meat consumption but generally do not capture whether they lead to unintended consequences for other health or sustainable behaviours. Comparing the environmental impact of

meat consumption to that of driving a car might effectively promote lower meat diets but might it reduce the perceived impact of driving? Environmental sustainability labels might reduce selection of meat in supermarkets but might they increase purchases of sugary drinks and confectionary, which are generally sustainable products? Sensational headlines about the health impact of eating meat might increase the number of people intending to cut down on bacon, but might they also lead to some people disengaging from or discrediting other public health messages, such as those on the risks of smoking, drinking, or excess energy intake? Future research should aim to take a more holistic approach and assess whether behavioural interventions aiming to reduce meat consumption are synergetic or at least compatible with interventions aiming to protect human health and the natural environments through other routes.

Finally, my DPhil findings might not generalise - or indeed be relevant - to contexts beyond high income western countries and well-educated middle class people: The vast majority of studies in my systematic reviews took place in western countries, my RCT and public engagement activities primarily enrolled white middle class participants, and even the theories I used to structure my research and develop my intervention were developed in by highly educated academics working in elite western Universities. Researching how to promote sustainable diets in other settings should therefore be considered a priority going forward. (388)

4. Future directions

My research has several implication for research and policies aiming to promote healthier and more sustainable diets. My systematic reviews found that some behavioural interventions can reduce meat consumption and could thus represent an important policy option. Interventions targeting conscious behavioural determinants might be particularly appealing for stakeholders aiming to increase conscious intentions to eat less meat or to support people translate pre-existing intentions into action.

Interventions restructuring micro-environments might be more appealing for policy makers aiming to promote wider shifts towards plant-based diets, regardless of pre-existing intentions.

While behavioural interventions were the focus of my thesis, it is important to highlight that these approaches only represent one of many tools to reduce meat consumption and that they are unlikely to generate the required population-wide dietary changes, if delivered in isolation. Instead, behavioural interventions should be delivered in combination and used as part of a wider portfolio of policies including fiscal and regulatory measures, such as (i) taxes and subsidies based on the environmental footprint of foods, (ii) mandatory environmental labels on foods, or (iii) nation-wide rakings of food retailers based on the sustainability of their offer.(20) The impact of these regulatory and fiscal measures will not come exclusively from changing consumer behaviour (e.g. labels changing customer's food choices) but also from producers changing their menus, reformulating their products, or improving their production practices to avoid sanctions, unfavourable labels, or other measures perceived to negatively affect their profit.

That said, within the realm of behavioural interventions, RE-MAP led to one of the largest effects currently reported in the literature suggesting that meat substitutes represent an acceptable replacement for meat and can effectively reduce meat intake when offered as part of a wider behavioural programme. When discussing RE-MAP with other researchers, my intervention is often perceived as very effective but also incredibly resource intensive. Many comment that real world policies will never aim for the same level of ambitiousness and they commonly argue that if providing ad-libitum access to free meat substitutes for several weeks to people who willingly enrol in a study to reduce meat consumption does not work, nothing will. Yet RE-MAP 'only' led to a 43% reduction in ruminant red meat during the intervention provision and to a (non-statistically significant) 33% reduction four weeks after the intervention completion. This is substantively less than the sustained >50% reductions in ruminant red meat required to keep food systems within planetary

boundaries.(1,11) If RE-MAP is considered extremely resource intensive, these results give a sense of the scale and ambitiousness of the policies that are required to ensure that meat reduction targets for sustainable food systems are met.

However, it is certainly true that RE-MAP is too expensive to represent an immediately scalable policy option. Future research should explore how to replicate its impact in a scalable way and my qualitative interviews offered some pointers for how this might be achieved. For example, my interviews suggested that it was the opportunity to try a range of meat substitutes that enabled recipients to identify enjoyable products and subsequently reduce their meat intake, rather than the repeated exposure to these products. Instead of RE-MAP's expensive long-term provision of meat substitutes, future research could test the impact of providing 'one off' opportunities to try meat substitutes. This could involve offering vouchers for meat substitutes when people select comparable meat products, featuring meat substitutes in settings where food is provided for free (e.g. conferences), and providing free tasters of meat substitutes in supermarkets and restaurants.

Another policy implication of my thesis is that providing meat substitutes for four consecutive weeks resulted in some short-term health, nutritional, and environmental benefits, suggesting that meat substitutes can play a role in the promotion of healthy and sustainable diets, at least in the short term. However, compared to other protein-rich plant-based foods (e.g. pulses), meat substitutes are generally higher in salt and saturated fatty acids and their production normally results in greater levels of environmental degradation.(4,374) Manufactures of meat substitutes should continue to improve the nutritional composition and sustainability of their products, without negatively affecting their taste. Simultaneously, research should explore whether meat substitutes could be used as a 'transition aid' to support people to move from high meat diets to 'natural' plant-based diets (e.g. one in which meat is predominantly replaced with pulses). Anecdotal evidence from a RE-MAP participant suggests that after the trial, her household continued to eat less meat but started to use natural plant-

based foods as replacement. Future research could test whether this effect could be promoted more widely through an intervention.

In line with previous research, my DPhil suggested that reducing meat intake is a process with high potential for social influence.(371,389) Some RE-MAP recipients used the intervention materials and foods to promote low meat diets among their social environment. This insight has important implications for future interventions. RE-MAP was not designed to foster this social influence but since this effect occurred naturally, future interventions could leverage this mechanism by making it easy for recipients to influence others. For example, future interventions using infographics could deliver these resources digitally and encourage recipients to share this material through easy call to action buttons. Similarly, interventions providing vouchers for meat substitutes could enable recipients to 'duplicate' vouchers for products they particularly liked and to share these duplicates with members of their social environment - perhaps adding a message outlining what they liked about the product. A recent report by the World Economic Forum suggested that "building a narrative (around meat substitutes) that promises the same taste, appearance and overall eating experience as conventional animal foods has been a central goal of those supportive of alternative protein developers". (376) Based on the findings of my thesis, promoting first hand exposure to meat substitutes could naturally contribute towards disseminating this narrative.

Many of the aforementioned recommendations could be easily delivered as part of a digital intervention (e.g. a smartphone app), which is a field that received surprisingly little attention to date. Many RE-MAP components could be implemented - or indeed enhanced - if delivered digitally. For example, my qualitative interviews highlighted that recipients did not feel motivated from reading success stories from 'strangers'. A digital intervention could address this issue by allowing people to add 'buddies' to their meat reduction app and let them share their own success stories with one another. Similarly, some RE-MAP recipients felt that the information in the infographics was not

sufficiently tailored to them personally. A digital intervention could address this issue by asking people to record their diets (e.g. through a digital food diary) and provide tailored feedback about the environmental footprint of their personal food choices. The idea of using vouchers to encourage consumption of meat substitutes could also be easily implemented in a digital app. What's more, a digital app could help to tailor vouchers to recipients' diets and encourage them to progressively move towards natural plant based diets (e.g. gradually moving from vouchers for mycoprotein burgers, to vouchers for bean burgers, to vouchers for beans). Finally, qualitative research suggests that some people believe that their own individual dietary changes won't suffice to make a discernible difference to the natural environment.(178) A digital intervention might help to address this perception by providing feedback about the environmental impact of users' individual meat reduction as well as the impact made by all app users collectively. Developing and evaluating digital interventions to reduce meat consumption thus represents another important avenue for future research.

5. Conclusion

Since I started my DPhil, meat consumption in the UK has slightly declined and awareness about the detrimental impact of eating meat has increased. However, based on current trajectories the UK is still far from achieving meat consumption targets that would keep food systems within sustainable planetary boundaries. Taken together, my DPhil research suggests that some behavioural interventions targeting conscious determinants of human behaviour and restructuring physical micro-environments can help to reduce meat consumption. Providing meat substitutes for four consecutive weeks along with supporting informational material is one of the most effective interventions to reduce meat consumption tested to date. This intervention also led to some promising impact on weight, nutritional intake, markers of environmental degradation, and psychosocial variables linked with the consumption of meat and meat substitutes. Priorities for future research include (i) updating my systematic reviews to include new studies and quantitatively synthesise their results, (ii) exploring

the longer-term health and environmental benefits of replacing meat with meat substitutes, (iii) developing a more scalable version of RE-MAP aiming to retain its effectiveness, (iv) designing more interventions to promote plant-based diets in low and middle-income countries, (v) developing interventions to increase the public demand for strong regulatory action to reduce meat consumption, and (v) studying whether interventions promoting plant-based diets may lead to unintended consequences for other environmentally sustainable or health behaviours.

I hope that my DPhil will help to promote healthier diets and sustainable food systems.

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Appendices

Appendix 1: Catalogue of meat substitutes used in RE-MAP

Products available on the 2018/07/29 (Products slightly varied throughout the study based on availability)
Burgers
Sainsbury's Love Your Veg! Vegan Mix Burger 225g
Sainsbury's Meat Free Burgers x8 454g
Quorn Vegan Burgers 160g
Quorn Meat Free 4 Sausage Patties 168g
Linda McCartney Mozzarella Burger 227g
Quorn Burgers x4 200g
Linda McCartney Quarter Pounder Burger 227g
Linda McCartney's 2 Vegetarian Pulled Pork 1/4lb Burgers 227g
Sainsbury's Quinoa Sweet Potato, Lentil Burgers 350g
Sainsbury's 4 Indian Lentil and Spinach Quarter Pounders 454g
Sainsbury's Love Your Veg! Vegan Spiced Cauliflower Burger 225g
Linda McCartney 2 Vegetarian Mushroom & Spinach Burgers 220g
Vivera Veggie Burgers x2 200g
Garden Gourmet Meat Free Classic Burgers x2 160g
Panned Burgers
Quorn Burgers, Southern Style 252g
Quorn Meat Free Vegan Hot & Spicy Burgers x4 264g
Sainsbury's Cauliflower Cheese Grills 214g
Sainsbury's 4 Spicy Bean Quarter Pounders 454g
Sainsbury's 4 Vegetable Quarter Pounders 454g
Sainsbury's Smokey Jalapeno Burger x2 280g
Escalopes and Nuggets
Quorn Cheese & Broccoli Escalope 240g
Quorn Garlic & Mushroom Escalopes x2 240g
Goodlife Mushroom & Spinach Kiev with a Creamy Garlic & Cheese Sauce x2 250g
Quorn Meat Free Vegan Nuggets 280g
Quorn Southern Fried Bites 300g
Quorn Crispy Nuggets 300g
Mince and Meatballs
Sainsbury's Meat-free Meat Balls 380g
Quorn Swedish Style Balls 300g
Linda McCartney Chilled Vegetarian Meatballs 240g
Quorn Meat Free Mince 300g
Sainsbury's Vegetarian Mince 500g
Sainsbury's Mushroom Mince 250g

Quorn Meat Free Mince 350g
Granose Soya Mince 2x50g
Garden Gourmet Meat Free Simply Mince 480g
Vivera Veggie Mince 220g

Ready Meals

Quorn Steak Style & Gravy Pies 400g
Sainsbury's Love Your Veg! Chilli Bean Non Carne & Rice 400g (Serves 1)
Quorn Cornish Style Pasties 300g
Sainsbury's Love Your Veg! Mushroom Stroganoff & Rice 400g (Serves 1)
Linda McCartney Deep Dish Country Pie 380g
Sainsbury's Vegetarian Cottage Pie 400g (Serves 1)
Quorn Mini Sausage Rolls 210g
Aunt Bessie's Meat Free Toad in the Hole 190g
Linda McCartney Sausage Roll 342g
Quorn Chicken Style & Leek Pie 400g
Quorn Steak Style Slice 173g
Sainsbury's On the Go Vegan Spicy Pulled Jackfruit Wrap with Asian BBQ Sauce

Pieces

Cauldron Marinated Tofu Pieces 160g
Upton's Naturals Original Jackfruit 200g
Quorn Roast Chicken Style Sliced Fillets 140g
Quorn Steak Strips 300g
Vivera Veggie Kebab 175g
Quorn Meat Free Chicken Pieces 300g
Linda McCartney's Vegetarian Shredded Hoisin Duck 300g
Vivera Veggie Chicken Pieces 175g
Cauldron Original Tofu 396g
Quorn Meat Free Vegan Pieces 280g
Linda McCartney's Vegetarian Pulled Chicken 300g
Quorn Vegan BBQ Strips 280g
Vivera Smokey BBQ Pulled Veggie 175g
Sainsbury's Sweet & Smoky BBQ Pulled Jackfruit 350g
Garden Gourmet Meat Free Simply Pieces 450g
Tofurky Slow Roasted Chick'n Lightly Seasoned 227g
Upton's Naturals Smoky Barbecue Jackfruit 200g

Sausages

Quorn Best Of British Sausages 240g
Sainsbury's Love Your Veg! Vegan Cumberland Sausages 350g
Quorn Sausages x8 336g
Linda McCartney Vegetarian Sausages 300g
Cauldron Vegan Sausages x6 300g

Cauldron Lincolnshire Sausages x6 276g
Tofurky Italian Sausage with Sun-Dried Tomatoes and Basil 250g x4
Goodlife French Bean & Spinach Sausages with Wensleydale Cheese x6 250g
Linda McCartney Rosemary Vegetarian Sausages x6 300g
Sainsbury's 6 Glamorgan sausages 300g
Linda McCartney Vegetarian Sausages x6 300g
Linda McCartney's 6 Vegetarian Chorizo & Red Pepper Sausages 300g
Sainsbury's Vegetarian Cumberland Sausage 264g
Sainsbury's Vegetarian Hot Dog 270g
Quorn Low Fat Sausages x6 300g
Cauldron Cumberland Sausages x6 276g
Sainsbury's Love Your Veg! Vegan Carmelised Onion Sausages 350g

Fillets

Quorn Fillets x6 312g
Quorn Gammon Steaks 248g
Linda McCartney's Vegetarian Beef Roast with Red Wine & Shallot Glaze 500g
Quorn Family Roast 454g

Snacks

Linda McCartney's Vegetarian Chorizo Cocktail Sausages 320g
Quorn Mini Savoury Eggs 240g
Linda McCartney's Vegetarian Beef Wellington Bites 340g
Quorn Mini Cocktail Sausages 180g
Quorn Sausage Roll 130g

Slices

Quorn Deli Style Turkey & Stuffing Slices 100g
Quorn Deli Style Ham, Wafer Thin 180g
Tofurky Hickory Smoke Flavour Turkey Style Deli Slices 156g
Quorn Vegan Chicken Free Slices 100g
Sainsbury's Vegetarian Smoky Bacon Rashers 150g
Quorn Smoky Bacon Style Slices 150g

Appendix 2: Ethical approval

MEDICAL SCIENCES INTERDIVISIONAL RESEARCH ETHICS COMMITTEE

Research Services, University of Oxford, Wellington Square, Oxford, OX1 2JD
Tel: +44(0)1865 616577 Fax: +44(0)1865 280467
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CONFIDENTIAL

Ref: R54329/RE001

Filippo Bianchi
Nuffield Department of Primary Care Health Sciences
University of Oxford
Radcliffe Observatory Quarter
Woodstock Road
Oxford

7th November 2017

Dear Filippo,

Research Ethics Approval - CUREC 1

Study title: Replacing Meat with Alternative Protein Sources (RE-MAP Study): A randomised controlled trial of a complex behavioural intervention to reduce meat consumption

The above application has been considered on behalf of the Medical Sciences Interdivisional Research Ethics Committee (IDREC) in accordance with the procedures laid down by the University for Ethical Approval of all research involving human participants.

I am pleased to inform you that, on the basis of the information provided to the IDREC, the proposed research has been judged as meeting appropriate ethical standards, and approval has been granted for a period of **4 years**, commencing on **7th November 2017**. The reference number for this study is **R54329/RE001**.

This is **subject to:**

a) **your following the BPS guidelines for online research**

b) **your agreeing to follow Approved Procedure 24**

c) **it is your responsibility to comply with the requirements for administering any tests or questionnaires and, if in doubt, to contact the publisher of those tests or questionnaires.**

d) **if new research staff are engaged, the PI is responsible for ensuring they are suitably qualified by training and/or experience.**

I would like to remind you that your study may be selected for review by the MS IDREC during an annual audit.

Amendments

Should there be any subsequent changes to the study, which raise ethical issues not covered in the original application, you should submit details to the IDREC for consideration and approval. If there are significant alterations then the Committee will require a succinct letter explaining these. If your study received University Sponsorship through CTRG, then the amendment will first need to be submitted to CTRG for approval of continued Sponsorship.

Please do not hesitate to contact me if you have any queries.

Yours Sincerely



Dr. Helen Barnby-Porritt
Research Ethics Manager, Medical Sciences

Appendix 3: Information sheet

Replacing **M**eat with **A**lternative **P**rotein **S**ources (RE-MAP Study) Participant Information Sheet.
Ethics Approval Reference: R54329/RE001

Thank you very much for your interest in our study. Before you decide whether you want to participate, it is important that you understand why we are conducting this study and what participating would involve for you. Please take your time to read and to consider the following information and to ask questions to the researcher if there is anything that is not clear or if you would like more information.

1. What is this study about?

The results of many scientific studies suggest that eating less meat may be beneficial for health and the natural environment. However we know that it is hard to change our eating habits. This research will test whether meat substitutes can help people eat less meat.

2. *Am I eligible to take part to this study?*

To be eligible to participate in the study you must:

- Be at least 18 years old;
- Eat meat or poultry regularly;
- Live in an adult-only household;
- Be willing to try meat alternatives, and own a fridge or freezer to store them;
- Have an e-mail account and a phone that is compatible with the app 'myfitnesspal';
- Have no relevant food allergies or intolerances;
- Have no eating disorder;
- Not currently eat meat substitutes more than once a week on average;
- Not be pregnant or planning pregnancy during the study;
- Not belong to the same household as a person who is already participating to this study.

3. Do I have to take part?

No, whether or not you decide to participate is entirely up to you. If you agree to participate, you can still withdraw from the study at any time and without giving a reason. At your request we will delete any information we hold about you. You will have no penalty as a result of your decision to withdraw.

4. What will happen to m eif I participate in the study?

We will divide people into two groups:

- **Group 1:** If you are allocated to the first group, you will receive free meat substitutes for four weeks along with information on the health and environmental benefits of eating less meat and some recipes and other suggestions to help you eat less meat.
- **Group 2:** If you are allocated to the second group, we will only monitor what you normally eat.

You will not be able to choose which group you are allocated to, this will be decided by chance alone – like tossing a coin. Both groups are equally important for this research and you should be willing to continue with the study whichever group you are allocated to. The study will last for 9 weeks. Over this time, you will be asked to visit our research centre on 4 occasions for about one hour each time. The research centre is in Green Templeton College Oxford, on 43 Woodstock Road.

5. *What data will you collect during this study?*

Regardless of the group to which you will be allocated, we will collect exactly the same information from every participant. This will happen on three occasions – before you start the study, after 4 weeks and at the end of the study.

- **Weight, height and blood pressure:** A researcher will measure your height at the beginning of the study and your weight, body fat percentage, and blood pressure at each measurement point. This will take up to 10 minutes as we need to measure your blood pressure three times to get a reliable reading.
- **Questionnaires:** We will ask you to answer a questionnaire, which will take about 25 minutes to complete on the first occasion and a little less on subsequent occasions. This will include information about you, your attitudes and beliefs and questions about your diet.
- **Food diaries:** We will ask you to record everything you eat and drink in a diary for one week on three occasions using an app called myfitnesspal, which we will reimburse you for. In total you will record your diet for three weeks (21 days).
- **Finger Prick Blood Samples:** A trained researcher will collect a small finger prick blood sample to measure the levels of your blood cholesterol. You should not consider this procedure as a clinical diagnostic test and the researcher won't be able to provide you health advice. However, if we find any results, which cause concern we will encourage you to contact your GP.

If you are allocated to Group 1 you will be asked to make a fortnight order of meat-substitutes that you can select from a catalogue. At the very end of the study we will ask people from the first group if they may be willing to stay for an interview about their feelings and thoughts regarding the study. These interviews will be audio-recorded.

6. *Will I be compensated for my time?*

We understand that participating to this study may require you to invest some time and effort. You will receive an honorarium of £100 in three separate instalments: £20 after the first measurement point at the start of the study, £40 at the 4 week visit and a further £40 at the last measurement visit. Participants allocated to group 2 will also receive an additional £20 at the end of the study.

7. *Are there any potential risks in taking part?*

Participating in this study is considered to be safe and to have very few potential risks. Still, there are some aspects of this research that we would like you to consider

- Taking the finger prick blood sample will create a small puncture wound on your finger and may be uncomfortable. Strict hygiene standards will be applied for this procedure to minimise the risk of infections.

- Some of you will receive meat substitutes. We advise you to read the labels of these products carefully to check that you are not allergic to any of the ingredients, and to store and handle these products according to the instructions.
- As part of this study we will only offer commercially available products that were approved by the Food Standards Agency. Nevertheless, some of these foods may be new to you and if you experience mild allergic reactions and you suspect they were caused by a new food, please stop consuming this food and contact the clinically trained member of our research team: paul.aveyard@phc.ox.ac.uk. Should you experience an acute allergic reaction please contact the emergency and urgent care services at 111. We will also ask you to stop being involved in the study.

8. *Are there any benefits in taking part?*

Once this research has finished, we will send you a report explaining our findings, which you may find useful.

9. *How has the public been involved in this study?*

We have developed the ideas for this study with members of the public and they have reviewed our final plans. They have reviewed the questionnaires we will ask you to complete and checked that the questions are appropriate and understandable.

10. *What happens to my data?*

All your responses and data will be anonymised as soon as it is practical to do so and all the information that is collected about you during this study will be kept strictly confidential. If you will participate in our final interviews, we will transcribe and anonymise these interviews before carrying out our analyses. We might directly quote some of the things you tell us during the study but we would do this in a strictly anonymous way. The original audio recording files and the transcriptions will be stored with the rest of the anonymised data on our secure research server and will not be copied onto any other storage medium. An external company may be asked to help us transcribe these recordings. They will be asked to sign a confidentiality contract before receiving the recordings. Access might be given to appropriate members of the research team for the aim of data cleaning and data analyses. Responsible members of the University of Oxford may be given access to data for monitoring and/or audit of the study to ensure that the research is complying with applicable regulations. Personally identifiable data will be deleted as soon as they are no longer needed, while anonymised records will be stored for a minimum of three years after we publish or publicly release the results of this research. If you are allocated to the first group we may share your address, contact number, and selection of meat- substitutes with Sainsbury's to enable them to deliver the foods to you. Sainsbury's privacy policy will apply to these deliveries.

11. *Will this research be published?*

The results of this study will be used as part of a student PhD thesis and may be presented at scientific meetings or published in scientific journals. We may also advertise our results through social media, such as Facebook or Twitter. The University of Oxford is committed to the dissemination of its research for the benefit of society and the economy and, in support of this commitment, has established an online archive of research materials. This archive includes digital

copies of student theses successfully submitted as part of a University of Oxford postgraduate degree programme. If you agree to participate in this project, the research will be written up as a thesis. On successful submission of the thesis, it will deposited both in print and online in the University archives, to facilitate its use in future research.

12. *Who reviewed and funded this study?*

This study has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee. The Wellcome Trust, the Medical Research Council, the National Institute for Health Research, and Green Templeton College at the University of Oxford funded this study.

13. *Who do I contact if I have a concern about this study or if I wish to complain?*

If you have any concerns about this study, please initially contact the principal researcher, Filippo Bianchi (e-mail: RE-MAP@phc.ox.ac.uk) or Filippo's supervisors Professor Susan Jebb (email: susan.jebb@phc.ox.ac.uk) or Professor Paul Aveyard (e-mail: paul.aveyard@phc.ox.ac.uk). We will do our best to answer your questions or to acknowledge your concerns within ten working days, and to give you an indication of how we intend to deal with your concern. If you remain unhappy or if you wish to make a formal complaint, please contact the chair of the Medical Sciences Inter-Divisional Research Ethics Committee at the University of Oxford, who will seek to address the issue. Their contact details are Email: ethics@medsci.ox.ac.uk; Address: Research Services, University of Oxford, Wellington Square, Oxford OX1 2JD

14. *Contact Details*

If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact Filippo Bianchi at: RE-MAP@phc.ox.ac.uk
Thank you for your interest in my research.

Appendix 4: Informed consent form



Principal Researcher: Filippo Bianchi
Contact Details: RE-MAP@phc.ox.ac.uk
Departmental web page: www.phc.ox.ac.uk
Department's address: Nuffield Department of Primary Care health Sciences, Radcliffe Observatory Quarter, Woodstock Road, Oxford. OX2 6GG
University web page: www.ox.ac.uk

Participant ID: _____

Replacing Meat with Alternative Protein Sources (RE-MAP STUDY)

Participant Consent Form. CUREC-Approval Reference: R54329/RE001

The purpose of this study is to test the effectiveness of a behavioural intervention designed to help people reduce their consumption of meat.

Please initial the boxes to confirm you agree

I confirm that I have read and understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without having to give any reason, and without any adverse consequences.	☐
I understand that designated individuals may look at research data collected during the study where it is relevant to my taking part in this study. I give permission for these individuals to access my data.	☐
I understand that this project has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee.	☐
I understand who will have access to personal data provided, how the data will be stored, and what will happen to the data at the end of the project.	☐
I understand that three finger prick blood samples will be taken from me during this study to measure blood cholesterol. I understand the procedure that will be used to carry out these analyses.	☐

1

I understand this research will be written up as a student's thesis, I understand how personal data included in that thesis will be published and stored.	☐
I understand that I may be quoted in an anonymous way in publications pertinent to this study and that I will *not* be identified personally in any of these publications.	☐
I understand how to raise a concern or make a complaint.	☐
I consent to being audio recorded.	☐
I understand how audio recordings will be used in research outputs	☐
I consent to take part in the above study.	☐
Optional: Should I be allocated to the intervention group, I understand and consent for my name, address, telephone number, and selection of meat substitutes to be shared with Sainsbury's to carry out the food deliveries.	☐
Optional: I agree for research data collected in this study to be given to researchers, including those working outside of the EU, to be used in other research studies. I understand that any data that leave the research group will be fully anonymised so that I cannot be identified.	☐

Name of participant	Date	Signature

Name of person taking consent	Date	Signature

Appendix 5: Baseline questionnaire (answer options described in the main text)

Page 2: About this survey

Dear participant,

Thank you for taking the time to help us with this study. These questions will help us by telling us about how people change their views on meat or help explain why they don't.

The first part of this questionnaire is about what you ate over the last week and the way you think and feel about eating meat, meat alternatives and other foods. The second part is about you, your age, sex and so on.

Please remember that there is **no right or wrong answer** in this survey. We want to know how you genuinely think and feel.

This survey will take approximately 25 minutes to do.

With thanks,

Filippo

Page 3: What did you eat over the past week?

On this page we would like you to think about what you have eaten **over the past week**.

Before you start, take a moment to think back over the last week and what you have been doing. This will prompt your memory about the foods you have eaten. Don't look back over your entries in myfitnesspal or elsewhere to try adding up the exact number, just estimate the number of times you have eaten different foods as best you can.

Some dishes may be made up of different foods. For these dishes try to think about the main components of the dish. For example, if you had a pizza with tomato and cheese you should count it as starchy (the pizza base), vegetables (the tomato), and cheese. A beef burger would count as meat (the beef patty) and starchy (the bun). If you have chips as well count two starchy foods. A ready meal might come with meat and a starchy food like potatoes or rice.

If you have any questions please feel free to ask the researcher.

Please indicate **how many times over the past week** you have had these foods or drinks.

Unprocessed meat consumption over the past week.

Pork meat without processing (except for basic mincing). This includes for example pork steak, joint, ribs or mince. ✱ *Required*

If you selected Other, please specify:

Omits the same question for all other food groups mentioned in the main thesis

Page 4: Your thoughts and feelings about eating a low-meat diet

On this page we will ask you a few questions regarding your thoughts and feelings about **eating a low-meat diet.**

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
Overall, eating a low-meat diet would be unpleasant.	○	○	○	○	○	○	○
If I wanted to, it would be easy for me to eat a low-meat diet.	○	○	○	○	○	○	○
There are things beyond my control that make it difficult for me to eat a low-meat diet.	○	○	○	○	○	○	○
Overall, it would be good to eat a low-meat diet.	○	○	○	○	○	○	○
People I value would encourage me to eat a low-meat diet.	○	○	○	○	○	○	○

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
My family and friends would encourage me to eat a low-meat diet.	○	○	○	○	○	○	○
Even if I wanted to, I would find it difficult to eat a low-meat diet.	○	○	○	○	○	○	○
Overall, it would be beneficial to eat a low-meat diet.	○	○	○	○	○	○	○
In my social environment it is common to eat a low-meat diet.	○	○	○	○	○	○	○
I intend to eat a low-meat diet.	○	○	○	○	○	○	○

Page 5: Your attachment to meat products

On this page we will ask you a few questions regarding your **thoughts and feelings about meat products**.

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
To eat meat is one of the good pleasures in life.	○	○	○	○	○	○	○
Meat is irreplaceable in my diet.	○	○	○	○	○	○	○
According to our position in the food chain, we have the right to eat meat.	○	○	○	○	○	○	○
I feel bad when I think of eating meat.	○	○	○	○	○	○	○

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
I love meals with meat.	○	○	○	○	○	○	○
To eat meat is disrespectful towards life and the environment.	○	○	○	○	○	○	○
To eat meat is an unquestionable right of every person.	○	○	○	○	○	○	○
A good steak is without comparison.	○	○	○	○	○	○	○

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
I would feel fine with a meatless diet.	○	○	○	○	○	○	○
I'm a big fan of meat.	○	○	○	○	○	○	○
If I couldn't eat meat I would feel weak.	○	○	○	○	○	○	○

If I was forced to stop eating meat I would feel sad.	○	○	○	○	○	○	○

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
Meat reminds me of disease.	○	○	○	○	○	○	○
By eating meat I'm reminded of the death and suffering of animals.	○	○	○	○	○	○	○
Eating meat is a natural and indisputable practice.	○	○	○	○	○	○	○
I don't picture myself without eating meat regularly.	○	○	○	○	○	○	○

Page 6: Your thoughts and feelings about using meat-alternatives

What are your thoughts and feelings about **using meat-alternatives**, such as Quorn, soy products, tofu or other plant-based meat-alternatives?

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
My family and friends would encourage me to use meat-alternatives.	○	○	○	○	○	○	○
There are things beyond my control that make it difficult for me to use meat-alternatives.	○	○	○	○	○	○	○
Overall using meat-alternatives would be unpleasant.	○	○	○	○	○	○	○
If I wanted to, it would be easy for me to use meat-alternatives.	○	○	○	○	○	○	○

Overall, using meat-alternatives would be beneficial.	○	○	○	○	○	○	○

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
In my social environment it is common to use meat-alternatives.	○	○	○	○	○	○	○
Overall, using meat-alternatives would be good.	○	○	○	○	○	○	○
Even if I wanted to, I would find it difficult to use meat-alternatives.	○	○	○	○	○	○	○
People I value would encourage me to use meat-alternatives.	○	○	○	○	○	○	○
I intend to use meat-alternatives.	○	○	○	○	○	○	○

Page 7: What would your ideal meat-alternative be like?

Ideally, how similar to meat should a meat-alternative be?

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
I want the texture of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○
I want the taste of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○
I want the smell of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○
I want the appearance of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○

I want the protein content of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
I want the energy content of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○
I want the product name of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○
I want the required preparation of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○

I want the packaging of meat-alternatives to be as similar to meat as possible.	○	○	○	○	○	○	○
I want meat-alternatives in general to be as similar to meat as possible.	○	○	○	○	○	○	○

Page 8: Your view of yourself

When it comes to your eating identity, which of these do you identify with the most?

If you selected Other, please specify:

Page 9: Your views about eating new foods

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
I like sampling new and different foods.							
I don't trust new foods.							
If I don't know what a food is, I prefer not to try it.							
I like trying foods that I have not tried before.							
When eating out, I will try new foods.							
I am afraid to eat things I have never had before.							

Page 10: A few questions about self-control

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
I am good at resisting temptation.	○	○	○	○	○	○	○
I have a hard time breaking bad habits.	○	○	○	○	○	○	○
I do certain things that are bad for me, if they are fun.	○	○	○	○	○	○	○
I wish I had more self-discipline.	○	○	○	○	○	○	○

Please select the answer that best applies to you.

	disagree strongly	disagree	disagree slightly	neither agree nor disagree	agree slightly	agree	agree strongly
People would say that I have iron self-discipline.	○	○	○	○	○	○	○

Pleasure and fun sometimes keep me from doing what I should do.	○	○	○	○	○	○	○
I am able to sacrifice short-term rewards to achieve long-term goals.	○	○	○	○	○	○	○
Sometimes I can't stop myself from doing something, even if I know it is wrong.	○	○	○	○	○	○	○

Appendix 6: Environmental data and assumption underlying environmental impact analysis of RE-MAP

Food group	Estimated portion size	Methodology and reference for estimated portion size	Estimated land use (m^2/1g)	Estimated GHG emissions (kg of CO_2-eq/1g)	Methodology and reference for estimated portion size
Pork meat	N/A	Disaggregated from RE-MAP food diaries	0.0174	0.0123	Average impact for pork meat from Poore and Nemecek, 2018
Red ruminant meat	N/A	Disaggregated from RE-MAP food diaries	0.348	0.0696	Average impacts of beef and lamb/mutton from Poore and Nemecek, 2018
White meat	N/A	Disaggregated from RE-MAP food diaries	0.0122	0.0099	Average impact for poultry from Poore and Nemecek, 2018
Mycoprotein meat substitutes	76	Average portion size from quorn mince, tofu, soya mince, vegetarian sausages, veggie burgers from British Nutritioun Foundation portion size booklet	0.0004	0.0024	Average impact for Quorn from Head et al. 2011
Soy-based or TVP meat substitutes	76	Average portion size from quorn mince, tofu, soya mince, vegetarian sausages, veggie burgers from British Nutritioun Foundation portion size booklet	0.0035	0.0032	Average impact for tofu from Poore and Nemecek, 2018
Other meat substitutes	76	Average portion size for Quorn mince, tofu, soya mince, vegetarian sausages, veggie burgers from British Nutritioun Foundation portion size booklet	0.0052	0.001453	Average impact for pulses, vegetables, and starch from Poore and Nemecek, 2018
Milk and yoghurt	146	Average portion size for milk on cereal (skimmed; semi-skimmed; whole), milk as a drink (skimmed; semi-skimmed; whole), yogurt (fruit, low fat) small pot, yogurt plain low fat from British Nutritioun Foundation portion size booklet	0.009	0.0032	Average impact for milk from Poore and Nemecek, 2018
Cheese	40	Average portion size for soft cheese (spreadable, low fat), cottage cheese, hard cheese (e.g. cheddar), reduced fat hard cheese, stilton-type cheese, full fat soft cheese, brie-type cheese from British Nutritioun Foundation portion size booklet	0.0878	0.0239	Average impact for cheese from Poore and Nemecek, 2018
Dairy-free milk and yoghurt alternatives	146	Average portion size for milk on cereal (skimmed; semi-skimmed; whole), milk as a drink (skimmed; semi-skimmed; whole), yogurt (fruit, low fat) small pot, yogurt plain low fat from British Nutritioun Foundation portion size booklet	0.0007	0.001	Average impact for soy milk from Poore and Nemecek, 2018
Dairy-free cheese alternatives	40	Average portion size for soft cheese (spreadable, low fat), cottage cheese, hard cheese (e.g. cheddar), reduced fat hard cheese, stilton-type cheese, full fat soft cheese, brie-type cheese from British Nutritioun Foundation portion size booklet	0.0035	0.0032	Average impact for tofu from Poore and Nemecek, 2018
Fish and seafood	103	Average portion size for White fish fillet (not battered or breaded) - cooked, canned tuna, prawns, smoked mackerel pate, fish fngers (3), salmon fillet - grilled, mackerel fillet grilled, breaded frozen white fish fillet from British Nutritioun Foundation portion size booklet	0.0057	0.02025	Average impact for fish and crustaceans from Poore and Nemecek, 2018
Eggs	90	Average portion size for eggs (2), boiled egg from British Nutritioun Foundation portion size booklet	0.0063	0.0047	Average impact for eggs from Poore and Nemecek, 2018
Pulses	104	Average portion size for lentils, beans and other pulses, baked beans, reduced fat houmous, ready-made falafel (2) from British Nutritioun Foundation portion size booklet	0.01155	0.0014	Average impact for peas and other pulses from Poore and Nemecek, 2018
Vegetables	80	Average portion size for 3 heaped tablespoons of carrots/sweetcorn/mixed vegetables, 1/2 pepper/1 medium tomato/ 1 medium parsnip from British Dietetic Association portion size booklet	0.0005	0.0008	Average impact for tomatoes, onions and leeks, root vegetables, brassicas, other vegetables from Poore and Nemecek, 2018
Starchy foods	85	Average portion size for flaked breakfast cereals, weetabix-type cereal biscuits (2), wholegrain malted wheat cereal, shredded wheat type cereal (2 biscuits), multigrain hoops, muesli, porridge (dry weight), 2 slices of medium-sliced, ½ small baguette, pitta bread, mashed potato (mashed with spread), cooked new potatoes, wrap, sandwich thins, bagel thins, garlic bread (¼ small baguette), 1 medium wholemeal bread roll, 1 small chapatti, plain microwave rice, plain pasta - cooked, rice - cooked, couscous – cooked, large wholemeal bread roll, bagel, oven chips, roast potatoes, egg noodles - cooked, 1 large chapatti, 2 slices thick-sliced bread, cooked baked potato, plain naan bread (½ naan), oat cakes (2), plain rice cakes (3), 1 slice of medium-sliced wholemeal bread, small roll, mini wrap, mini pitta (2 small, 1 medium), 1 crumpet from British Nutritioun Foundation portion size booklet	0.00362	0.00216	Average impact for wheat & rye, maize, oatmeal, rice, potatoes from Poore and Nemecek, 2018
Nuts and seeds	20	Average portion size for unsalted nuts and seeds from British Nutritioun Foundation portion size booklet	0.01105	0.0018	Average impact for nuts and groundnuts from Poore and Nemecek, 2018

Fruit	80	Average portion size for 1 apple/pear/orange/banana, a handful (10-12) grapes/ berries, 2 plums/apricots/kiwis/ satsumas from British Dietetic Association portion size booklet	0.00134	0.00086	Average impact for citrus fruit, bananas, apples, berries and grapes, and other fruit from Poore and Nemecek, 2018
Savoury and sweet snacks	39	N/A	N/A	N/A	N/A
Soft drinks (sugar in)	10	Sugar in can of soft drink, assuming that an average soft drink can is 330 ml and that the average sugar content in 2018 was 2.9 g/100 ml (based on Bandy et al.2020).	0.002	0.0032	Average impact for cane sugar from Poore and Nemecek, 2018
Alcoholic drinks	359	Average portion size from standard wine glass, bottle of beer/lager/cider, can of beer/lager/cider, pint of beer/lager/cider, half pint based on NHS information page on portion sizes of alcoholic drinks	0.00145	0.0015	Average impact for wine and barley (beer) from Poore and Nemecek, 2018

British Nutriton Foundation portion size booklet available from: https://www.nutrition.org.uk/attachments/article/1193/Find%20your%20balance_%20full%20portion%20size%20list.pdf

British Dietetic Association portion size booklet available from: https://www.bda.uk.com/resource/food-facts-portion-sizes.html

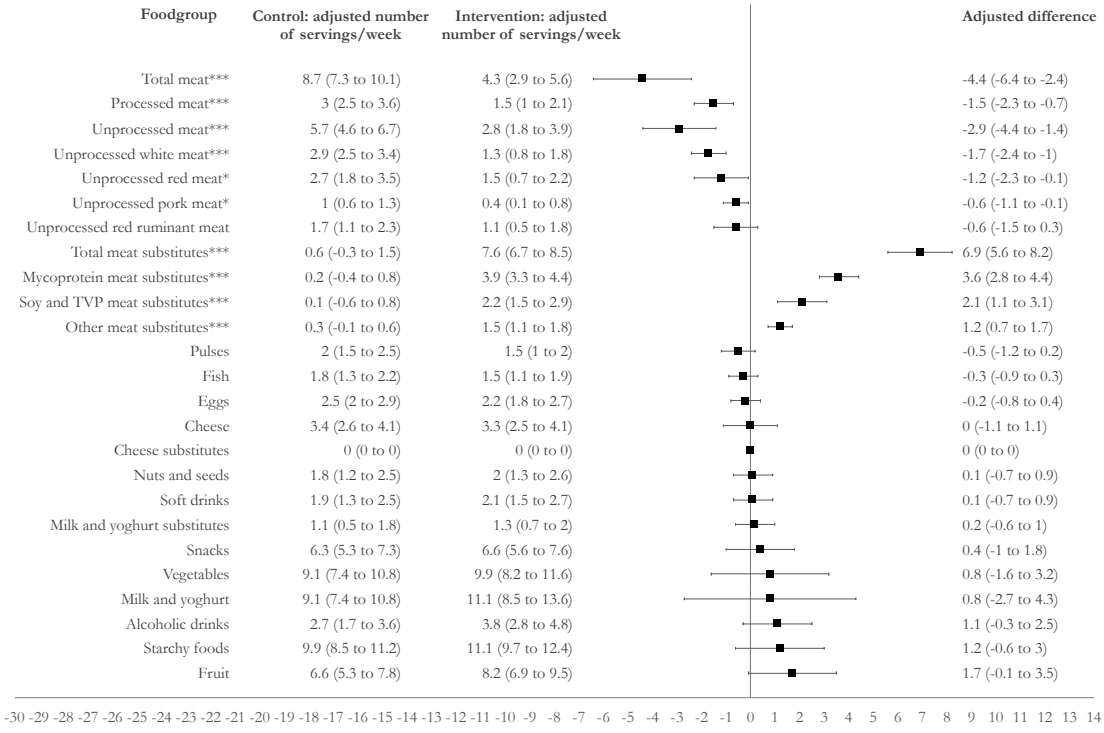
Alcoholic drinks portion sizes available from: https://www.nhs.uk/live-well/alcohol-support/calculating-alcohol-units/#:~:text=Knowing%20your%20units%20will%20help,as%2014%20units%20a%20week

Poore and Nemecek (2018) database available from: https://science.sciencemag.org/content/360/6392/987

Head and colleagues (2011) database available from: https://www.cedelft.eu/publicatie/life_cycle_impacts_of_protein-rich_foods_for_the_superwijzer_app/1264

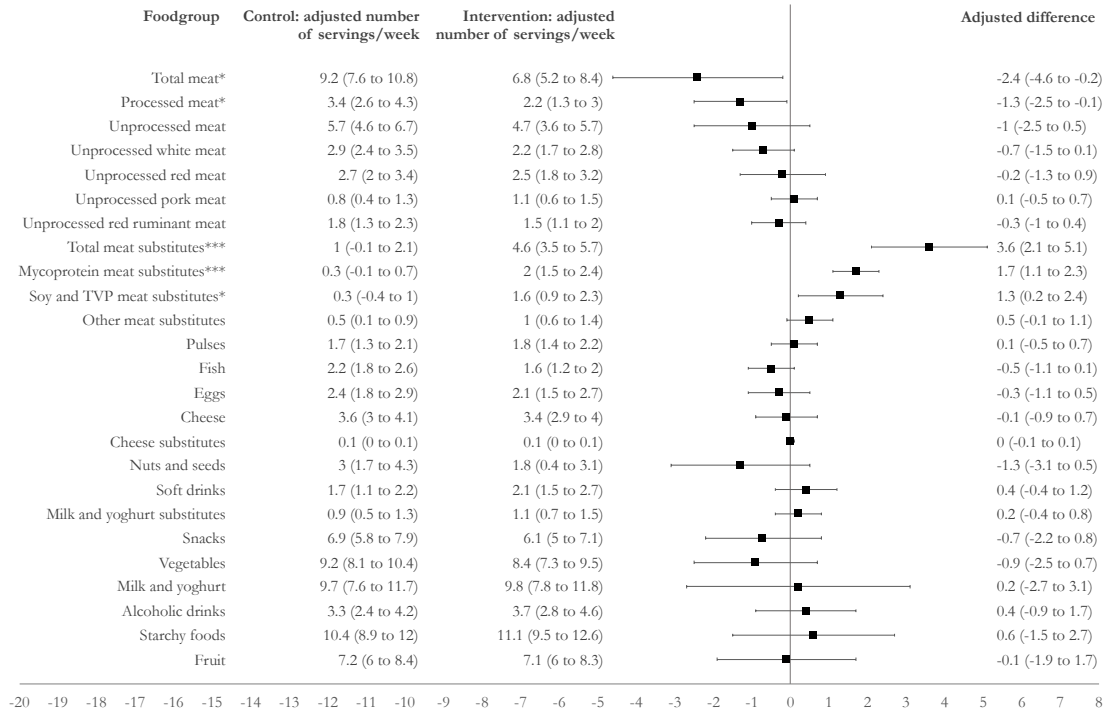
Appendix 7: Intervention impact based on retrospective dietary recall

Appendix 3.1: Impact of the intervention on retrospectively assessed daily servings of differed food groups at the four weeks follow up



Mixed effect models with fixed effects for randomised group, baseline consumption of the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. N=113. Unprocessed white meat includes unprocessed game and 'other' meat. Stars refer to the adjusted differences and represent * p<0.05, ** p<0.01, *** p<0.001.

Appendix 3.2: Impact of the intervention on retrospectively assessed daily servings of differed food groups at the eight weeks follow up



Mixed effect models with fixed effects for randomised group, baseline consumption of the respective food group, gender, and random effects for the intercept and slope. Values are mean and 95% confidence interval. N=112. Unprocessed white meat includes unprocessed game and 'other' meat. Stars refer to the adjusted differences and represent * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Appendix 8: Interview guide

RE-MAP Semi Structured Interviews
Discussion Guide

General: Before the intervention

- What made you interested in this study?
- Did you ever consider reducing your consumption of meat before? If so, what motivated you?
- In what way did you try to reduce your consumption of meat previously?
- What prevented you to succeed in reducing meat consumption?

Introduce the intervention:

- Remind participant of the four intervention components (meat substitutes, infographics, success stories, cookbooks).
- Explain that you will go through each component to understand what participant thinks.

Intervention

Meat substitutes

Overall what did you think about the meat substitutes?

- What were the things you particularly liked? How so?
- What were the thinks you particularly disliked. How so?
- What were the advantages and disadvantages compared to meat?
- How do you picture yourself integrating these products in your routine diet?
- Was there a particular types of meat substitutes you particularly liked? What was it that made it so appealing to you?

How did the meat substitute change your diet?

- How do you feel that having the receiving the meat substitutes available changed your diet in general?
- How about your consumption of meat in particular?
- How did your perception of meat substitutes change over the course of the study?
- Did you replace your meat with meat substitutes 1 to 1 or did you start eating products you do not normally eat, even in their meat form?

Did you ever share the meat substitutes with your family and friends?

- What are the barriers to use meat substitutes when eating with other people? E.g. BBQ/invite people over?
- How did you introduce these meat substitutes to them?
- What were the reactions of friends?

Info-graphics

Overall what did you think about the infographics on the health and environmental benefits of eating less meat?

- What were the things you particularly liked
- What were the thinks you particularly disliked
- Was anything surprising to you? What was it?
- Did you learn anything new?

How did the infographics influence what you eat?

- How motivating did you find learning about the health and environmental benefits of eating less meat?
- What were the things you found most/least motivating for reducing your meat consumption?
- Did you feel more motivated by the health or environmental infographics? How so?

How convincing and credible did you find the infographics?

- What made the infographics credible/not credible to you (e.g. source/referencing7clarity of message)?
- What makes an information source a credible one to you?

Success stories

Overall what did you think about the vignettes of the people who reduced their meat consumption?

- How did reading these stories make you feel and think any differently about eating less meat?
- What where the things you could identify with, and those you could not?
- Did you try out any of the strategies that worked for those people?
- When you hear the story of somebody who reduced their meat consumption how do you feel and what are the things you look out for in these stories?

Recipes

Overall what did you think about cookbooks – both the one focussing on meat-substitutes and the describing more general plant based recipes?

- Was receiving these cookbooks helpful for reducing your consumption of meat? How so?
- What did you feel about cooking skills when you're trying to eat less meat?
- What did you think about trying out some recipes?
- Was there anything you liked or disliked particularly about the cookbooks?

General questions: During the intervention

- Of the things we provided which one did you find most helpful to reduce your consumption of meat? How so?
- How did the intervention help you to overcome some challenges to reduce your meat consumption?
- How did you feel that the intervention changed your eating habits in general?

- What else would have helped you transition to a more plant-based diet that we did not provide?
- How did the intervention affect your motivation to eat less meat?
- What strategies did you use during the intervention month to eat less meat?

General questions: After the intervention

How did you get on when we stopped providing the intervention?

- How did you feel about eating a low meat diet after we stopped providing the intervention? How so?
- How about missing meat?
- After we stopped providing the intervention did you use any specific strategy to continue eat less meat? Which ones?