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RETHINKING SOCIAL INFLUENCE ON FOOD CHOICES: BEHAVIOURAL
PATHWAYS FROM CONSUMPTION TO WASTE

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Rethinking Social Influence on Food Choices: Behavioural Pathways from Consumption to Waste

Abstract

The transition toward sustainable and healthy food systems requires a deeper understanding of how social influences shape individual food choices within complex food environments. This thesis investigates whether and under which conditions social norms can support healthier and more sustainable eating behaviours. The research adopts an integrated multi-method design that combines a systematic review and meta-analysis, agent-based scenario modelling, and a cluster randomized controlled trial conducted in Italian primary schools.

The first chapter synthesizes existing evidence to assess the effectiveness of social norm interventions in shaping eating behaviours and identifies key moderating factors. The second chapter applies a validated agent-based model to simulate behavioural responses to nudging strategies in an all-you-can-eat buffet context, exploring how social norms interact with individual characteristics and sequential decision-making processes. The third chapter evaluates a participatory descriptive social norm intervention aimed at reducing vegetable plate waste in primary school canteens.

Results indicate that social norms exert a small but statistically significant influence on eating behaviours, with effects moderated by age, message framing, and behavioural observability. Simulation findings suggest that behavioural interventions interact with multiple behavioural drivers along decision pathways, often generating compensatory responses that limit overall waste reduction. Evidence from the field experiment shows no average reduction in vegetable plate waste, although heterogeneous and context-dependent responses emerge across settings.

The findings suggest that social norms should not be considered stand-alone policy instruments but rather complementary tools whose effectiveness depends on environmental design and population characteristics. By integrating evidence synthesis, behavioural modelling, and field experimentation, this research advances theoretical understanding of social influence and provides practical guidance for designing interventions that promote healthy and sustainable eating.

Keywords

Social norms; Food choices; Food waste; Behavioural change; Behavioural intervention; Food environment

Table of Contents

Abstract.....	i
Introduction.....	1
Food systems at the nexus of health and sustainability.....	1
From individual decision-making to systemic outcomes.....	3
Aim of the study.....	5
Methodological and theoretical background.....	6
Structure of the thesis.....	10
References.....	12
Chapter 1.....	17
Framing the Influence of Eating Social Norms on Eating Behaviours: A Systematic Literature Review and Meta-Analysis of Moderators.....	18
Abstract.....	18
Keywords.....	18
1.1 Introduction.....	19
1.2 Methods and materials.....	22
1.2.1 Sample construction.....	22
1.2.2 Data extraction.....	25
1.2.3 Data analysis and meta-analytic model.....	28
1.3 Results.....	31
1.3.1 Overview of the sample.....	31
1.3.2 Overall effect of social norms on eating behaviours.....	34
1.3.3 Moderators influencing social norms effectiveness.....	38
1.4 Discussion.....	40
1.4.1 Limitations and directions for future research.....	44
1.5 Conclusions.....	45
CRediT authorship contribution statement.....	46
Declaration of competing interest.....	46

Declaration of generative AI.....	46
References.....	47
Chapter 2.....	52
A Bite Too Much: Scenario-Based Analysis of Simulated Plate Waste Behaviour at a Hotel Breakfast Buffet	53
Abstract.....	53
Keywords	53
2.1 Introduction.....	54
2.2 Methods.....	58
2.2.1 ABM overview.....	58
2.2.2 Scenarios design.....	59
2.2.3 Data analysis.....	62
2.3 Results.....	65
2.3.1 Descriptive scenario results.....	65
2.3.2 Regression analysis.....	68
2.3.2.1 Portion model - Determinants of first portion decisions	68
2.3.2.2 Refill model – Determinants of extra serving decisions.....	71
2.3.2.3 Mediated Leftovers model – Determinants of mean leftovers	74
2.3.2.4 Total-effect Leftovers model – Combined direct and indirect effects.....	77
2.4 Discussion	77
2.4.1 Limitations and future work.....	81
2.5 Conclusions.....	82
CRedit authorship contribution statement	84
Declaration of competing interest.....	84
Funding	84
Acknowledgements.....	84
Declaration of generative AI.....	84
References.....	85
Chapter 3.....	90

Do Social Norms Shape Food Waste Behaviour in Primary School Canteens? Experimental Evidence from a Cluster Randomized Controlled Trial	91
Abstract	91
Keywords	92
3.1 Introduction.....	92
3.2 State of the art: social norm interventions in school eating contexts.....	95
3.3 Theoretical background.....	100
3.4 Methods.....	103
3.4.1 Sampling and participants	103
3.4.2 Intervention co-design.....	105
3.4.3 Procedure.....	106
3.4.4 Data collection.....	107
3.4.5 Outcome measures	109
3.4.6 Data analysis.....	110
3.5 Results.....	113
3.5.1 Sample characteristics and baseline conditions.....	113
3.5.2 Descriptive patterns of plate waste.....	116
3.5.3 Average treatment effect on SiD PW	117
3.5.4 Dynamic effects and time evolution.....	120
3.5.5 Spillover effects on FD and SeD.....	122
3.5.6 Exploratory mechanisms: second servings.....	124
3.6 Discussion	126
3.6.1 Main findings	126
3.6.2 Methodological insights from large-scale RCT field experiments	127
3.6.3 Mechanisms and boundary conditions of social norm interventions	129
3.6.4 Limitations and future research.....	130
3.7 Conclusions.....	131
CRedit authorship contribution statement	133

Declaration of competing interest	133
Acknowledgements	133
Declaration of generative AI.....	133
References.....	134
Conclusions.....	145
Summary of evidence.....	145
Contributions to the state of the art	147
Methodological contributions	147
Empirical and policy-relevant contributions	147
Limitations and implications for future research	149
Concluding remarks	151
Declaration of generative AI and AI-assisted technologies in the writing process.....	151
Supplementary Materials	152
Supplementary Materials I.....	159
Supplementary Materials II.....	179
Supplementary Materials III	193

List of Figures

Figure 1.1: PRISMA 2020 flow diagram.....	23
Figure 1.2: Moderators included in the meta-analysis.....	27
Figure 1.3: Number of articles per publication year by country and cumulative growth rate (Full sample).....	31
Figure 1.4: Forest plot of the 88 effects	36
Figure 2.1: Establishment Diner ABM decision steps. After the first serving, agents can decide whether to finish, leave food or go back and refill. Only factors relevant for this study are depicted, further details in Puga-Gonzalez et al. (2025)	59
Figure 2.2: Messages influence on guests' decisions through reactance	61
Figure 2.3: Predictor structure of the regression models. Arrows colours refer to each model pathway: Green = Portion model; Yellow = Refill model; Purple = Mediated Leftover model	65
Figure 2.4: 36 simulated scenarios and PW results	66
Figure 2.5: Effects of key scenario parameters on simulated leftovers per guest. Panel (A) shows the influence of sustainability awareness, (B) the proportion of business guests, (C) plate size, and (D) communication strategy. Red dots indicate the mean value.	67
Figure 2.6: Increment in mean portion size per guest changing a) small → large plate size; b) no message → positive/provocative message.....	70
Figure 2.7: Increment in mean extra portion per guest changing a) small → large plate size; b) no message → positive/provocative message.....	73
Figure 2.8: Increment in mean PW per guest changing a) small → large plate size; b) no message → positive/provocative message	76
Figure 2.9: Pathway of the three regression models and example coefficients for plate size (red), sustainability awareness (light green), their interaction (dark green), mean portion size (pink) and mean extra servings (orange) across models, illustrating their in.....	77
Figure 2.10: Overview of how experimental variables influence portioning, refilling, and PW outcomes	79
Figure 3.1: Sampling process based on CONSORT guidelines (Moher et al., 2012).....	105
Figure 3.2: Intervention and data collection process in an exemplifying school with a 4-week menu rotation	108
Figure 3.3: Distribution of PW% by meal course, experimental group, sample, and measurement period.	117
Figure 3.4: Dynamic treatment effects on SiD PW%: event-study estimates, full sample.....	121

Figure 3.5: Dynamic treatment effects on SiD PW% by Vast Area.....	122
Figure 3.6: Dynamic treatment effects on FD PW%	123
Figure 3.7: Dynamic treatment effects on SeD PW%.....	123
Figure 3.8: Dynamic treatment effects on SiD PW% stratified by pre-treatment SiD second serving propensity.....	124
Figure 3.9: Dynamic treatment effects on SiD second serving propensity stratified by baseline SiD PW%	125
Figure 3.10: Dynamic treatment effects on SiD PW% stratified by baseline SiD PW%.	126

List of Tables

Table 1.1: Existing review articles on the effect of social norms on eating behaviours	21
Table 1.2: Inclusion and Exclusion criteria for articles' eligibility	24
Table 1.3: Coding scheme for the moderators included in the meta-analysis.....	26
Table 1.4: Description of the full sample and sub-sample of effect sizes included in the meta-analysis.....	33
Table 1.5: Subgroup analyses of the effect of social norms on eating behaviours	37
Table 1.6: Model from Eq. 1.2 and Model from Eq. 1.3 results. Online, Medium Familiarity Setting, Adults, Mixed Gender, Unhealthy Food omitted (baseline conditions).	39
Table 2.1: Values used for parameter variation in what-if scenario simulations.	62
Table 2.2: Portion model – Key standardized coefficients (with interactions).....	68
Table 2.3: Refill model – Key standardized coefficients (with interactions).....	71
Table 2.4: Mediated Leftovers model – Key standardized coefficients (with interactions)	74
Table 2.5: Total-effect Leftovers model - Key standardized coefficients	77
Table 3.1: Previous articles implementing a social norm-based intervention to influence children's eating behaviours at school.	98
Table 3.2: Sampling structure in the study.....	104
Table 3.3: Descriptive statistics for the two experimental groups (full sample).....	114
Table 3.4: Frequency of dish categories across courses in all classes during T0 and T1	115
Table 3.5: Descriptive statistics of PW% per dish, for Vast Areas and full sample.....	116
Table 3.6: Average treatment effect for the full sample, for each Vas, and for urban/rural segmentation	118
Table 3.7: DiD variable interacted with urban/rural dummy within VA.....	119

List of Abbreviations

ABM	Agent-Based Model	PF	Prepared Food
AIPW	Augmented Inverse Probability Weighting	PP	Percentage Points
ATT	Average Treatment Effect on the Treated	PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
AUSL	Azienda Unità Sanitaria Locale (Local Health Authority)	PW	Plate Waste
CF	Consumed Food	RCT	Randomized Controlled Trial
CONSORT	Consolidated Standards of Reporting Trials	REML	Restricted Maximum Likelihood
CREA	Consiglio per la Ricerca in Agricoltura	RQ	Research Question
DiD	Difference-in-Differences	SD	Standard Deviation
FD	First Dish	SDGs	Sustainable Development Goals
FW	Food Waste	SeD	Second Dish
HDFE	High-Dimensional Fixed Effects	SF	Served Food
ICC	Intraclass Correlation Coefficient	SiD	Side Dish
LaRiSo	Laboratorio di Ristorazione Sostenibile (Regional Laboratory for Sustainable School Catering)	SW	Service Waste
MOA	Motivation-Opportunity-Ability	TWFE	Two-Way Fixed Effects
MUFPP	Milan Urban Food Policy Pact		
NCDs	Non-Communicable Diseases		

Introduction

Food systems at the nexus of health and sustainability

Food systems have emerged in the past decades as a core of the sustainability debate (Bodirsky et al., 2025). The way food is produced, transformed, distributed, and consumed lies at the intersection of environmental, economic, health, and social issues that shape the way humans, societies, and nature coexist and interact (Rosentrater et al., 2019). Food systems are also inherently interconnected to global crises, from climate change to diet-related diseases, as their dynamics contribute to exacerbating them and at the same time are influenced by them (Swinburn et al., 2019). Food overconsumption coexists with malnutrition and food insecurity, revealing structural inefficiencies where unsustainable production and unbalanced dietary patterns exist together with large-scale waste along supply chains.

Overweight, obesity and diet-related non-communicable diseases (NCDs) have reached alarming proportions at the global level. In 2022, 43% of adults were overweight, including 16% living with obesity, marking a steady rise from 25% in 1990 (WHO, 2022). The prevalence of overweight and obesity among children and adolescents aged 5–19 has more than doubled in the same period, from 8% to 20%, reflecting a persistent global trend and posing the bases for health-related problems for the future generations (WHO, 2022). These health conditions are primarily determined by an imbalance between caloric intake and energy expenditure, aggravated by unhealthy dietary patterns and sedentary lifestyles (Jannasch et al., 2024; Shan et al., 2020). Promoting balanced diets rich in fruits, vegetables, and pulses plays a pivotal role in preventing obesity and reducing the incidence of cardiovascular diseases, diabetes, and other NCDs (Yuan et al., 2023).

Addressing overweight and obesity is key to progress towards several United Nations Sustainable Development Goals (SDGs): SDG 2 on Zero Hunger, SDG 3 on Good Health and Wellbeing, and SDG 12 on Responsible Consumption and Production. Encouraging healthy and sustainable diets contributes to nutritional security, reduces inequalities (SDG 10), and supports the transition toward sustainable food systems (Candio et al., 2023). In this regard, individual eating behaviours, meaning what people choose and how much they consume, emerge as critical levers for achieving food system and health objectives.

At the same time, food waste (FW) represents an interconnected challenge. It is estimated that globally 19% of all food reaching the final stages of the supply chain is wasted at the household, food

service, and retail levels (UNEP, 2024). The overproduction, overconsumption, and subsequent discarding of food not only exacerbate environmental stress through excess greenhouse gas emissions, water use, and land degradation, but are also in opposition to nutritional and equity goals (Brennan & Browne, 2021; Conrad et al., 2018). In Europe, 28% of total FW originates from food service activities such as canteens, restaurants, and hotels, and 75% of the waste generated by the hospitality sector is classified as avoidable (Oliveira et al., 2016). The behavioural dimension is particularly evident in these contexts: individual portioning decisions, food preferences, and social norms all contribute to plate waste, the portion of food served but left uneaten (Muposhi & Musavengane, 2023).

In hospitality settings, FW arises from both operational factors, such as overproduction, menu variety, forecasting errors (Heikkilä et al., 2016; Papargyropoulou et al., 2019), and behavioural drivers like portion sizes, guest attitudes, and buffet dynamics (Berkowitz et al., 2016; Juvan et al., 2018). Self-service abundance leads to overserving, with plate waste estimates ranging from 15 to 300g per guest, particularly among children and first-time diners (Liu et al., 2022; Oliveira et al., 2016).

Moreover, school canteens represent a dual challenge: despite guidelines recommending 5 daily fruit/vegetable portions (CREA, 2019), 25.9% of Italian 8-year-olds skip them daily, while 53% of vegetables served in school canteens are wasted (OKkio alla SALUTE, 2024; Petruzzelli et al., 2025). Establishing healthy habits here is critical, as childhood dietary patterns predict lifelong obesity risk (Saavedra & Prentice, 2023; WHO, 2016), making schools strategic for nutrition and waste interventions (MUFPP, 2024).

Reducing FW and promoting healthy diets share common drivers and policy relevance. Both require reshaping everyday food behaviours and environments in which choices are made. The Agenda 2030 explicitly calls for halving per capita FW (Target 12.3) while ensuring access to nutritious food for all (Target 2.1). Achieving these goals demands integrated strategies that link health and sustainability objectives across sectors. In order to progress towards these objectives, behavioural change represents a cost-effective and scalable strategy (Reisch, 2021). Addressing individual micro-level decisions has the potential to influence macro-level outcomes such as public health and FW generation.

Therefore, aligning individual dietary patterns with planetary and human health is not only a nutritional challenge but also a behavioural, social, and policy one, placing eating behaviours at the center of food system transformation.

From individual decision-making to systemic outcomes

Behavioural science has reshaped how sustainability challenges are addressed in research and policy. Moving beyond the assumptions of perfect rationality, behavioural economics has shown that food-related decisions are strongly shaped by bounded cognition, social influence, habits, and emotions (Kahneman, 2011; Thaler, 2009). The context in which choices occur, or the food environment, influence outcomes. Food environments are defined as “the physical, economic, political, and sociocultural context in which each consumer engages with the food system” (Schönfeldt & Pretorius, 2018). This concept includes economic and physical access to food, communication and information regarding food and diets, and the quality and safety of what is available, acceptable and affordable to individuals. In addition to these elements, the cultural and political context in which individuals act also has an influence on what they decide to consume (Schönfeldt & Pretorius, 2018). The concept of food environment allows the adoption of a food system approach, starting from the consumer perspective. Food systems are defined as encompassing all the actors and activities that produce, process, distribute and consume food, interacting with the economic, social, and natural environments in which they are embedded (FAO, 2018). Food environments represent the interface through which consumers get into contact with all the operations and actors that are involved in the food production and distribution, which potentially influence consumption decisions. In fact, the way in which the food reaches the final consumer through production, processing, preparation, distribution, and retailing influences its accessibility, affordability, and nutritional quality (Schönfeldt & Pretorius, 2018). Within this broader framework, a useful distinction has been proposed between different domains of the food environment, including the community food environment (spatial access to outlets), the consumer food environment (availability, pricing), and the organizational food environment, which concerns settings such as schools, workplaces, hospitals, restaurants, and other collective catering contexts (Franco et al., 2016). Organizational environments are particularly relevant for this thesis, as school canteens and food service settings determine not only what foods are offered, but also how they are presented, portioned, and experienced by final consumers. Menus, service practices, time constraints, and social arrangements (e.g. seating, supervision, peer presence) all shape the food environment in ways that can promote or hinder the adoption of healthy diets and the reduction of food waste (de Castro & Canella, 2022).

Analytically, different theoretical frameworks have been elaborated and tested to study behavioural decisions taking into consideration both internal drivers and external ones related to food environments. One of those is the Motivation-Opportunity-Ability (MOA) framework, initially elaborated by MacInnis et al. (1991) to investigate advertising and communication outcomes as

mediated by individual characteristics. According to the MOA framework, individual behaviour is mediated by motivations, meaning the willingness to carry out certain actions. The willingness is in turn determined by the awareness of a specific issue, the attitude towards this issue and the social norms surrounding it. Second, behaviours are influenced by abilities, defined as the skills and knowledge of individuals, which could guide their actions in the desired direction. Finally, behaviours are influenced by opportunities, represented by the external constraints and available resources (Vittuari et al., 2021). These three dimensions can be influenced through interventions, in order to encourage specific behavioural outcomes such as reducing FW or promoting the adoption of healthy diets.

Among the different behavioural drivers, social norms represent a pervasive yet still underexplored determinant of eating behaviours. Social norms are the implicit rules that define what behaviours are common or socially approved within a group (Cialdini et al., 1991). In eating contexts, they operate as contextual cues that guide consumption amounts, food choices, and waste-related behaviours (Higgs, 2015). A key mechanism underlying their influence is pluralistic ignorance, where individuals misperceive the prevalence of healthy or sustainable behaviours as lower than reality, leading them to conform to an inaccurately perceived norm (Miller & McFarland, 2024). For instance, people may underestimate how many peers actually choose vegetables or finish their plates, leading them to adopt undesired behaviours. Because norms are socially shared expectations, interventions targeting these misperceptions represent a promising tool for promoting healthier and sustainable choices. By providing normative feedback that promotes a desired behaviour, such strategies can steer behaviours and break pluralistic ignorance cycles (Berkowitz, 2003). They can complement traditional instruments such as regulation, information, or pricing by leveraging social influence to align individual motivations with collective expectations. However, social norms effects do not emerge as uniform: messages perceived as overly moralizing can backfire, inducing psychological reactance or compensatory behaviours that hinder desired outcomes (Brehm & Brehm, 1981). Understanding under which conditions and for whom social norms succeed or fail is thus essential to inform effective behavioural interventions.

Recent behavioural research has adopted different approaches to link micro-level psychological mechanisms with macro-level systemic outcomes. By combining experimental, field-based, and simulation methods, behavioural science now examines how diverse drivers such as contextual factors, social interactions, and individual characteristics shape food-related decisions (Reisch, 2021; Scalco et al., 2019). This perspective allows understanding behaviour not as an isolated event but as part of broader pathways that connect individual choices, influenced by motivations, social norms, abilities and opportunities, with collective outcomes like the adoption of healthy diets and FW.

Adopting this systemic behavioural lens is essential to designing interventions that are effective, context-specific, and scalable.

Despite the growing application of behavioural approaches to understand individual eating behaviour and its linkage to macro-level outcomes, three major knowledge gaps remain.

First, the evidence on social norms and eating behaviours is fragmented and often inconsistent. Studies vary widely in design, population, and measures, hindering an integrated understanding of the role of social norms in influencing eating behaviours. Few reviews have systematically integrated results and quantified effects to identify moderators that amplify or weaken normative influence.

Second, most behavioural interventions focus on isolated effects, overlooking the dynamics and compensatory pathways through which individuals adapt to contextual changes. Even interventions that initially appear effective can trigger unexpected behavioural outcomes, neutralizing their impact on aggregate outcomes such as plate waste.

Third, field evidence testing the effect of social norms in real-world settings remains scarce. Laboratory or quasi-experimental designs dominate literature, providing limited external validity and therefore creating an ecological validity gap between behavioural theory and real-world food environments. Large-scale, randomized controlled trials on FW in collective catering are particularly scarce, despite their policy relevance.

These gaps highlight the need for an integrated framework connecting what influences food-related decisions and how individual mechanisms translate into systemic outcomes, from consumption decisions to waste. To address these gaps, this work combines a systematic synthesis and meta-analysis of existing knowledge (Chapter 1), simulation modelling of a food service setting (Chapter 2), and large-scale field testing of a behavioural intervention in school canteens (Chapter 3) to identify and investigate how individual eating behaviours are shaped by contextual, social, and individual characteristics in different settings.

Aim of the study

Against this background, this thesis aims to investigate how social influences shape food-related behaviours from consumption to waste, and to understand under which conditions social norms can effectively support healthier and more sustainable eating behaviours. The work seeks to connect individual-level mechanisms, including motivations, opportunities, abilities, and social expectations, with aggregate outcomes such as dietary patterns and FW generation in different food environments.

More specifically, the thesis addresses three main research questions:

- RQ1: Do social norms influence eating behaviours and under which conditions?

- RQ2: How do social norms and other contextual drivers in food service environments shape plate waste?
- RQ3: Does a social norm-based message delivered through a poster co-design activity increase vegetable intake and reduce plate waste in a primary school canteen setting?

By addressing these three research questions, the thesis aims to advance both theoretical and practical understanding of social influence in food systems: conceptually, by framing social norms within a broader behavioural lens; methodologically, by integrating systemic and quantitative synthesis of previous work, simulation scenarios, and experimental fieldwork; and operationally, by providing insights to design context-specific interventions that align health and sustainability goals in schools and food service settings.

Methodological and theoretical background

The present work adopts a behavioural pathway perspective, analysing how social influence shapes food-related decisions across different contexts and stages, from portioning and consumption to waste. It integrates three complementary theoretical and analytical frameworks that are deployed in the three chapters.

Social norm theory provides the lens for understanding how they influence eating behaviours. Social norms are defined as “unwritten codes and informal understandings that define what we expect of other people and what they expect of us” (Young, 2015), operating as context-dependent cues that guide what, how much, and how often people eat (Higgs, 2015). Social norms can be distinguished into descriptive norms (perceptions of what most people do) and injunctive norms (perceptions of what most people approve or disapprove), influencing food choices, intake quantities, preferences, and waste behaviours (Binder et al., 2019; Gumussoy & Rogers, 2023; Sharps et al., 2021). Their effects are moderated by multiple factors, including participant characteristics (age, gender), norm features (framing, majority/minority status), referent attributes (authority, similarity, familiarity), setting familiarity, delivery mode, and outcome observability (Lapinski & Rimal, 2005; Rhodes et al., 2020; Stok et al., 2016). These moderators explain the heterogeneous evidence on norm effectiveness, where norms are successful in some cases (Mollen et al., 2023) while in others they do not show results (Çoker et al., 2022). Chapter 1 systematically investigates these dimensions through a PRISMA literature review and a meta-analysis of the moderators. Additionally, social norm theory is deployed in Chapter 3 to design and test a social norm-based intervention in school canteens, highlighting the role of social norms in influencing children’s eating behaviour.

While social norm theory explains what kind of social information influences behaviour, it does not fully specify how these influences translate into actual behavioural outcomes. To address this, the present work integrates the Motivation-Opportunity-Ability (MOA) framework, which provides a structured lens to analyse how social norms interact with other behavioural drivers and are converted into action.

In this perspective, behavioural economics and the MOA framework are used to explain how norms translate into action and how different behavioural drivers interact with each other. Originally developed for consumer responses to communication (MacInnis et al., 1991), the MOA framework hypothesizes that behaviour emerges from the interplay of motivation (awareness, attitudes, social norms influencing personal consideration), ability (knowledge, skills enabling action), and opportunity (external resources, contextual constraints facilitating action) (Vittuari et al., 2021). In food contexts, norms primarily shape motivation, while food environments' characteristics (e.g., portion sizes, time pressure, observability) determine opportunity, and self-control affects ability. Interventions can target all three dimensions (e.g., social norm messages could increase motivation, smaller plates modify opportunity, co-design activities including educational elements increase ability) and reveal pathways where single nudges may trigger reactance (Brehm & Brehm, 1981) or compensating effects. This framework underlines the whole thesis, but it is particularly evident in Chapters 2 and 3. In Chapter 2, social norms messages and other behavioural drivers are investigated to explain sequential decisions leading from portioning to wasting outcomes in a simulated food service setting; in Chapter 3, results of a field social norm-based intervention are analyzed to determine its effectiveness in reducing vegetable waste in school canteens, alongside different food environment characteristics.

Finally, the behavioural approach is integrated into the agent-based model (ABM) analysis used in Chapter 2. Behavioural simulations via agent-based modelling allow the integration of micro and macro-levels by simulating emergent outcomes from heterogeneous agents (Macal & North, 2010). ABMs represent individuals with distinct motives, norms, and constraints interacting in shared environments, capturing feedback loops, compensatory dynamics, and non-linear effects that would not be observable in field studies (Bonabeau, 2002). In Chapter 2, the validated Establishment Diner ABM (Puga-Gonzalez et al., 2025) is used. It integrates the MOA and HUMAT (Jager et al., 2025) frameworks, allowing the simulation of decision-making processes as influenced by internal and external drivers. Through this ABM, 36 scenarios are simulated, resulting in the identification of different behavioural pathways and insights to design context-specific strategies to reduce FW in food service settings.

The theoretical and methodological frameworks used in this thesis interconnect: social norm theory identifies influence mechanisms and moderators; the MOA framework structures behavioural drivers analysis; ABM scenarios are used to simulate systemic interactions. This integration progresses from systematic evidence synthesis (Chapter 1, RQ1), to pathway exploration (Chapter 2, RQ2), to field implementation (Chapter 3, RQ3). This progression is depicted in Figure A.

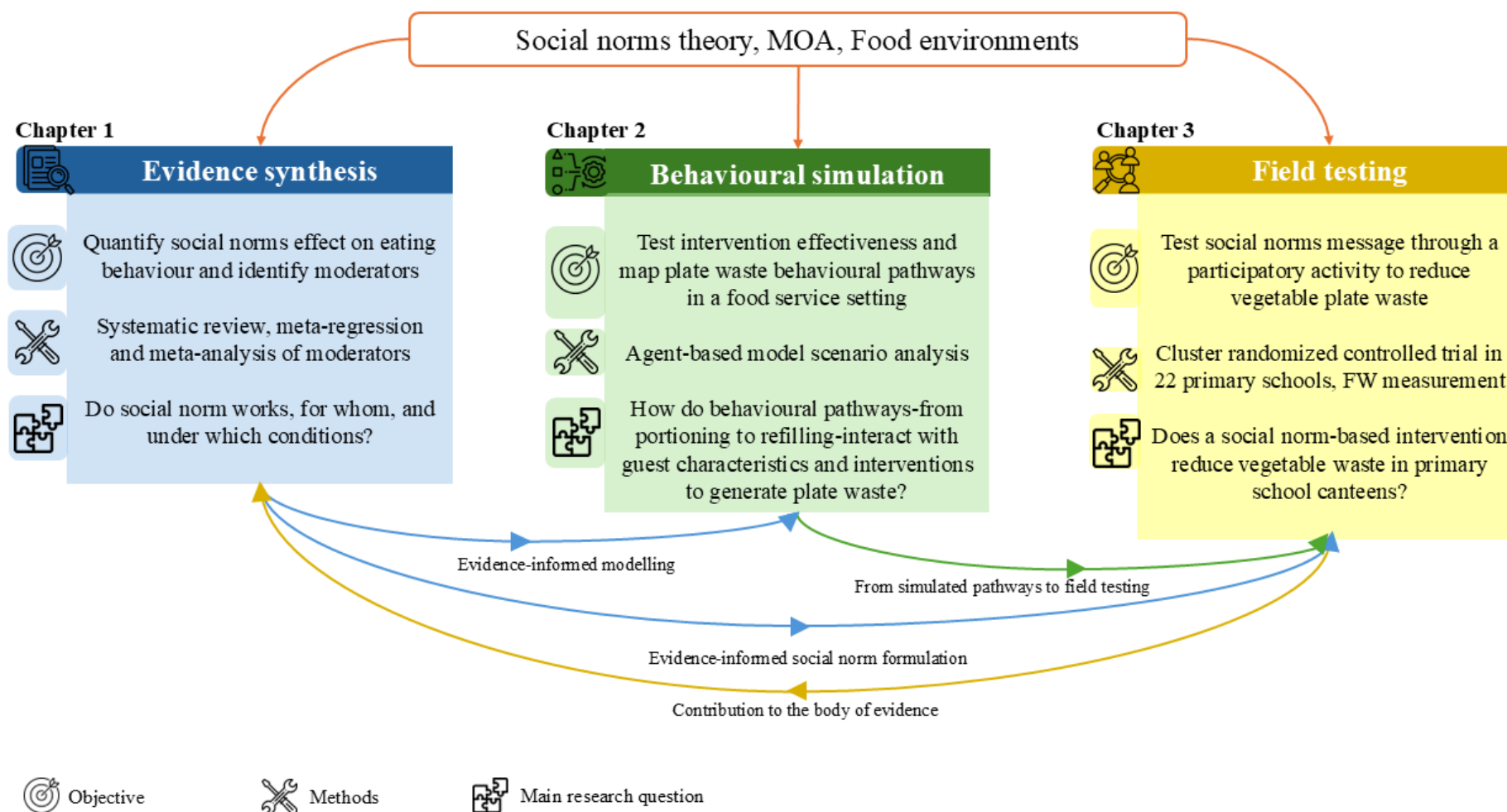


Figure A: Thesis structure with conceptual and methodological progression

Structure of the thesis

The thesis addresses the knowledge gaps described above through three interconnected studies that progress from conceptual synthesis to modelling and empirical testing. The thesis is organized as follows:

Chapter 1 – Framing the Influence of Eating Social Norms on Eating Behaviours: a Systematic Review and Meta-Analysis of Moderators. The first chapter presents a systematic review and meta-analysis of the influence of social norms on eating behaviours, quantifying their effects and identifying moderating conditions. This study adopts a dual methodological approach, using a semi-quantitative and quantitative approach to synthesize the results of 128 sign-and-significance effects and 88 quantitative effect sizes. These samples are analyzed to assess the overall effectiveness of social norms in influencing eating behaviours. This study also identifies key moderators related to participants, settings, and message characteristics that influence the likelihood and magnitude of social norms' influence on eating behaviours. Findings indicate that social norms exert a small but consistent positive effect. Additionally, they have stronger effects among younger individuals, when using proscriptive messages, and when coming from older referents. The chapter establishes the evidence base for the subsequent studies.

Chapter 2 – A Bite Too Much: Scenario-Based Analysis of Simulated Plate Waste Behaviour at a Hotel Breakfast Buffet. This chapter develops a scenario-based analysis using an agent-based model to analyse behavioural pathways and compensatory mechanisms underlying different intervention outcomes. Using the Establishment Diner ABM, the study simulates plate waste across 36 scenarios varying guest composition, sustainability awareness, plate size, and communication messages. The results reveal a behavioural pathway in which interventions interact with guest characteristics, often generating compensatory effects: for example, larger plates reduce refills but increase initial servings, resulting in limited net reductions in food waste.

Chapter 3 – Do Social Norms Shape Food Waste Behaviour in Primary School Canteens? Experimental Evidence from a Cluster Randomized Controlled Trial. The third chapter reports a large-scale randomized controlled trial of a social norm-based intervention in Italian primary school canteens. Building on the meta-analytic evidence presented in Chapter 1, the study tests whether a norm-based message, combined with a participatory poster co-design activity, can reduce vegetable plate waste in routine school catering settings. Conducted in 22 schools across the Emilia-Romagna region, the trial finds no evidence of an average reduction in vegetable plate waste attributable to the intervention. Instead, results highlight substantial heterogeneity across territorial contexts and short-lived, non-systematic responses. Beyond intervention effectiveness, the chapter contributes methodologically by providing one of the first large-scale field evaluations of social norm

interventions targeting children's eating behaviour, and institutionally by demonstrating the feasibility of implementing rigorous experimental designs and high-quality plate waste data collection within public school catering systems.

The three studies follow a methodological and conceptual progression. The thesis develops from knowing (meta-analysis) to understanding (simulated experiment) and testing (field experiment), connecting theoretical insights on social norms with practical implications for designing effective interventions targeting food-related choices from consumption to waste.

At the methodological level, this work demonstrates how combining meta-analysis, modelling, and field experimentation allows for a broader understanding of behavioural mechanisms. At the practical level, it offers evidence-based insights for policy design across food environments, highlighting when social norm interventions can be expected to work, for whom, and under which contextual conditions.

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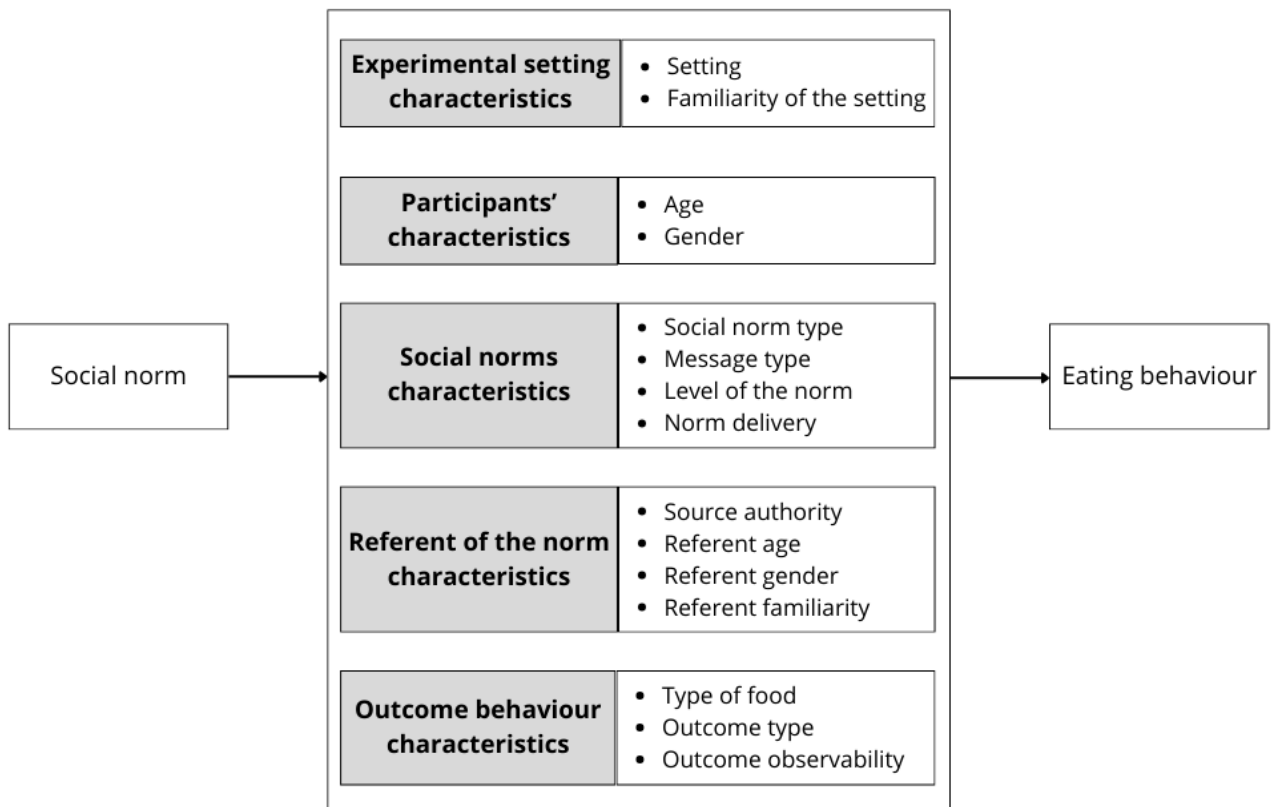
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Chapter 1

Framing the Influence of Eating Social Norms on Eating Behaviours: A Systematic Literature Review and Meta-Analysis of Moderators

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Moderators included in the meta-analysis

Framing the Influence of Eating Social Norms on Eating Behaviours: A Systematic Literature Review and Meta-Analysis of Moderators

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Abstract

Social influences play a crucial role in shaping what and how people eat. Intervening on social norms represents a relatively low-cost and scalable action to complement traditional public health interventions aimed at supporting healthier eating behaviours. Despite a growing research interest in the influence of social norms on eating behaviours, a comprehensive understanding of the conditions under which social norms are most effective is still needed. On this background, we aim to synthesize the effectiveness of social norms on eating behaviours and identify the factors that moderate this influence, by focusing on five categories of moderators: (1) experimental setting characteristics, (2) participants' characteristics, (3) social norm characteristics, (4) referent of the norm characteristics, (5) outcome behaviour characteristics. Through a PRISMA review and meta-analysis we selected 39 articles, comprising 51 studies and reporting 128 effects. Using regression models to examine the sign and significance of all effects, and meta-regression models for a quantitative sub-sample, we find that social norms have a moderate positive effect on changing eating behaviours in the desired direction. Among the investigated moderators, social norms show stronger effects for younger individuals, when framed as proscriptive messages, depicting the behaviour of a majority of individuals, referring to older peers as the normative source, and when behaviours are observable by others. The findings identify actionable levers to enhance the employment of social norms, offering policymakers and practitioners insights to promote healthier eating behaviours.

Keywords

Social influence, Food intake, Behavioural change, Systematic review, Meta-analysis, Norm framing, Moderators

1.1 Introduction

Promoting healthy eating behaviours, intended as dietary practices that promote health and prevent disease (WHO & FAO, 2024), plays a crucial role in achieving multiple international policy targets simultaneously. What and how people eat has in fact significant potential to progress towards specific goals of Agenda 2030 (Grosso et al., 2020), such as SDG2 (zero hunger) and SDG3 (good health and well-being), as well as towards aspirations of the international legacy of the Milan Urban Food Policy Pact (MUFPP) on promoting better consumption habits (action 7) (FAO, 2019; Milan Urban Food Policy Pact, 2015). Yet, current dietary patterns fall far from these aspirations, with a rapidly growing share of the population experiencing overweight and obesity (WHO, 2020), insufficient consumption of fruits, vegetables and whole grains, and increasing intakes of red and processed meat (Micha et al., 2015), free sugars (Gillespie et al., 2023), and ultra-processed foods (Baker et al., 2020), all of which exacerbate the burden of noncommunicable diseases (NCDs) (Jannasch et al., 2024).

This evidence makes it both urgent and essential for policymakers to identify which factors are more effective in facilitating the adoption of healthier eating behaviours across different population groups (Gorsky & Roberto, 2015).

Following the political impulse, the attention of the scientific community has increasingly focused on the influence of the social eating context on individuals' eating habits (Higgs et al., 2019). In each social context, the influence of other people plays a key role in individuals' decisions about food, via the so-called social norms. Social norms are intended as “unwritten codes and informal understandings that define what we expect from other people and what they expect of us” (Young, 2015). More specifically, social norms related to eating behaviours, also called eating social norms, are perceived standards indicating the appropriate consumption amount and/or food choice for individuals (Higgs, 2015). Eating social norms may influence the quantity and frequency of food consumption (Sharps et al., 2021), the choice related to healthy or unhealthy food options (Binder et al., 2019), the liking of specific foods (Zandstra et al., 2017), or even the decision to consume novel food products (Gumussoy & Rogers, 2023). Two main categories of (eating) social norms exist: descriptive ones, related to the perceptions of what most people do, and injunctive ones, referring to the perception of what most people approve or disapprove (Cialdini et al., 1991). The influence of (eating) social norms on individuals is moderated by different factors, called moderators. Moderators (e.g., participants' characteristics, contextual elements, message framing) can interact with how the norm is perceived, influencing the direction and strength of social norms' effect on eating behaviours (Stok et al., 2016). Understanding when and how social norms influence eating behaviours is

therefore essential for advancing theoretical knowledge and for informing their potential employment in shaping food-related decisions.

Despite the increasing academic interest in eating social norms (Higgs et al., 2019), a lack of scientific consensus emerged on the proven effectiveness of such norms in influencing individuals' eating behaviours. Howland et al. (2012) show that eating social norms influence eating behaviour within established friendships, revealing that individuals adjust their consumption patterns in response to the eating behaviours of friends. Also, Mollen et al. (2023) found evidence that perceptions of other people on the frequency and quantity of food to be eaten can influence the eating choices of individuals in the short term. Interestingly, Templeton et al. (2016) documented that individuals exposed to a healthy social norm reported lower preferences for unhealthy foods, a difference that persisted for three days, but this manipulation did not affect immediate eating behaviour. However, no influence of eating social norms on eating behaviours is found in studies investigating, for example, the influence of social norms on the choice of plant-based meals (Çoker et al., 2022) or on young women's food intake (Hermans et al., 2012). These conflicting results raise questions about why social norms succeed in shaping behaviour in some cases and fail to do so in others.

To navigate the labyrinth of results, various systematic and non-systematic reviews have compared the effects of eating social norms on eating behaviours in different settings (see Table 1.1). Of these, only three out of eight (Robinson et al., 2014; Ruddock et al., 2019; Stok et al., 2016) adopted a systematic approach, with two of them only (Robinson et al., 2014; Ruddock et al., 2019) following the Preferred Reporting Items for Systematic Review (PRISMA). Articles analyzed in previous reviews range from 1974 to 2019. The type of analysis conducted for assessing the influence of social norms on eating behaviours differs, with most of the reviews using qualitative methods and only Robinson et al. (2014) and Ruddock et al. (2019) using quantitative ones. Quantitative methods, when compared to qualitative techniques, provide a more systematic way of synthesizing evidence, allowing for the estimation of the magnitude of effects. Most reviews take into consideration descriptive social norms only, leaving injunctive ones apart. Stok et al. (2016) take into consideration both types of norms, but their field of investigation is restricted to adolescents' and young adults' behaviours, falling short in providing results for adult samples. Previous reviews recognize that the effects of social norms are influenced by different moderators, but they mostly address these factors qualitatively. Only Vartanian et al. (2015), with a non-systematic review focusing only on descriptive norms, examine moderators quantitatively, although with a limited analytical scope. In synthesis, no systematic reviews quantitatively investigating the influence of social norms and the role of moderators exist up to now.

Table 1.1: Existing review articles on the effect of social norms on eating behaviours

Article	Type of data collection	Temporal scope	Content scope	Both descriptive and injunctive norms	Quantitative analysis	Moderators analysis	Population considered
Robinson et al. (2013)	Non-systematic	Not reported	Social modelling of intake and food choice	No	No	Qualitative	All
Robinson et al. (2014)	Systematic	2001-2013	Social norms' influence on food choices and intake and moderating and mediating factors	No	No (for food choice), Yes (for food intake)	Qualitative	All
Cruwys et al. (2015)	Non-systematic	1974-2014	Social modelling of food choices and intake	No	No	Qualitative	All
Higgs (2015)	Non-systematic	Not reported	Reasons for following eating social norms and their influence on eating behaviours	Yes	No	Qualitative	All
Vartanian et al. (2015)	Non-systematic	2005-2013	Social modelling of food intake and moderating factors	No	Yes	Quantitative	All
Higgs & Thomas (2016)	Non-systematic	Not reported	Social norms' influence towards healthy diets	No	No	Qualitative	All
Stok et al. (2016)	Systematic	1996-2015	Peer social norms' influence on young people eating behaviour and moderating factors	Yes	No	Qualitative	Adolescents and young adults
Ruddock et al. (2019)	Systematic Non-systematic	1985-2019	Social facilitation of eating and moderating factors	No	Yes	Qualitative	All
This research	Systematic	2000-2025	Social norms' influence on eating behaviours and moderating factors	Yes	Yes	Quantitative	All

Building on and extending the scope of previous literature synthesis, the present review takes a broader scope, systematically examining the influence of social norms on eating behaviours and the role of moderating factors in amplifying or reducing this influence. Specifically, the work advances on previous literature by (i) extending the scope of similar reviews (see Table 1.1) to all age groups, including both children and adults, (ii) applying quantitative and semi-quantitative methods to the analysis of the effects of the norms and role of moderators, and (iii) incorporating research up to 2025. The PRISMA method is adopted for selecting the final set of studies, providing a structured method to identify the articles included in the review. Based on these studies, we provide the first such examination considering the role of five categories of moderators. Namely: (1) experimental setting characteristics, (2) participants' characteristics, (3) social norm characteristics, (4) referent of the norm characteristics, (5) outcome behaviour characteristics.

To investigate the effect of social norms on eating behaviours we set our first research question on the sub-sample of studies providing quantitative effects of social norms on eating behaviour, as follows:

- RQ1 – What is the effect of social norms in influencing eating behaviours?

Next, we investigate the importance of different moderators in enhancing or decreasing this influence via an additional research question:

- RQ2 - Which moderators influence the (a) likelihood and the (b) magnitude that social norms successfully guide eating behaviours in the intended direction?

Given the wide variety of study designs and outcomes measured in the reviewed studies, we assess RQ2 on two levels. For RQ2a, we include all collected studies and implement a semi-quantitative analysis as suggested by Card et al. (2018), while for RQ2b, the sub-sample of studies providing quantitative effects only is used.

1.2 Methods and materials

1.2.1 Sample construction

The systematic review identified the studies via the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021). The process is presented in the flow diagram of Figure 1.1.

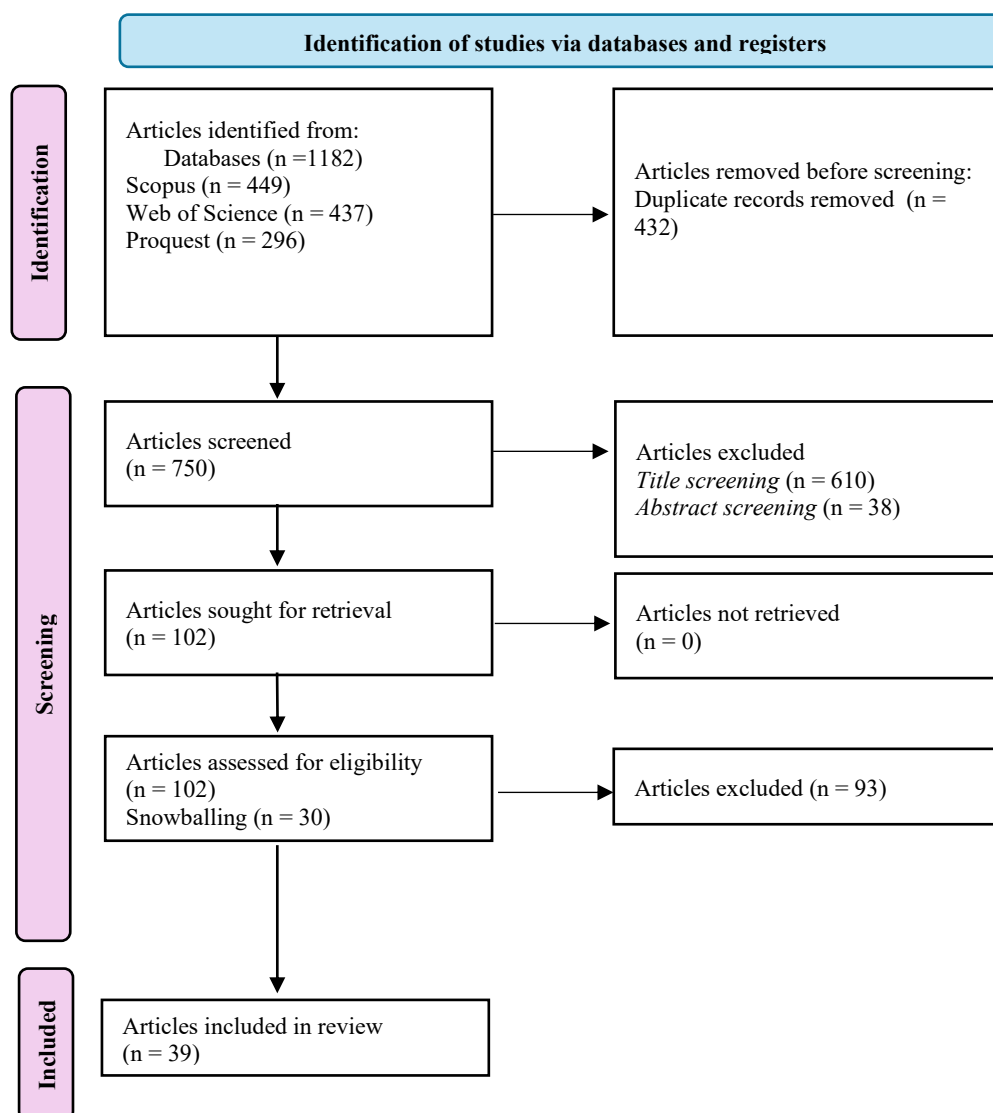


Figure 1.1: PRISMA 2020 flow diagram

Three databases, namely Scopus, ProQuest, and Web of Science, were searched up until the end of April 2025, as they are deemed to ensure comprehensive coverage of high-quality academic sources, reducing selection bias. The search was restricted to research papers published in English, as it represents the international standard for scientific literature and facilitates interpretation (Table 1.2, C1). The search query aimed to collect studies on food-related behaviours in eating contexts, such as food choice, intake, or waste, and social norms, either descriptive or injunctive (C2). Studies focusing on disordered eating, feeding practices, or food purchasing behaviours were not considered relevant despite belonging to the field of investigation, and therefore appropriate terms were added to the string for excluding them (C2). These behaviours involve different psychological mechanisms or external constraints, which could confound the effects of social norms on typical eating behaviour. Only studies with human participants were searched, excluding clinical populations or animals, to

ensure the relevance of findings to general eating behaviour (C3). Only peer-reviewed full-length papers were included (C4, C5) to ensure the quality and reliability of the studies considered. The search query (Supplementary Table I.A) yielded 1182 articles. Results were uploaded in the free web application Rayyan (Ouzzani et al., 2016) to organize and manage the review of such a large sample of articles. 432 duplicates were detected and deleted, then a total of 750 records were screened according to title and abstract, following the inclusion and exclusion criteria listed in Table 1.2. Studies were excluded if not aligned with the search query (C1-C5). Experimental studies with a non-treated control group were included to allow for causal inference, while observational studies, computer simulations, or experiments without a non-treated control group were excluded (C6). Outcomes were restricted to actual behaviour or behavioural intentions regarding eating, to directly capture the influence of social norms (C7). To ensure quality, only peer-reviewed research papers reporting primary data were included, while reviews, commentaries, theses, and grey literature were excluded. 648 articles were excluded as a result of this step.

The full texts of 102 articles were retrieved and assessed against the inclusion and exclusion criteria, leaving 29 articles. Following Robinson et al. (2014), we supplemented the databases search with a revision of the reference sections of the included articles to improve the coverage of the review. This step led to the inclusion of 10 additional articles, defining a final corpus of 39 articles. The list of included articles is available in Supplementary Table I.B.

Table 1.2: Inclusion and Exclusion criteria for articles' eligibility

Criteria	#	Inclusion	Exclusion
Language	C1	English	Other languages
Relevance (Topic)	C2	Food-related behaviours in eating settings: food choice, food intake, food waste	Behaviours related to disordered eating, feeding practices, dieting, or food purchase
Population	C3	Human participants	Non-human populations; Clinical populations (e.g., eating disorders); Special populations (e.g., cancer survivors, athletes, pregnant women)
Publication type	C4	Research papers	Editorials, comments, reviews, books/chapters, conference papers, grey literature, theses/dissertations
Revision process / Quality	C5	Peer-reviewed	Not peer-reviewed
Study design	C6	Experimental studies with a non-treated control group and manipulating an eating social norm	Observational studies; Experimental studies without non-treated control group; Computer simulations (ABMs, cellular automata)
Outcome measures	C7	Actual behaviour or behavioural intentions regarding food choice, intake, or waste; Data sufficient to calculate the influence of social norms	Outcomes not related to actual behaviour or behavioural intentions
Social norms specification	C8	Explicit investigation of social norms (descriptive or injunctive)	Studies that do not specify the type of social norm; Studies on modeling/peer pressure without explicit reference to social norms

1.2.2 Data extraction

Based on the final set of 39 articles, data were extracted and organized following three steps.

Step 1: Moderators' selection

To select moderators, we followed a mixed deductive/inductive approach (Villiger et al., 2021). Potential moderators were initially identified through a review of previous literature on social norms and eating behaviours. Specifically, we started from the list of moderators reported in the systematic and non-systematic reviews summarized in Table 1.1 and integrated it with moderators extracted from three meta-analyses considered as gold standards (Chen et al., 2024; Melnyk et al., 2022; Rhodes et al., 2020). From the full list of moderators extracted from the literature, we retained only those for which information was consistently available across all studies included in our dataset. This selection process ensured that each moderator could be systematically coded and statistically analyzed in the subsequent meta-regression. The final set of moderators is summarized in Figure 1.2. The theoretical rationale for each moderator included is presented in the Supplementary Materials (Section I.1). Table 1.3 shows the coding scheme for the moderators included in the meta-regression model.

Table 1.3: Coding scheme for the moderators included in the meta-analysis

Category	Variable	Description	Code
Experimental setting characteristics	Field	Experiment conducted in a real-world or naturalistic setting (e.g., restaurant, cafeteria)	Dummy. 1= yes; 0 = otherwise
	Laboratory	Experiment conducted in a laboratory or non-eating setting (e.g., classroom)	Dummy. 1= yes; 0 = otherwise
	Online	Experiment conducted online	Dummy. 1= yes; 0 = otherwise
	Low Familiarity Setting	Experiment conducted in an unfamiliar setting for participants (e.g., laboratory)	Dummy. 1= yes; 0 = otherwise
	Medium Familiarity Setting	Experiment conducted in a setting already known/attended by participants (e.g., classroom, restaurant)	Dummy. 1= yes; 0 = otherwise
Participants' characteristics	Children	Participants were children under 12 years old	Dummy. 1= yes; 0 = otherwise
	Adolescents	Participants were adolescents under 18 years old	Dummy. 1= yes; 0 = otherwise
	Young Adults	Participants were young adults under 26 years old	Dummy. 1= yes; 0 = otherwise
	Adults	Participants were adults above 26 years old	Dummy. 1= yes; 0 = otherwise
	Male	Sample composed of more than 80% males	Dummy. 1= yes; 0 = otherwise
	Female	Sample composed of more than 80% females	Dummy. 1= yes; 0 = otherwise
	Mixed	Sample composed of mixed gender participants	Dummy. 1= yes; 0 = otherwise
Social norm characteristics	Social Norm Type	Type of norm: descriptive (i.e. the message describes the behaviour of others, or there is a confederate present) or injunctive (i.e. the message describes what is approved/suggested by others)	Dummy. 1 = descriptive; 0 = injunctive
	Message Type	Type of message: prescriptive (the social norm describes what is done or what should be done) or proscriptive (the social norm describes what others refrain from doing or what should be avoided)	Dummy. 1 = prescriptive; 0 = proscriptive
	Level of the Norm	Reference group: minority (e.g., "30% of students eat sufficient vegetables") or majority (e.g., 70% of Australians are trying to reduce meat consumption, or a confederate is present)	Dummy. 1 = minority; 0 = majority
	Norm Delivery	Mode of delivery: physical, the norm is communicated in-person or through real-world interaction. Includes oral communication, live observation, or written signs in a real-life context. Example: a teacher telling children what others eat, or participants observing confederates eating; or virtual, the norm is communicated virtually or remotely, such as in online surveys, videos, digital text, or through remote confederates. Example: norm shown via screen, written text in a survey.	Dummy. 1= physical; 0 = virtual
Referent of the norm characteristics	Source Authority	Norm referent has authority (e.g., teacher) or does not have authority on the participants.	Dummy. 1= referent with authority; 0 = peer
	Referent Age	Norm referent is of similar age as participants	Dummy. 1= yes; 0=otherwise
	Referent Gender	Norm referent is of same gender as participants	Dummy. 1= yes; 0=otherwise
	Referent Familiarity	Participants already knew the norm referent before the experiment (classmate, teacher, friend)	Dummy. 1= yes; 0 = otherwise
Outcome behaviour characteristics	Healthy Food	Outcome measured with healthy food (fruit, vegetables, cereals, salads, low-energy snacks).	Dummy. 1= yes; 0 = otherwise
	Unhealthy Food	Outcome measured with unhealthy food (energy-dense snacks, meat, pizza).	Dummy. 1= yes; 0 = otherwise
	Other Food	Outcome measured with other foods (insects, pasta, bread, mixed foods).	Dummy. 1= yes; 0 = otherwise
	Outcome Type	The investigated behaviour is an actual behaviour or an intended one.	Dummy. 1= actual behaviour; 0 = intended behaviour
	Outcome Observability	Participants' behaviour was observed during the experiment or participants acted in anonymity (e.g., online survey) or they were not observed by others during the experiment	Dummy. 1= observable behaviours; 0 = behaviour not observable

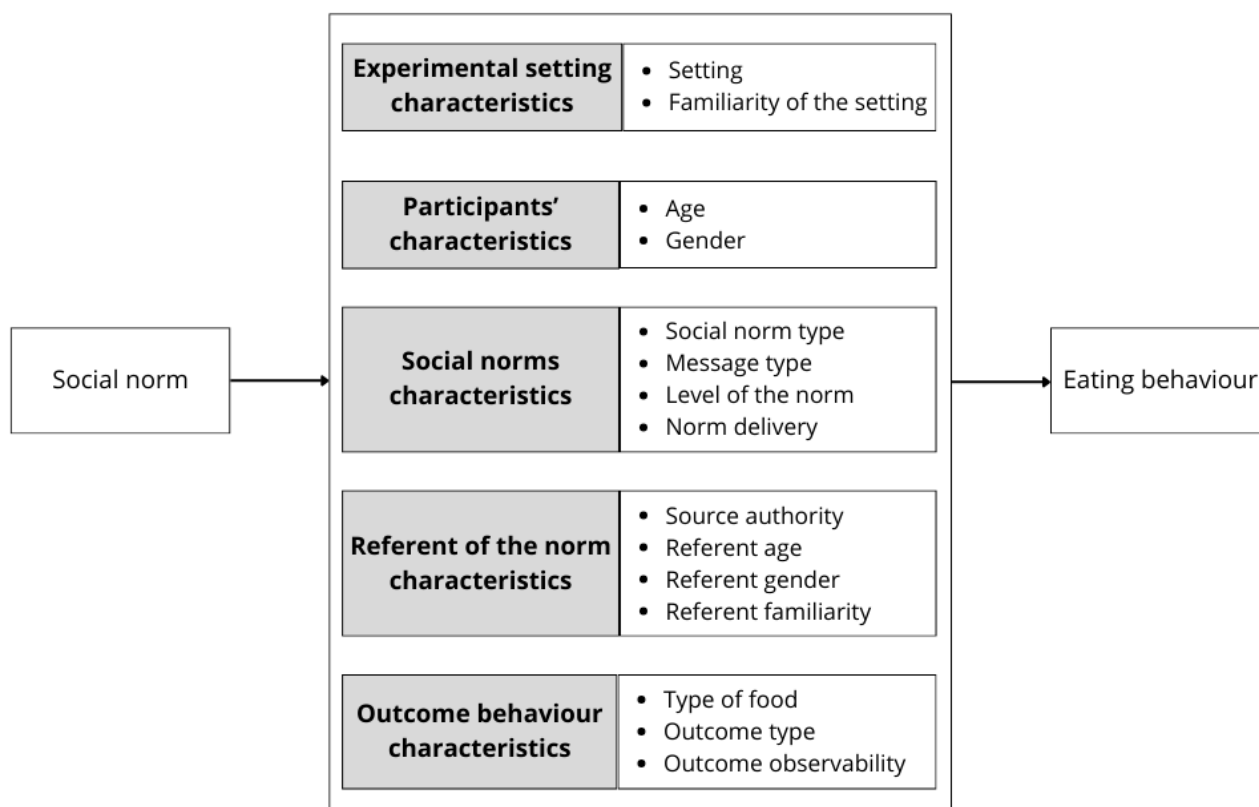


Figure 1.2: Moderators included in the meta-analysis

Step 2: Data extraction

Data were extracted from each publication and collected into a standardized spreadsheet (using Microsoft Excel). Extracted data were classified according to seven main categories: bibliographic information; experimental setting characteristics; participants' characteristics; social norms characteristics; social norm referents' characteristics; outcome behaviour characteristics; and social norms' effect on the outcome variable. Extracted data were then coded in a standardized format, following a metadata and coding scheme (available in the Supplementary Table I.C). In cases where a single article included more case studies, data from each case study was extracted. The coding process followed an iterative process, as suggested by Villiger et al. (2021). An excerpt of the standardized spreadsheet used to extract data from publications is available in the Supplementary Table I.D.

Step 3: Effect size extraction

To analyze the impact of social norms on eating behaviours, a two-step approach was implemented. First, for all collected studies we classified each effect reported according to the direction and significance of the relation between social norms and eating behaviours, following Card et al. (2018). This is because the variety of study designs, outcome variables, effect size calculation methods, and

data availability made it impossible to have a ready-to-compare effect size. Specifically, based on the nature of each effect, we categorized them as follows:

- Positive: if the effect estimated was greater than 0 and statistically significant ($p < 0.05$), coded as +1. In such cases, the behavioural change goes in the direction suggested by the norm.
- Negative: if the effect estimated was less than 0 and statistically significant ($p < 0.05$), coded as -1. In such cases, the behavioural change is in the opposite direction of the norm's goal.
- Not statistically significant: if the estimated impact did not meet the criteria mentioned above, coded as 0.

For studies reporting separate effect estimates for different experimental groups, or on different food types or behavioural outcomes (e.g., effects on food choice, on food intake), we coded them separately. For example, Burger et al. (2010) presented two studies, from which we extracted four effects since each study comprised two treated groups and one control group. The resulting dataset was utilized to address RQ2a.

Second, we selected only the sub-sample of studies providing quantitative measures of the effects of social norms on eating behaviours. We extracted the quantitative effect sizes and converted them, selecting the most feasible conversion according to the available data and obtaining the mean effect sizes, the confidence intervals, and the standard errors. Whenever possible, we converted different effect sizes to *g*-effect sizes for analysis. Hedges' *g* is a standardized mean difference measure to compare a treatment and a control group using the difference between their means and standard deviations, commonly employed in meta-analysis when combining results from studies with different sample sizes (Lipsey & Wilson, 2000). Hedges' *g* was selected for our study as it statistically corrects for variance that may be introduced by studies with small sample sizes (Hedges, 1981). To calculate and convert effect sizes, we used the Practical Meta-Analysis Effect Size Calculator (Wilson, 2023). Effect size outliers were excluded from the subsample to ensure the robustness of our analyses. The resulting dataset was employed to address RQ1 and RQ2b.

1.2.3 Data analysis and meta-analytic model

To offer a preliminary overview of the full sample and the sub-sample, we performed descriptive analyses to show the distribution and main characteristics of the included observations (e.g., publication year, geographical distribution, sample composition).

Before conducting analyses, we assessed potential publication bias using a funnel plot (Sterne & Harbord, 2004) to evaluate whether the results might be influenced by selective publication of statistically significant findings. Then, to answer RQ1, we estimate the overall grand mean effect size and assess heterogeneity using Cochran's *Q* statistic and the *I*² index (Higgins et al., 2003) to quantify

variability across studies. To do so, we fit a multi-level meta-analytic model (Eq. 1.1). By specifying a study-level intercept, we allow for the dependence of multiple effect sizes extracted from the same study. The model is estimated using Restricted Maximum Likelihood (REML).

(1.1)

$$EffectSize_{is}^{sub\ sample} = \beta_0 + u_s + \varepsilon_{is}$$

where:

- i is the effect (e.g., each observation extracted from a study),
- s is the study from which each effect is drawn,
- u_s is a study-level random intercept capturing the dependence of multiple effects extracted from the same study,
- ε_{is} is the sampling error associated with each effect size.

We assessed the influence of individual studies using leave-one-out analyses, Cook's distance, and covratio statistics, following standard diagnostic procedures for meta-analytic models (Viechtbauer, 2020).

We also conducted subgroup analyses to obtain descriptive estimates of the effects of social norms within key study characteristics (i.e., moderators). Specifically, we estimated the same multilevel random-effects meta-analytic model (Eq. 1.1) separately for each level of the moderators. These analyses provide a descriptive overview of effect size magnitudes across subgroups but do not constitute formal statistical tests of between-group differences. To formally test whether differences between subgroups were statistically significant, we then ran a series of single-predictor mixed-effects meta-regressions, introducing each moderator individually into the model¹ (Borenstein et al., 2021).

To answer RQ2a on the full sample, we estimated a multiple linear regression model, following the approach proposed by Card et al. (2018). Eq. 1.2 explores the factors associated with the direction and statistical significance of the effects of social norms on eating behaviours, thus allowing us to assess which moderators increase or decrease such likelihood. The dependent variable is a three-level categorical outcome reflecting each study's reported effect (positive, non-significant, or negative). For estimation purposes, it was treated as a numerically coded variable in the linear regression model. Because several articles reported multiple effect sizes (e.g., for different outcomes or subgroups), we allow statistical dependency of observations within the same study (examples can be found in Supplementary Table I.D). To account for this structure of the data, as the effects are nested within

¹ Each single-predictor meta-regression corresponds to a simplified version of the mixed-effects model reported in Eq. 1.3, including one moderator at a time: $EffectSize_{is}^{subsample} = \beta_0 + X_{is} + u_s + \varepsilon_{is}$.

studies, we included the clustered standard errors in the model. Following Angrist & Pischke (2008), the clustered variance estimator is consistent as the number of studies gets large under any within-group correlation structure and not just in the parametric random effect model. To account for differences in statistical power across studies, we weighed observations by their sample size. Larger studies provide more precise estimates of the effect, while smaller studies are more prone to random variation. Weighting by sample size ensures that more reliable evidence has greater influence on the estimated coefficients (Borenstein et al., 2021).

(1.2)

$$EffectCategory_{is}^{full\ sample} = \beta_0 + \sum_{k=1}^{25} \beta_k X_{kis} + \varepsilon_{is}$$

where:

- i is the effect (e.g., each observation extracted from a study),
- s is the study from which each effect is drawn,
- X_{kis} is the value of the k^{th} moderator (ranging from 1 to 25) for effect i in study s ,
- β_k are the estimated coefficients for each moderator,
- ε_{is} is the error term, assumed to be correlated within studies and adjusted using clustered standard errors at the study level.

Following Card et al. (2018), we performed a robustness check by replicating this model on the sub-sample of studies reporting quantitative effect sizes, again using the Effect Category as the dependent variable. This additional model allows a direct comparison between the full sample and the sub-sample and provides a robustness check of whether the determinants of effect sign and significance remain consistent when restricting the sample.

To address RQ2b on the sub-sample of studies providing quantitative effect sizes, we employed a mixed-effects meta-regression model using the *metafor* package in RStudio (Eq. 1.3). Effect sizes and their variances are the dependent variable and weights, respectively. Because multiple effects were extracted from the same study, we specified a random intercept at the study level (random = ~1 | study_id), modelling within-study dependence and between-study heterogeneity (Kadlec et al., 2022).

(1.3)

$$EffectSize_{is}^{subsample} = \beta_0 + \sum_{k=1}^{25} \beta_k X_{kis} + u_s + \varepsilon_{is}$$

where:

- u_s is a study-level random intercept capturing the dependence of multiple effects extracted from the same study,
- ε_{is} is the sampling error associated with each effect size.

The model was estimated using Restricted Maximum Likelihood (REML). To avoid influences of unstable moderators with few observations, we estimated the main model by removing moderators with fewer than 10 observations. A second meta-regression model, including moderators with fewer than 10 observations was estimated as a robustness check. All analyses were conducted in RStudio (Version 2025.05.1).

1.3 Results

1.3.1 Overview of the sample

From the literature review, we identified 39 studies analyzing the effectiveness of social norms to influence eating behaviours. The interest in the influence of social norms on eating behaviour increased during the past decades, with an average cumulative increase of 20% per year between 2000 and 2024 (Figure 1.3).

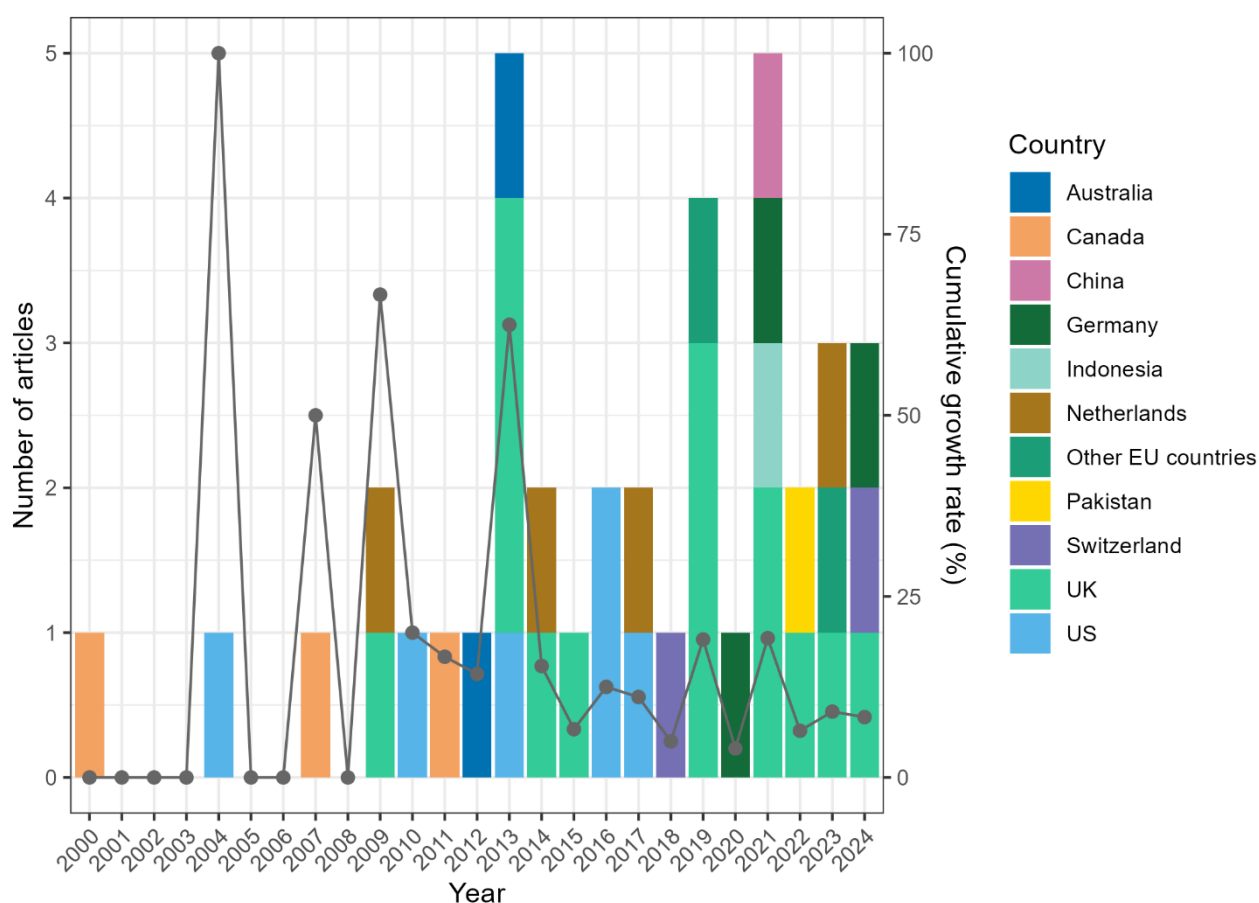


Figure 1.3: Number of articles per publication year by country and cumulative growth rate (Full sample)

The majority of articles conducted analysis in Europe (64.1%) and in North America (23.1%), with 12.9% of studies from other countries (Figure 1.3).

Table 1.4 reports the main descriptive information of the studies included in the analysis. Our full sample includes 128 effects, extracted from 51 separate studies presented in 39 scientific articles, while the sub-sample includes 88 effects², extracted from 38 studies coming from 29 articles.

² 95 quantitative effect sizes were extracted, 90 of which expressed as Hedges' g . Checking for outliers, following the conventional $1.5 \times \text{IQR}$ rule (Tukey, 1977), 2 observations were identified as statistical outliers (boxplot available in Supplementary Figure I.A). These outliers were excluded from the sub-sample used for subsequent analyses in order to reduce the influence of extreme values on the estimates, leaving us with a sub-sample of 88 effects.

Table 1.4: Description of the full sample and sub-sample of effect sizes included in the meta-analysis

	Full sample (128 sign and significance of effects)	Sub-sample (88 estimated effects)
Number of articles	39	29
Number of studies	51	38
Number of effects (sign and significance)	128	88
Type of setting		
Laboratory/Non-eating context (classroom)	92 (71.9%)	62 (70.5%)
Eating context (restaurant, canteen)	13 (10.2%)	5 (5.7%)
Online	23 (18%)	21 (23.9%)
Sample sizes		
Mean (Standard deviation)	139 (185)	123 (124)
Median	80	79
Min-Max	21-1711	21-570
Quartile 1	50	49.5
Quartile 3	170	135
Number of effects by Age of participants		
Children (<12y/o)	15 (11.7%)	11 (12.5%)
Adolescents (<18y/o)	11 (8.6%)	2 (2.3%)
Young adults (<26y/o)	85 (66.4%)	60 (68.2%)
Adults (>26y/o)	17 (13.3%)	15 (17%)
Number of effects by Gender of participants		
Mostly female (>80%)	60 (46.9%)	46 (52.3%)
Mostly male (>80%)	1 (0.8%)	1 (1.1%)
Mixed group	67 (52.3%)	41 (46.6%)
Social norm type communicated in the experiment		
Experimental group received a descriptive norm	104 (81.2%)	71 (80.7%)
Experimental group received an injunctive norm	24 (18.8%)	17 (19.3%)
Social norm referent		
Peer	104 (81.2%)	68 (77.3%)
Teacher	6 (4.7%)	3 (3.4%)
General referent	18 (14.1%)	17 (19.3%)
Type of outcome		
Intention	34 (26.6%)	26 (29.5%)
Behaviour	94 (73.4%)	62 (70.5%)
Observability of the outcome behaviour		
Observable (experiment conducted in the presence of researcher or other persons)	69 (53.9%)	42 (47.7%)
Not observable (self-reported behaviour, or experiment conducted without the presence of other persons)	59 (46.1%)	46 (52.3%)
Outcome behaviour of interest		
Intake (grams)	69 (53.9%)	50 (56.8%)
Choice (selection of one food type over another)	47 (36.7%)	27 (30.7%)
Liking (rating)	4 (3.1%)	4 (4.5%)
Preference	4 (3.1%)	4 (4.5%)
Food waste (grams of plate waste)	3 (2.3%)	3 (3.4%)
Portion size (selection of a portion size over another)	1 (0.8%)	/
Food type employed to measure the outcome behaviour		
Unhealthy food	53 (41.4%)	34 (38.6%)
Healthy food	69 (53.9%)	48 (54.5%)
Other food	6 (4.7%)	6 (6.8%)
Sign and significance effect categories		
Non significant (0)	86 (67.2%)	57 (64.8%)
Significant, negative effect (-1)	2 (1.6%)	1 (1.1%)
Significant, positive effect (1)	40 (31.2%)	30 (34.1%)

Most of the studies investigate the effect of social norms on eating behaviours in controlled settings such as laboratories and non-eating contexts, while a minority were implemented through field experiments in eating contexts, or online. Sample sizes show wide variability (21–1711 participants; IQR 50–170), suggesting heterogeneous statistical power across effects. The most targeted

participants are young adults between 19 and 26 years, followed by adults, children, and adolescents. Males are rarely targeted in isolation, while samples exclusively composed of females are more frequent. Around half of the effects are reported for groups of mixed gender. For this reason, the male moderator is excluded from the analysis as it is not sufficiently present in our sample.

Descriptive social norms are more often employed, and around 80% of the effects involve a peer norm, meaning that the norm is conveyed by individuals who do not hold an authoritative role over the participants. This indicates that, in most studies, the social influence stems from peers, such as classmates or fellow students, rather than authority figures like teachers. In relation to the type of outcome, most of the effects are about actual behaviours, while a minority are estimated on intentions. The outcome behaviours are observable by other participants or by researchers in about half of the sampled effects, while in the other half of the cases participants act in anonymity, either through self-reporting the outcome behaviour or left alone while performing the task.

The relative majority of effects are estimated on the variation in the intake of a certain food, meaning the variation in grams or portions of food consumed, or intended to be consumed, by participants. The largest share of effects examines changes in the intake or choice of healthy foods, including fruit, vegetables, and items like low-energy-dense cereal bars or low-sugar cookies. Another large share of effects is related to unhealthy foods, while the remaining is related to other food items. Looking at the distribution of effect sizes according to the three categories based on sign and significance, the majority of the effects are not significant, while 31.2% capture a significant positive effect on the outcome variable (i.e., the outcome behaviour changed in the desired direction) and just two effects suggest a discordance among the social norm and the outcome behaviour.

When comparing the full sample and the sub-sample, the two datasets show similarities in their overall composition. The distribution across experimental settings, participants' age groups, gender composition, and type of social norm is consistent between the two samples. However, some differences can be observed. The sub-sample includes a slightly larger proportion of online studies (23.9% versus 18%), while field studies conducted in eating contexts are less represented (5.7% versus 10.2%). Experiments involving adolescents are only 2. For this reason, subsequent analyses will not include adolescents as a moderating variable. Additionally, the sub-sample presents a slightly higher proportion of statistically significant effects (35.2% versus 32.8%), indicating that studies providing quantitative estimates might be more likely to report significant results.

1.3.2 Overall effect of social norms on eating behaviours

Visual inspection of the funnel plot (Supplementary Figure I.B) suggests no clear indication of publication bias, although this assessment is exploratory. To answer RQ1, we present the grand mean

effect size in our sub-sample resulting from Eq. 1.1. Social norms show a significant positive small-to-medium effect on eating behaviours. The meta-analytic model yields a grand mean effect size of $g = 0.273$ ($SE = 0.044$, $p < .0001$; 95% CI [0.19, 0.358]). The sub-sample shows high heterogeneity, with the Q-statistic (275.895) being statistically significant ($p < .0001$) (Borenstein et al., 2021). The I^2 statistic, which quantifies the proportion of variance related to real differences between studies rather than chance, is 38.46%, suggesting moderate heterogeneity. These results suggest that examining potential moderators through a meta-regression could help identifying sources of heterogeneity.

Influence diagnostics indicated that no single study has an extreme influence on the pooled effect size. Leave-one-out analyses showed that the overall estimate remained stable when each study was removed in turn, and no influential cases were identified based on Cook's distance or covratio statistics (Supplementary Figure I.C-E; Supplementary Table I.E). To further assess robustness, we conducted a sensitivity analysis excluding Hang et al. (2020), which exhibited moderately extreme values in the influence diagnostics. A small reduction in the overall effect size (from 0.273 to 0.245) and a significant decrease in between-study heterogeneity (τ^2 decreased from 0.045 to 0.032) are observed, yet the effect remains statistically significant (Supplementary Table I.F). We conclude that the grand mean effect size is robust to outliers.

Figure 1.4 shows the forest plot of all effect sizes included in the meta-analysis.

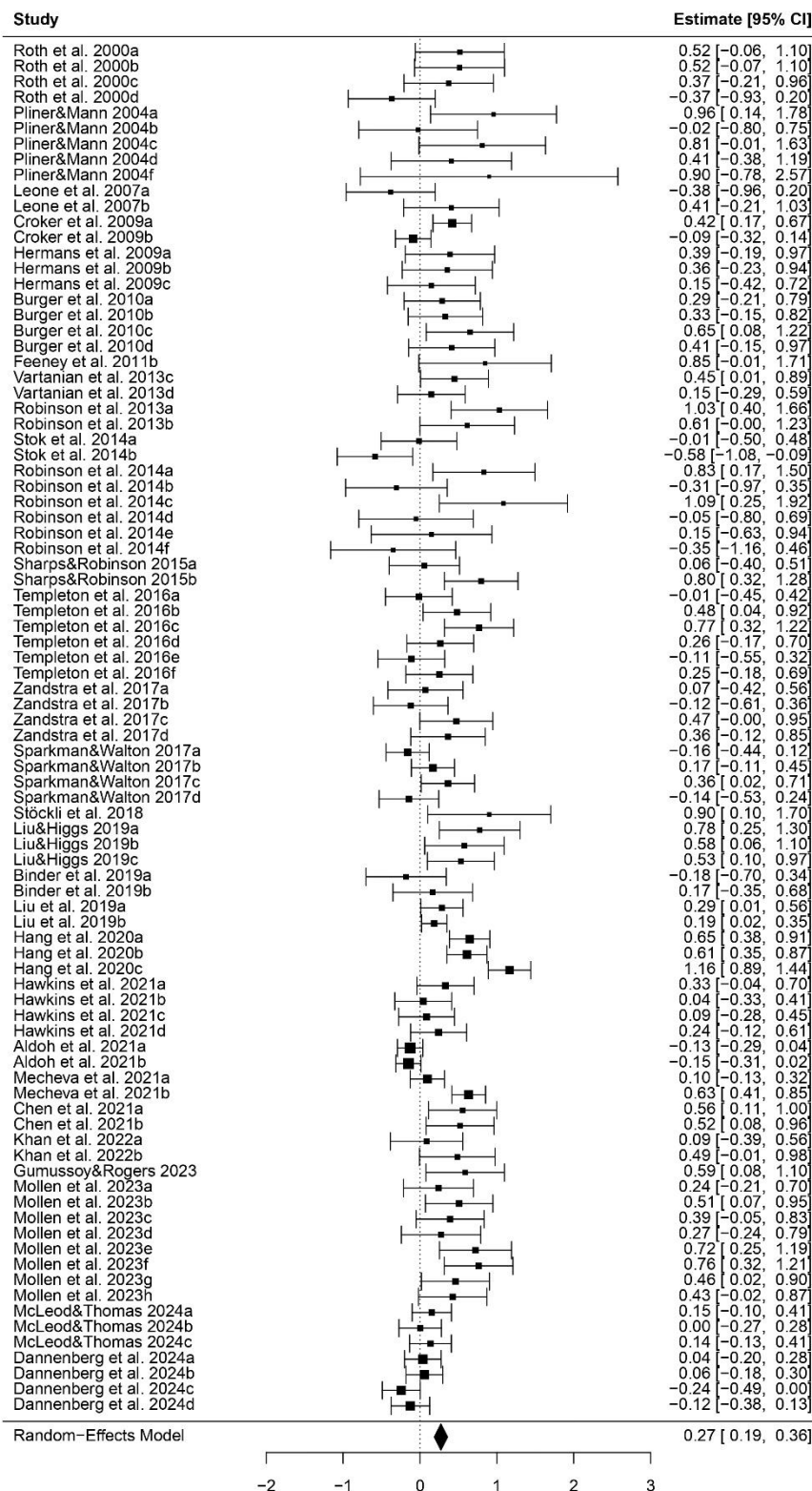


Figure 1.4: Forest plot of the 88 effects

Table 1.5 summarizes the grand mean effect sizes (random-effects multilevel meta-analyses, REML) and 95% confidence intervals for each subgroup, including heterogeneity statistics (τ^2 , I^2 , and Q-test). These subgroup estimates describe the magnitude of social norms effects within each category, to provide an initial view of which moderators are associated with larger or smaller effects.

Table 1.5: Subgroup analyses of the effect of social norms on eating behaviours

Moderators' levels	Observations (effects)	Hedges's g [95% CI]	Q (df)	τ^2	I ² (%)
Experimental setting characteristics					
Field	5	0.424 [0.123, 0.725] **	9.42 (4)	0.043	30.03
Laboratory	62	0.332 [0.227, 0.437] ***	160.42 (61)	0.004	31.47
Online	21	0.109 [-0.027, 0.246]	58.28 (20)	0.033	51.96
Setting familiarity					
Low familiarity	46	0.318 [0.232, 0.404] ***	63.39 (45)	0.004	3.98
Medium familiarity	18	0.342 [0.128, 0.557] **	86.49 (17)	0.087	62.92
Participants' age					
Children	11	0.397 [0.137, 0.657] **	54.26 (10)	0.068	62.15
Young adults	60	0.317 [0.220, 0.414] ***	112.09 (59)	0.028	24.63
Adults	15	0.086 [-0.030, 0.202]	37.03 (14)	0.013	24.87
Participants' gender					
Female	46	0.329 [0.213, 0.444] ***	70.81 (45)	0.032	24.27
Mixed	41	0.211 [0.083, 0.339] **	193.23 (40)	0.059	57.2
Social norm type					
Descriptive norms	71	0.272 [0.187, 0.357] ***	196.27 (70)	0.037	33.11
Injunctive norms	17	0.273 [-0.015, 0.561] .	67.51 (16)	0.151	69.19
Type of message					
Prescriptive messages	56	0.241 [0.138, 0.344] ***	169.85 (55)	0.048	37.61
Proscriptive messages	32	0.352 [0.225, 0.479] ***	105.94 (31)	0.052	45.92
Level of norm					
Minority norm	13	0.087 [-0.127, 0.302]	29.98 (12)	0.065	50.87
Majority norm	75	0.290 [0.204, 0.375] ***	198.87 (74)	0.039	34.39
Delivery mode					
Physical	46	0.147 [0.050, 0.244] **	101.87 (45)	0.024	23.54
Virtual	42	0.389 [0.267, 0.512] ***	123.56 (41)	0.048	41.49
Source authority					
Authority	3	0.727 [-0.143, 1.597]	17.06 (2)	0.369	88.71
Peer	85	0.262 [0.180, 0.345] ***	227.92 (84)	0.039	34.64
Source age					
Similar age	64	0.338 [0.234, 0.441] ***	155.46 (63)	0.041	32.34
Different age	24	0.227 [0.047, 0.406] *	104.06 (23)	0.089	79.8
Source gender					
Same gender	26	0.413 [0.319, 0.507] ***	34.27 (25)	0.000	-
Different gender	62	0.208 [0.107, 0.308] ***	220.93 (61)	0.047	46.1
Source familiarity					
Familiar	4	0.353 [0.211, 0.495] ***	12.84 (3)	0	-
Unfamiliar	84	0.270 [0.179, 0.361] ***	259.09 (83)	0.049	39.67
Type of food					
Healthy	48	0.271 [0.156, 0.386] ***	160.61 (47)	0.044	35.59
Unhealthy	34	0.293 [0.149, 0.437] ***	100.14 (33)	0.055	44.42
Other	6	0.258 [0.068, 0.448] **	8.98 (5)	0.025	39.55
Outcome type					
Behaviour	62	0.315 [0.223, 0.408] ***	128.72 (61)	0.025	22.08
Intention	26	0.178 [0.013, 0.343] *	145.85 (25)	0.071	67.13
Outcome observability					
Observable	42	0.377 [0.259, 0.494] ***	100.30 (41)	0.035	28.92
Private	46	0.185 [0.078, 0.292] ***	128.04 (45)	0.040	39.84

Significance codes: . $p < 1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Analyses were conducted using random-effects multilevel meta-analysis models with study-level random intercepts and REML estimation.

τ^2 = between-study variance; I^2 = proportion of total variability in effect sizes due to heterogeneity; Q -test = Cochran's Q statistic for heterogeneity. I^2 was computed based on the estimated between-study variance (τ^2) relative to the total variance (τ^2 + mean sampling variance), as recommended for multivariate meta-analytic models.

Positive values of Hedges' g indicate stronger effects of social norms on eating behaviours.

Social norms have a statistically significant positive effect on eating behaviours across most moderator categories and levels, with effect sizes generally in the small-to-moderate range (min 0.147, max 0.413). Non-significant or only marginally significant effects emerge for a limited number

of subgroups. Substantial heterogeneity persists within most subgroups, as indicated by Q-tests and I^2 statistics, supporting the use of meta-regression analyses to formally test moderator contrasts. Estimates of subgroups for which fewer than 10 observations are available are limited in terms of robustness, but highlight areas where evidence is currently scarce.

The results of single-predictor meta-regressions (Supplementary Table I.G) show that some contrasts that appeared meaningful in the subgroup analyses (e.g., descriptive norms, majority norms, low/medium familiarity) do not reach statistical significance when formally tested against other levels. No formal tests of between-group differences were performed for moderators in which one of the two levels is represented by fewer than 10 observations.

1.3.3 Moderators influencing social norms effectiveness

Results from Eqs. 1.2 and 1.3 illustrate which moderators influence the effectiveness of social norms in changing eating behaviours. Estimates are robust to sample differences (results available in Supplementary Table I.H).

Table 1.6: Model from Eq. 1.2 and Model from Eq. 1.3 results. Online, Medium Familiarity Setting, Adults, Mixed Gender, Unhealthy Food omitted (baseline conditions).

Variable	Model from Eq. 1.2: Sign and Significance for 128 observations Estimate (SE)	Model from Eq. 1.3: Effect sizes for 88 observations Estimate (SE)
Intercept	0.178 (0.219)	0.255 (0.172)
Experimental setting characteristics		
Field	0.165 (0.237)	-
Laboratory	0.496 (0.233) *	-0.012 (0.240)
Low familiarity setting	-0.304 (0.208)	0.087 (0.256)
Participants' characteristics		
Children	0.576 (0.283) *	0.406 (0.231) .
Adolescents	-0.197 (0.263)	-
Young adults	0.642 (0.229) **	0.424 (0.160)**
Female	-0.181 (0.191)	-0.111 (0.112)
Social norm characteristics		
Social norm type	0.094 (0.140)	0.120 (0.094)
Type of message	-0.375 (0.143) **	-0.163 (0.069)*
Level of the norm	-0.238 (0.095) *	-0.079 (0.079)
Norm delivery	0.008 (0.195)	-0.206 (0.132)
Referent of the norm characteristics		
Source authority	-0.553 (0.193) **	-
Source age	-0.291 (0.200)	-0.307 (0.121)*
Source gender	0.169 (0.229)	0.113 (0.156)
Source familiarity	-0.528 (0.192) **	-
Outcome behaviour characteristics		
Healthy food	0.170 (0.111)	-0.006 (0.084)
Mixed food	0.172 (0.182)	-
Outcome type	-0.276 (0.153) .	-0.0312 (0.147)
Outcome observability	0.0297 (0.113)	0.069 (0.100)
Model fit	Adjusted $R^2 = 0.29$	Model fit: $k = 88$ effect sizes, REML log-likelihood = -26.04, AIC = 84.09; BIC = 120.73 Random effects: Between-study variance: $\tau^2 = 0.050$ (SD = 0.223) Residual heterogeneity: $Q_E(73) = 150.32, p < .0001$ Test of moderators: $Q_M(14) = 29.62, p = .0086$

Significance codes: . $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$

In the analysis of the full sample (Eq.1.2), we examine the likelihood that social norms produce a significant effect on eating behaviours (RQ2a). As illustrated in Table 1.6, social norms are more likely to produce significant effects among children and young adults compared to adults, and experiments conducted in controlled environments (i.e., laboratories) are more likely to produce significant results than online ones. The type of message also influences outcomes. Prescriptive messages are less effective than proscriptive messages. Similarly, minority norms are less likely to produce significant effects compared to majority norms. Norms delivered by an authority figure are less effective than those delivered by peers, and norms from familiar referents are less likely to yield significant outcomes than those from unfamiliar referents. Norms targeting actual behaviours are marginally less likely to produce significant effects than those targeting intentions.

Estimations to address RQ2b (Eq. 1.3, Table 1.6) show that the moderators significantly explain a share of the variability in effect sizes across studies ($Q_M(14) = 29.62, p = .0086$). Residual

heterogeneity remains high ($QE(73) = 150.32, p < .0001$), suggesting that additional unmeasured moderators could contribute to differences in effects. Among the examined moderators, the type of message is negatively associated with effect size, indicating that prescriptive messages yield smaller effects compared to proscriptive messages, controlling for all other moderators. A significant positive effect is observed for young adults and a marginal one for children, suggesting a tendency for younger participants to be more influenced by social norms than adults. Social norms coming from similar-aged sources seem to yield smaller effects. While the subgroup analysis suggests that norms coming from similar-age referents have slightly larger effects, this difference is not statistically significant in the formal single-predictor meta-regression models (Supplementary Table I.G). In the multivariate meta-regression, the coefficient for Source Age is negative, probably reflecting the adjustment for other correlated moderators.

Compared with the single-predictor meta-regressions, the meta-regression model from Eq. 1.3 shows fewer significant moderators. This difference indicates that some apparent moderators' significance may be explained by other correlated moderators rather than representing independent effects.

Results of the robustness check are reported in Supplementary Table I.H, column 2. The pattern remains largely consistent in terms of direction and magnitude of the estimated effects. However, moderators with very limited empirical support become statistically significant in this specification, while the effect associated with young adults loses statistical significance. Given the small number of observations for these moderators, these estimates are likely unstable and should be interpreted with caution.

1.4 Discussion

The findings addressing RQ1, RQ2a, and RQ2b confirm that social norms have a reliable moderate influence on eating behaviours, with young individuals, proscriptive messages, majority norms, older sources, and observable outcomes emerging as key conditions for stronger effects. The consistency across semi-quantitative and meta-regression approaches strengthens these findings.

We found that social norm manipulations exert a small-to-medium positive overall effect on eating behaviours ($g = 0.273, 95\% \text{ CI } [0.19, 0.358]$). Concerning RQ1, this indicates that exposure to social norms shifts eating-related outcomes in the intended direction. However, effect sizes varied substantially, as signaled by the high heterogeneity in our sample, pointing to the relevant role of conceptual and methodological moderators. This aligns with recent evidence from broader analyses of food-related behavioural interventions, which suggest that average effects may be misleading if heterogeneity is not explicitly accounted for, and that identifying moderators is essential to understand

behavioural responses (Lohmann et al., 2026). Subgroup analyses further indicate that small-to-medium positive effects emerged across most levels of the examined moderators.

Beyond the presence of an overall effect, our results clarify the conditions under which social norms are more likely to be effective in influencing eating behaviours, providing an answer to RQ2a. Effects were more likely to reach statistical significance among children and young adults than among adults, when norms were framed proscriptively rather than prescriptively, when they communicated the behaviour of a majority rather than a minority, when they were conveyed by peers rather than authority figures, and when outcomes referred to behavioural intentions rather than actual behaviour. Consistent with these patterns, meta-regression analyses performed to address RQ2b identified message framing and participants' age as robust predictors of effect size magnitude. Proscriptive messages produced larger effects than prescriptive ones, and effects were stronger among children and young adults than among adults. Other moderators that appeared relevant in descriptive subgroup analyses did not retain statistical significance once multiple moderators were considered simultaneously, suggesting that their apparent influence may depend on shared variance with other study characteristics.

Our small-to-medium impact estimate is consistent with earlier work focused solely on descriptive social norms. Ruddock et al. (2019) reported a standardized mean difference of approximately 0.35, indicating increased food intake when eating with others. Robinson et al. (2014) observed comparable mean differences. Also, the meta-analysis of social modelling of Vartanian et al. (2015) reported a large overall effect ($r = 0.39$), suggesting a strong influence of others' eating behaviour on food intake. Direct comparison with these studies should be interpreted with caution, as prior meta-analyses often focused on specific normative mechanisms (e.g., modelling or facilitation) and used different effect size metrics. Beyond eating-related studies, similar effect sizes have been reported in broader consumers' behavioural domains (Bergquist et al., 2019; Melnyk et al., 2022), suggesting that social norms yield a reliable, yet modest, influence across contexts.

Disentangling the overall effect of social norms on eating behaviours via subgroup analyses shows that social norms were more effective when the target behaviour was observable, consistent with the idea that visibility increases both accountability and the perceived relevance of others' behaviour. This finding is coherent with the idea that eating in front of others makes social evaluation more salient. People strategically adjust what and how much they eat to avoid negative stereotypes (e.g., appearing greedy or lacking self-control) and to convey good impressions to others (Robinson et al., 2013; Vartanian et al., 2007).

The greater responsiveness of children and young adults aligns with evidence that younger individuals are particularly sensitive to social information in food-related contexts (Lally et al., 2011; Sharps &

Robinson, 2015) and with social cognitive theory, which emphasizes the role of observational learning during developmental phases (Bandura, 1977). Message framing also played a key role. Proscriptive messages were more likely to yield significant effects than prescriptive ones, a pattern that differs from findings in broader social norm research (Rhodes et al., 2020). A potential explanation of this discrepancy lies in the composition of our sample. The majority of proscriptive messages targeted the reduction of unhealthy food intake (23 out of 32 effects), while most prescriptive messages were directed towards the increase of healthy consumption (41 out of 56 effects). A plausible interpretation is that proscriptive message framing (i.e., messages emphasizing what people should not do) may be particularly effective when the behavioural goal involves reducing a socially disapproved behaviour, compared to the effectiveness of prescriptive messages (i.e., messages emphasizing what people should do) in increasing approved behaviours. This is consistent with evidence from Pavey et al. (2018), who found that proscriptive health messages (e.g., “you should not drink alcohol above recommended limits”) elicited stronger perceived moral norms and intentions than prescriptive messages. Since very few studies examined proscriptive messages aimed at reducing healthy eating, or prescriptive norms aimed at increasing unhealthy eating, the apparent advantage of proscriptive messages in our analysis may reflect the behavioural targets typically combined with each frame rather than an intrinsic higher effectiveness of proscriptive messages.

The stronger effectiveness of majority norms against minority norms in steering eating behaviours in the desired direction resonates with the Social Comparison Theory (Festinger, 1954), which states that individuals evaluate their own behaviours and attitudes by comparing themselves to others. In the context of social norms, observing or being informed that most people engage in a particular behaviour provides a reference point that guides individual choices and suggests what is typical or correct (Gardikiotis et al., 2005). Minority norms should be implemented with caution: messages highlighting that only a small proportion of people engage in desirable behaviour may unintentionally normalize low adherence to the norm and trigger the opposite effect (Higgs et al., 2019).

Social norms communicated by peers were also more likely to produce significant effects than those delivered by authority figures. This pattern can be interpreted through the lens of Reactance Theory (Brehm & Brehm, 1981), which hypothesizes that individuals tend to resist directions when they perceive their freedom to choose is threatened. When normative messages come from an authority figure, the implied pressure may increase the threat, triggering reactance and reducing compliance (Fitzsimons & Lehmann, 2004).

Finally, studies measuring actual behavioural outcomes showed lower probabilities of statistically significant effects than those assessing behavioural intentions. This discrepancy can be understood considering the intention–behaviour gap. Although intentions are often utilized as proxies for

behaviour, the translation of intentions into action is not automatic (Sheeran, 2002). A range of factors, including situational constraints, habit, and competing motivations, can prevent intended behaviours from being executed (Conner & Norman, 2022; Sheeran & Webb, 2016). Accordingly, our findings suggest that social norms might be effective in shaping eating-related intentions, but that these intentions do not always translate into actual behaviour.

Interestingly, in the meta-regression model, social norms coming from similar-age referents showed smaller effects, in contrast with what observed in the sub-group analyses. This contrast may reflect multicollinearity across moderators, which is not considered in descriptive analyses. For instance, similar-age referents tend to appear in studies involving younger participants or specific settings (e.g., school classes), making it difficult to isolate their unique contribution. Empirically, this result aligns with Tarrant et al. (2015), who found that participants reported healthier eating intentions and behaviours when an older referent was employed.

Understanding how social norms influence eating behaviours is not only of theoretical relevance but also of societal and political importance. Our findings can support interventions related to SDG2 and SDG3 in multiple ways. We confirm that social norms offer a scalable and low-cost opportunity to complement traditional public health strategies promoting healthy eating behaviours. We also identify when and for whom social norms are most effective, an insight that practitioners and policymakers can benefit from for practically designing food and health communication campaigns. Specifically, we clarify that proscriptive messages aimed at reducing the consumption of unhealthy food appear more effective than prescriptive ones promoting the consumption of healthy foods. This suggests that public health campaigns aligned with SDG3 objectives may be more effective if explicitly discouraging disapproved eating behaviours through social norm messages, particularly in contexts where overconsumption of unhealthy foods is prevalent. Also, focusing on norms that convey the behaviour or opinions of a majority (i.e., majority norms) outperform minority norms, since messages stating that only a small number of people behave in a desirable way can backfire by suggesting that most people do not follow the recommendation. Children and young adults show higher responsiveness, meaning that social norm-based interventions may be particularly effective when implemented in schools and universities. This insight is directly relevant for policies addressing early-life dietary habits, which are central to long-term health conditions. Importantly, the insight related to the observability of behaviours suggests that using social norms in social eating contexts (e.g., school canteens, restaurants) could amplify their effect and lead to the desired outcome. In contrast, interventions targeting private settings, such as households, may require alternative approaches that do not rely on visibility and social evaluation. Finally, given the reliable but modest effect of social norms we observe, together with the substantial heterogeneity across contexts and populations, we

suggest policymakers not to consider social norms a stand-alone solution. On the contrary, they can be combined with, for example, broader awareness-raising campaigns to target obesity, unhealthy diets, and food-related inequalities.

1.4.1 Limitations and directions for future research

While providing significant advancements in literature, the meta-analysis comes with some limitations to be addressed by future research. Although our search strategy was intentionally comprehensive, our inclusion criteria prioritized experimental designs with a non-treated control group and explicit norm manipulations. This choice may have resulted in the underrepresentation of certain study characteristics, such as male-only samples, field experiments, injunctive norms, minority norms, and authoritative referents. A second limitation concerns the set of moderators included in the meta-regression models. To ensure consistency and comparability across studies, we restricted the analysis to moderators that were extractable from our sample. This decision may have contributed to the residual heterogeneity of effects observed in the sample, as potentially relevant factors such as cultural context, baseline norm strength, or habit strength could not be examined. Expansion of the list of moderators to be investigated can serve in future meta-analysis to gain additional knowledge on factors influencing social norms effectiveness. A third limitation concerns how social norm effects were operationalized in this meta-analysis. Our focus on directional effects aligned versus misaligned with the norm, rather than on specific behavioural outcomes (e.g., intake quantity, food choice, or waste), limits our ability to identify whether norms affect different eating outcomes in distinct ways. Finally, only effects measured against a non-treated control group were included in our synthesis, given the need to maintain analytical parsimony and avoid the complexities of multi-level effect size comparisons. Such a choice prevents a direct assessment of the relative effectiveness of different norm manipulations via comparisons among treated experimental groups. Future research should test social norms through the implementation of interventions in more diverse geographical contexts, to understand how social norms' influence on eating behaviours changes according to cultural and social contexts. A particular gap is related to the scarcity of field experiments: addressing it would allow to observe social norms in real-life eating contexts, where behaviours occur naturally and multiple drivers of eating behaviours concur. Additionally, longitudinal designs are needed to assess whether normative influences persist over time and contribute to habit formation. Increased transparency in reporting (e.g., full message wording, exposure conditions, and behavioural visibility) would also enable more precise moderator coding in future meta-analyses and replication. Analytically, future meta-regressions should explore subgroup differences, potentially revealing stronger moderators' roles within specific groups. Similarly, future

research should clarify if the larger effect of proscriptive norms observed in this study varies according to the observability of outcome behaviour or according to the behavioural target (reduction or promotion).

1.5 Conclusions

In this study, we explored whether, and under which conditions, social norms influence eating behaviours by synthesizing evidence from 39 studies using semi-quantitative analyses on the full sample and multilevel meta-analytic and meta-regression models on the sub-sample of quantitative effects. The meta-analysis we conducted brings significant advancement in theory and practice. We are the first to apply Card et al. (2018) analysis to assess the influence of social norms on eating behaviours, which enables an extensive analysis across heterogeneous outcomes and experimental designs. Unlike prior reviews, we also provide the first quantitative meta-regression of moderators, identifying robust predictors of both effect likelihood (RQ2a) and magnitude (RQ2b). To do so, we select a sample of studies that includes both descriptive and injunctive norms across all age groups and outcome types, which was not explored so far. For practitioners, the meta-analysis reveals the conditions under which social norms appear to be more effective, and that can be employed for more successful communication campaigns on food selection and intake. Specifically, our results suggest that social norms exert a small but reliable positive influence on eating behaviours, with stronger effects among younger individuals, through proscriptive messages, majority norms, referencing older normative sources, and when behaviours are socially observable. Therefore, these target groups and type of messages should be more often considered when designing social-norm based strategies to complement public health and policy actions aimed at facilitating the adoption of healthier eating behaviours. Although further work is needed to clarify how and when social norms influence food-related behaviours, this study could help researchers and practitioners leverage these norms to promote healthier eating.

CRedit authorship contribution statement

Caterina Rettore: Writing – original draft, Writing – review/editing, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization. **Mara Petruzzelli:** Writing – original draft, Writing – review/editing, Conceptualization, Methodology, Validation. **Matteo Vittuari:** Writing – review and editing, Conceptualization, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of generative AI

During the preparation of this work, the authors used ChatGPT to improve the readability of the text. After using this tool, the authors carefully reviewed and edited the text generated and take full responsibility for the content of the manuscript.

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Chapter 2

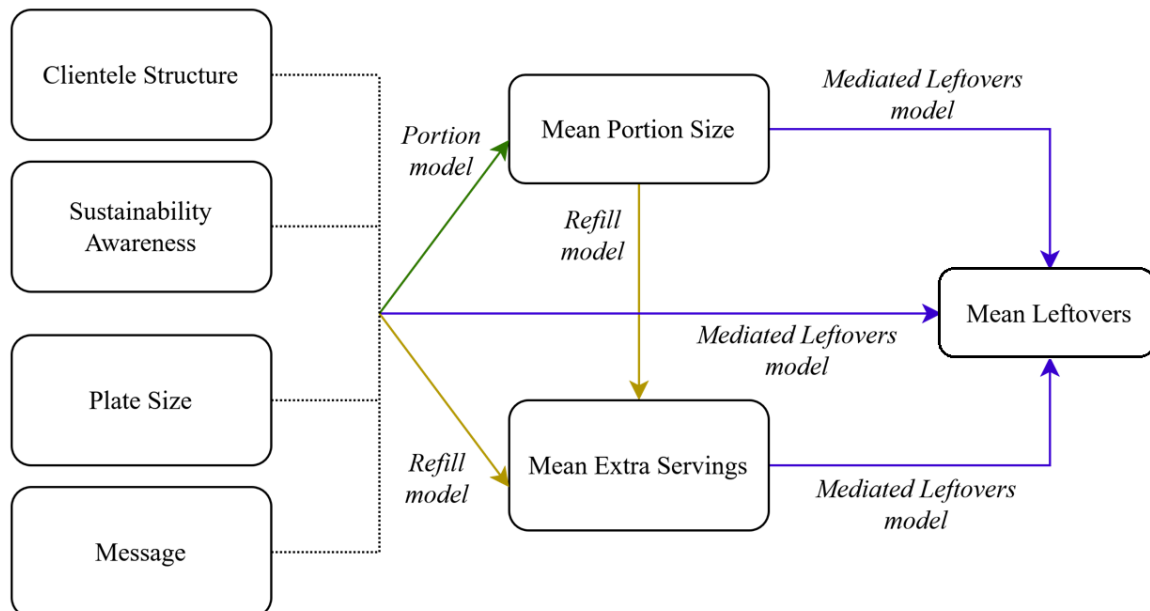
A Bite Too Much: Scenario-Based Analysis of Simulated Plate Waste Behaviour at a Hotel Breakfast Buffet

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Behavioural-pathway framework linking guest characteristics, plate size, and messaging to portioning decisions, refills, and mean leftovers

A Bite Too Much: Scenario-Based Analysis of Simulated Plate Waste Behaviour at a Hotel Breakfast Buffet

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Abstract

Plate waste at hotel breakfast buffets contributes substantially to food waste, yet interactions between guest characteristics, portioning decisions, and behavioural interventions remain understudied. This study conducts scenario analysis using the validated Establishment Diner agent-based model, simulating plate waste across 36 scenarios varying plate size, clientele structure, guest sustainability awareness, and buffet communication messages. The model captures guests' sequential decisions on initial portioning, refilling, and leftovers, driven by internal motives, social norms, and external constraints.

Across the simulated scenarios, simulated plate waste outcomes range from 9.7 g to 277 g per guest per day. The analysis highlights how plate waste emerges from a sequence of behavioural decisions rather than from a single action. A behavioural pathway analysis of the simulated outputs indicates that interventions affecting one stage of the decision process may trigger compensatory responses that limit or even reverse their intended effects.

While sustainability awareness and clientele structure shape baseline behavioural tendencies within the ABM, the simulations show that the effectiveness of interventions depends strongly on contextual conditions and guest profiles. In particular, communication messages interact with guest characteristics, producing different outcomes depending on sustainability awareness and clientele composition.

These results underscore the value of scenario-based simulations for testing unintended compensatory dynamics and reactance in buffet settings that would be difficult to observe in field settings. The findings should be interpreted as simulation-based insights rather than empirical evidence and suggest that hospitality interventions should move beyond isolated

nudges and instead consider how guest characteristics and behavioural pathways jointly influence waste outcomes.

Keywords

Food waste; Behavioural interventions; Scenarios; Agent-based model; Food service

2.1 Introduction

Food waste (FW) is a global sustainability challenge with environmental, social, and economic consequences. A significant portion of FW originates in the downstream stages of the food supply chain, particularly at the consumer and food service levels (UNEP, 2024). Food services (e.g., canteens, restaurants, and hotels) account for 28% of global FW (UNEP, 2024), with 75% avoidable hospitality FW (Oliveira et al., 2016). In parallel, the expenditure on restaurants and accommodation has steadily increased in the EU (EUROSTAT, 2025), highlighting the need to measure FW and analyze its determinants.

Within hospitality, FW occurs across planning, preparation, serving, and consumption (Oliveira et al., 2016). Determinants include prediction and procurement practices (Heikkilä et al., 2016), preparation methods, the use of prepared versus fresh ingredients (McAdams et al., 2019), and staff skills (Kasavan et al., 2019; McAdams et al., 2019). Additionally, operational practices (e.g., overproduction, excessive menu variety) contribute to the issue (Kasavan et al., 2019; Papargyropoulou et al., 2019). Strict food safety regulations around food safety and liability limit the reuse or donation of leftovers (Chawla et al., 2021; Filimonau et al., 2020), constituting recognized systemic drivers of FW. On the operational side, better forecasting, simplified menus, and staff training can reduce FW (Wu & Teng, 2022), but the most effective strategies are systematic, combining waste monitoring, corporate reduction targets, and redistribution partnerships, which also influence customers' commitment to reduce waste (Wu & Teng, 2022; Zhu & Liu, 2025). In fact, while organizational factors shape service-level FW, consumers' behaviours determine plate waste (PW), the share of FW occurring directly on guests' plates and defined as the food served but not consumed. PW is influenced by abundant portion sizes (Berkowitz et al., 2016; von Massow & McAdams, 2015), individual preferences with respect to ingredients or preparation methods, individual attitudes towards FW (Dhir et al., 2020; Okumus et al., 2020), and social norms (Muposhi & Musavengane, 2023). In buffet settings, where guests serve themselves, usually in an all-you-can-eat mode (Juvan et al., 2018), PW is particularly relevant. The abundance of food and all-you-can-eat pricing lead guests to

overserve and leave food uneaten (Juvan et al., 2018, 2021). Few studies have measured the amount of PW in hotel buffets, resulting in very different figures spanning from an average of 15.6 grams (Juvan et al., 2018) to 300 grams per guest (Papargyropoulou et al., 2016). Socio-demographic and cultural characteristics of guests are also a key element (Juvan et al., 2018). For example, children and first-time diners at a given buffet establishment tend to leave more food unconsumed (Juvan et al., 2018, 2021). On the other hand, no previous research has explored how different types of guest, beyond socio-demographics, may differ in their wasting behaviour due to professional identities and situational norms. While studies found that tourists' cultural backgrounds influence PW (Liu et al., 2022), research has not yet examined business and leisure guests as categories following distinct motivations, social norms, and with different behavioural constraints.

Different strategies have been tested to reduce PW. Guest-oriented interventions, such as smaller plates, informative signage, and behavioural nudges, have shown promise (Guimarães et al., 2024). Despite these efforts, PW in buffet settings remains substantial and important research gaps remain. Several of the abovementioned determinants are well established, such as the role of portion size, sustainability attitudes, and operational establishment practices, but evidence is inconsistent for others, particularly for influences related to time or social identity on guest behaviour. Additionally, existing studies usually examine individual drivers, providing limited insight into how their interactions shape portioning, refilling, and waste generation. The behavioural pathways leading from initial serving to leftovers remain understudied. These gaps highlight the need for an analysis capable of capturing interactions, compensatory dynamics, and messaging backfire, elements that are inherently difficult to observe, isolate, or manipulate in field studies, particularly when interventions operate across multiple decision stages.

To address these gaps, this study uses the Establishment Diner agent-based model (ABM) developed and validated by Puga-Gonzalez et al. (2025) to simulate PW (measured as leftovers per guest) in all-you-can-eat breakfast buffets. ABMs simulate systems composed of individual agents whose decisions and interactions produce emergent outcomes (Macal & North, 2010). ABMs are particularly valuable for capturing emergent phenomena that arise from localized interactions and heterogeneous behaviours (Bonabeau, 2002). They are suited to investigate FW determinants, as they capture heterogeneity and feedback among individuals (Boz et al., 2024; Kandemir et al., 2020; Puga-Gonzalez et al., 2025; Ravandi & Jovanovic, 2019; Skeldon et al., 2018). Moreover, ABMs enable the exploration of “what-if” scenarios that would be difficult to implement empirically (Ravandi & Jovanovic, 2019). The ABM developed by Puga-Gonzalez et al. (2025) integrates psychological, behavioural, and social mechanisms through

the HUMAT (Jager et al., 2025) and Motivation-Opportunity-Ability (MOA) (MacInnis et al., 1991) frameworks and simulates key behavioural mechanisms relevant to PW, including portioning and refill decisions, finishing behaviour, social influence, and individual motives and opportunities. Given that PW emerges from a sequence of guest decisions (i.e., initial portioning, refilling, and finishing behaviour), in this study, we adopt a behavioural-pathway perspective, examining how interventions influence each stage of this decision process.

Using this ABM, we simulated 36 scenarios combining variations in plate size, guest sustainability awareness, clientele structure, and communication strategies. The objective is not to estimate empirical effects, but to analyse behavioural mechanisms and interactions as they emerge within a controlled computational environment. The ABM is used as a virtual laboratory to generate and explore behavioural pathways under systematically varied conditions. Scenario analysis allows us to explore how these factors and their interactions shape portioning, refills, and PW in an all-you-can-eat breakfast buffet, under combinations that would be difficult to manipulate and isolate in field experiments. Importantly, all findings reported in this study derive from simulated behavioral trajectories generated by the ABM under hypothetical configurations. Through simulated scenarios, this study addresses the following research questions (RQ).

- RQ1 – How does plate size influence the behavioural pathway from initial portioning to refills and PW?

Previous studies show that plate size affects portion perception and consumption norms (Wansink & van Ittersum, 2013), with large plates leading to increased PW (Freedman & Brochado, 2010; Van et al., 2011), while smaller plates may reduce waste (Kallbekken & Sælen, 2013). However, most evidence comes from isolated interventions and single-stage outcomes, neglecting potential interactions with individuals' characteristics and behavioural pathways.

- RQ2 – How do different mixes of business and leisure guests affect portioning, refills, and PW, and do they amplify or hinder the effects of interventions?

Based on social identity theory (Tajfel & Turner, 1979) and professional self-categorization (Ellemers et al., 2004), we assume business guests are more efficiency-oriented, with less time and greater conformism, while leisure guests behave more indulgently. In other words, we assume business guests adhere to situational social norms suggesting what is perceived as more appropriate in a certain context (Rimal & Real, 2005). Conformism matters in buffets, as guests can observe and adjust their behaviour based on what others do (Cialdini & Goldstein, 2004), and time constraints may either reduce PW by encouraging selective portioning (Cohen et al., 2016; Price & Just, 2015; Wansink, 2004), or increase it, if portions exceed finishing capacity.

Empirical evidence comparing business guests and leisure guests is not available. Thus, starting from the abovementioned assumptions, we test whether business guests' efficiency-oriented motives (higher conformism, lower indulgence) amplify nudges effects, and whether leisure-dominated settings hinder them.

- RQ3 - Under which conditions (guest composition, sustainability awareness) do communication messages reduce PW?

Communication studies indicate that positive/informative messages can reduce waste (Chen & Jai, 2018; Cozzio et al., 2021; Nisa et al., 2022), while messages perceived as moralizing may backfire due to psychological reactance (Li & Shi, 2025; Yuan & Kuehl, 2023), a motivational state occurring when one's freedom of choice is threatened (Brehm & Brehm, 1981). Reactance reduces willingness to comply with norms, decreases goal-directed attitudes, and increases the tendency towards restricted behaviour (Kavvouris et al., 2020; Sprengholz et al., 2023). Individual's characteristics have an influence on reactance (Ward et al., 2021). Therefore, testing how different messages perform and interact with individuals' characteristics is essential to prevent potential backfiring effects.

- RQ4 – How does sustainability awareness shape the behavioural pathways leading to PW, and how does it moderate the impact of plate size and communication messages?

Pro-environmental values and sustainability awareness are associated with lower waste (Visschers et al., 2016; Williams et al., 2012), yet their interaction with nudges and contextual factors in self-service buffets is unclear. Simulating guests with high versus low sustainability awareness helps us understand how personal values drive PW, and how these values interact with behavioural interventions along the portioning–refilling pathway.

- RQ5 – To what extent do changes in initial portioning induce compensatory refilling behaviour, and how do these dynamics jointly determine PW?

Portion size strongly predicts both intake and leftovers (Lorenz-Walther et al., 2019; Visschers et al., 2020), but most studies do not follow guests across multiple servings. Through the ABM, we simulate guest portioning and refilling behaviours to assess their influence on PW.

By addressing these questions, the scenario analysis moves beyond testing whether single drivers affect PW and instead examines how interacting drivers and behavioural pathways produce waste in all-you-can-eat buffets. The contribution of this study is primarily theoretical and simulation-based. Rather than aiming to produce empirical estimates or causal inference, the ABM is used as a generative laboratory to explore how behavioural mechanisms interact and produce emergent outcomes. This supports the identification of intervention combinations that minimize PW while accounting for compensatory dynamics and messaging backfire. For

hospitality actors, simulated scenarios can help identify the most effective combinations of interventions to reduce PW. From a policy perspective, scenario results can inform guidelines or incentive programs that promote sustainable consumption practices in the hospitality sector.

2.2 Methods

2.2.1 ABM overview

The Establishment Diner ABM simulates guests' daily meal choices, including portioning, refilling, and PW generation. A detailed description, calibration, and validation of the base model are provided in Puga-Gonzalez et al. (2025), where the model was calibrated using real-world hotel data on guest composition and buffet food waste. A graphical representation of the model flow and its most relevant factors for this study is represented in Figure 2.1. The population consists of individuals differentiated by gender (male/female) and guest type (business or non-business). Business guests represent individuals staying for work, typically eating earlier and under time pressure, while non-business guests represent leisure visitors. During breakfast, agents decide when to eat, how much to serve, how often to refill, and how much to leave uneaten.

Individual decision-making depends on personal attributes and key internal motives: hunger, fullness, weight control, conformism, indulgence, and sustainability awareness. These interact with opportunities and abilities such as self-control and time availability. The process unfolds in stages: agents first choose portions based on internal motives, time available, and self-control. Agents are also influenced by what other agents around them are doing. The decision to leave leftovers also depends on ability, sustainability awareness, hunger level, conformism, and time.

The ABM integrates the HUMAT socio-cognitive architecture (Jager et al., 2025) and the Motivation-Opportunity-Ability (MOA) framework (MacInnis et al., 1991), enabling realistic simulation of portioning, refilling, and PW emerging from the interplay of personal and contextual factors.

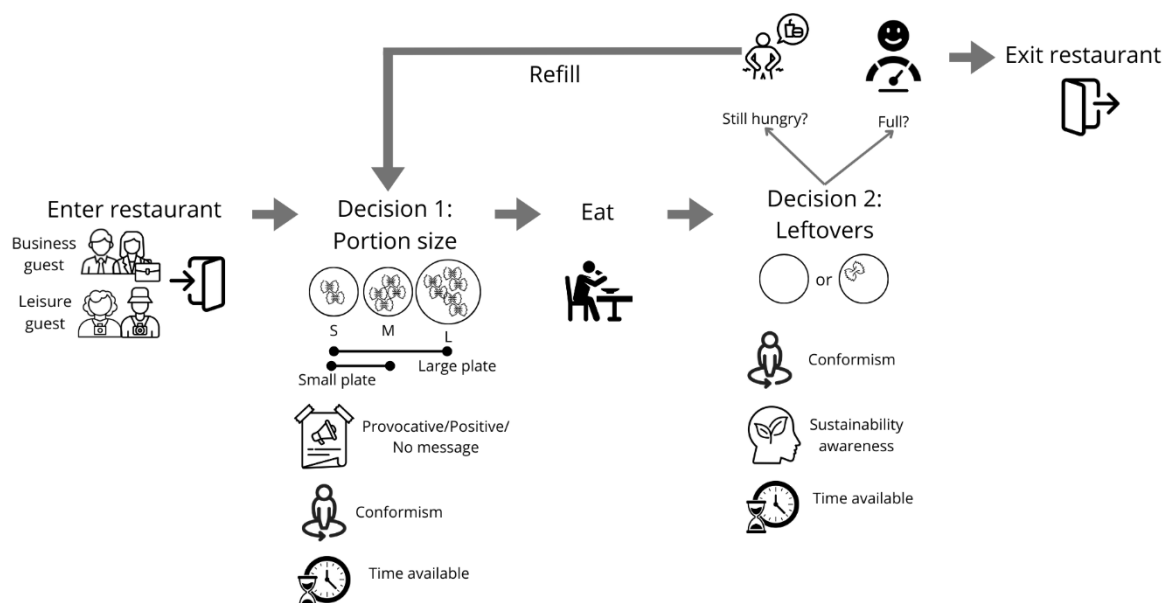


Figure 2.1: Establishment Diner ABM decision steps. After the first serving, agents can decide whether to finish, leave food or go back and refill. Only factors relevant for this study are depicted, further details in Puga-Gonzalez et al. (2025)

2.2.2 Scenarios design

Scenarios were defined through a participatory co-design process involving researchers and hospitality practitioners in the context of the Horizon Europe CHORIZO project, ensuring that the tested scenario configurations reflect realistic operational conditions in hotel buffet settings. Participants were introduced to the ABM and invited to propose interventions targeting guests' behaviours and PW. The research team evaluated the feasibility and relevance of the proposals, resulting in four experimental factors combined into simulation scenarios: plate size, clientele structure, sustainability awareness, and communication strategy.

Other ABM parameters were adopted from Puga-Gonzalez et al. (2025) (see Supplementary Table II.A). The scenarios explored in this study do not represent empirically observed interventions, but plausible configurations derived from stakeholder consultation and existing empirical literature. Scenario parameters were therefore introduced as variations within this validated model structure to explore potential behavioural dynamics under hypothetical but realistic conditions.

The 36 scenarios are defined by the unique combination of four key parameters. The first parameter is related to plate size. It affects portion choices: small plates allow small or normal

portions (200-300g), while large plates also enable large portions (400g). In the ABM, portion decisions are guided by hunger, weight control, indulgence, fullness, and sustainability motives. The second parameter is defined by guest composition. It varies across three population distributions: 70% business dominant, 50% balanced, 30% business minority. Assumptions regarding clientele structure are informed by empirical hotel datasets used in the original model calibration (Puga-Gonzalez et al., 2025). Business guests are assumed to be more conformist and less indulgent than non-business guests, based on social identity theory and professional self-categorization (see Section 2.1). In the model, the level of conformism determines to what extent an agent is influenced by what other agents present in the restaurant are doing.

The third parameter captures guests' levels of sustainability awareness, which influences whether they finish or leave food. Two levels are tested: high awareness and low awareness.

Finally, hotel communication strategies test the influence of messages on guests' behaviours. The implementation of messages in the model is grounded in the psychological reactance theory (Brehm & Brehm, 1981), which hypothesizes that when individuals perceive messages as threatening their autonomy, they tend to resist. In our model, this is coded as a comparison between individuals' tolerance level and the message threat degree. Reactance is thus modelled as a graded motivational process rather than a binary response, allowing heterogeneous and context-dependent reactions to the same message across individuals and guest types. Messages previously tested empirically in field experiment conducted in eight Norwegian hotels (Alonso Miquélez et al., 2024) are coded as positive, provocative, or absent. The message calibration process and data are presented in the Supplementary materials (Supplementary Table II.B), while details about how message influences were coded in the ABM are presented in Supplementary Section II.3 .

When serving themselves, agents see a displayed message. Each message has a threat potential level: positive messages are minimally threatening, while provocative ones have high threat potential (Shen, 2015). Based on Ebbinghaus' forgetting curve theory (Murre & Dros, 2015), it was assumed that, as guests are exposed to the message at the beginning of the mealtime, their reaction to the message gradually diminishes in proportion to the time between serving and finishing their meal. Individual reaction depends on their tolerance, which is influenced by their self-control: high self-control guests tolerate threatening messages better. It was assumed that self-control can moderate reactance by allowing people to approach the message with a more considered perspective (Middleton et al., 2015).

The ABM incorporates two decision routes for portioning and leftovers. Agents follow different routes depending on how their tolerance compares with the message's threat level. When the

message threat exceeds an agent's tolerance, reactance occurs in the form of purposefully disobeying the communicated request (Figure 2.2). If the individual does not perceive the message as threatening, they conform to what the message encourages them to do. Message effects on motives were determined through expert consensus among FW researchers, psychologists, and modelers, as no prior research existed.

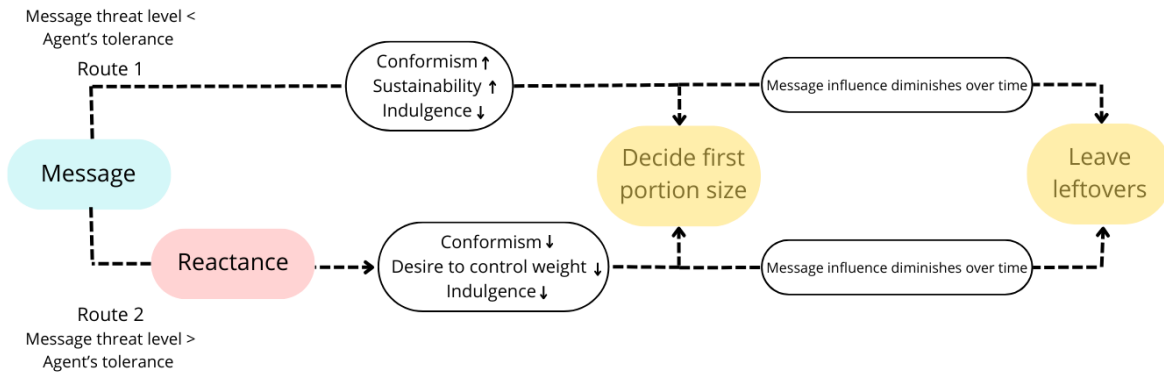


Figure 2.2: Messages influence on guests' decisions through reactance

Route 1 (message perceived as unthreatening): guests conform to the message by increasing conformism (follow social norms for appropriate actions) and sustainability motives, while reducing indulgence. These effects gradually decay over time, so when the agent decides how much food to leave uneaten, all three motives might already be at the initial level (or still slightly higher, depending on how much time it takes the individual to consume the portion of the chosen size).

Route 2 (message perceived as threatening): guests react with psychological reactance, disobeying the message by decreasing conformism, desire to control weight, and indulgence motives (e.g., taking larger portions despite "small portion" message) (Boukamcha, 2016). These effects gradually recover during eating, approaching but not exceeding baseline levels at the time of leaving leftovers.

Details about how message influences were coded in the ABM are presented in the Supplementary Section II.3 .

Table 2.1 summarizes parameters and their values used in what-if scenarios.

Table 2.1: Values used for parameter variation in what-if scenario simulations.

Variable	Scenario	Value
Small_plate	Small	Max 300 grams
	Large	Max 400 grams
Clientele_structure	High business guests proportion	0.7
	Equal guests proportion	0.5
	Low business guests proportion	0.3
Sustainability	High	For women = 0.5
		For men = 0.4
	Low	For women = 0.2
		For men = 0.1
Message	No message	Threat level = 0.5
	Provocative message	Threat level = 0.6
	Positive message	Threat level = 0.2

2.2.3 Data analysis

Each of the 36 scenarios was simulated 150 times, yielding 5400 simulations. Because empirical calibration data are aggregated at the hotel rather than the individual level (Puga-Gonzalez et al., 2025) analyses are conducted on aggregated outputs (simulated average PW per agent per simulation). Overall scenario differences were assessed using Tukey’s Honest Significant Difference (HSD) test (Tukey, 1949), complemented with heatmap visualizations and boxplots illustrating the effects of key factors.

To address RQ1-RQ5 and to interpret the simulation results in a coherent way, we analyse the outputs through a behavioural-pathway framework that reflects the sequential structure of guest decision-making in the ABM: portioning decision, refill decision, and leftovers (PW) generation. We estimated four multiple linear regression models with heteroskedasticity-consistent (HC1) robust standard errors, implemented in the *sandwich* package in R (Zeileis et al., 2020). All continuous predictors were standardized to facilitate comparison across scales. Standardized coefficients represent the change in the dependent variable associated with a one-standard deviation increase in each predictor. Interaction terms were incorporated to test for moderation effects. Analyses were conducted in RStudio, using the *lm()* function for estimation and the *sandwich* and *lmtest* packages for inference. The regression models do not estimate empirical relationships in real-world populations. Rather, they serve as secondary analytical models used to systematically summarize and decompose patterns generated by the ABM. While the ABM constitutes the primary generative model producing simulated behavioural results, the regression framework serves to quantify marginal effects, identify interaction

patterns, and formally decompose behavioural pathways embedded in the model structure. This approach allows structured interpretation of high-dimensional simulation outputs without implying statistical inference to real-world populations. Importantly, causal relationships between variables are defined by the behavioural rules embedded in the ABM. The regression models do not establish causality but provide a structured statistical summary of the simulated relationships generated by these underlying model mechanisms.

Each model links to a specific behavioural decision. The Portion model (Eq. 2.1) tests how experimental manipulations affect standardized average portion size (*mean_portion_size_s*). We include main effects and the four two-way interactions that test whether the effect of plate size or message depends on sustainability awareness or clientele structure.

(2.1)

$$\begin{aligned} \text{mean_portion_size_s}_i &= \beta_0 + \beta_1 \text{Small_plate}_i + \beta_2 \text{sustainability}_i + \beta_3 \text{Clientele_structure}_i \\ &+ \beta_4 \text{message}_i + \beta_5 (\text{Small_plate}_i \times \text{sustainability}_i) \\ &+ \beta_6 (\text{Small_plate}_i \times \text{Clientele_structure}_i) \\ &+ \beta_7 (\text{message}_i \times \text{sustainability}_i) \\ &+ \beta_8 (\text{message}_i \times \text{Clientele_structure}_i) + \epsilon_i \end{aligned}$$

The Refill model (Eq. 2.2) predicts the average number of extra portions (*Total_extra_mean_s*), controlling for initial portion size:

(2.2)

$$\begin{aligned} \text{Total_extra_mean_s}_i &= \beta_0 + \beta_1 \text{Small_plate}_i + \beta_2 \text{sustainability}_i + \beta_3 \text{Clientele_structure}_i \\ &+ \beta_4 \text{message}_i + \beta_5 (\text{Small_plate}_i \times \text{sustainability}_i) \\ &+ \beta_6 (\text{Small_plate}_i \times \text{Clientele_structure}_i) \\ &+ \beta_7 (\text{message}_i \times \text{sustainability}_i) \\ &+ \beta_8 (\text{message}_i \times \text{Clientele_structure}_i) + \text{mean_portion_size_s}_i + \epsilon_i \end{aligned}$$

The Mediated Leftovers model (Eq. 2.3) estimates standardized mean leftovers per guest (*mean_leftovers_s*) as a function of portioning, refilling, and scenario variables (including interactions). This model investigates how portioning and extra-ordering jointly determine PW, while also controlling for any remaining direct effects of the scenario manipulations.

(2.3)

$$\begin{aligned}
\text{mean_leftovers}_{s_i} &= \beta_0 + \beta_1 \text{mean_portion_size}_{s_i} + \beta_2 \text{Total_extra_mean}_{s_i} \\
&+ \beta_3 (\text{mean_portion_size}_{s_i} \times \text{Total_extra_mean}_{s_i}) + \beta_4 \text{Small_plate}_i \\
&+ \beta_5 \text{sustainability}_i + \beta_6 \text{Clientele_structure}_i + \beta_7 \text{message}_i \\
&+ \beta_8 (\text{Small_plate}_i \times \text{sustainability}_i) \\
&+ \beta_9 (\text{Small_plate}_i \times \text{Clientele_structure}_i) \\
&+ \beta_{10} (\text{message}_i \times \text{sustainability}_i) \\
&+ \beta_{11} (\text{message}_i \times \text{Clientele_structure}_i) + \epsilon_i
\end{aligned}$$

After breaking down the behavioural pathways leading to PW, the Total-effect Leftovers model (Eq. 2.4) captures the total effect of experimental manipulations on `mean_leftovers_s`, excluding mediators (portion size and refills) to estimate combined direct and indirect influences.

(2.4)

$$\begin{aligned}
\text{mean_leftovers}_{s_i} &= \beta_0 + \beta_1 \text{Small_plate}_i + \beta_2 \text{sustainability}_i + \beta_3 \text{Clientele_structure}_i \\
&+ \beta_4 \text{message}_i + \beta_5 (\text{Small_plate}_i \times \text{sustainability}_i) \\
&+ \beta_6 (\text{Small_plate}_i \times \text{Clientele_structure}_i) \\
&+ \beta_7 (\text{message}_i \times \text{sustainability}_i) \\
&+ \beta_8 (\text{message}_i \times \text{Clientele_structure}_i) + \epsilon_i
\end{aligned}$$

In all models, ϵ_i captures stochastic variability across simulation runs induced by the probabilistic structure of the ABM.

Robustness checks include re-estimations without interactions and regression diagnostics (Supplementary Section II.7 -8). Figure 2.3 shows the paths examined in Models 1-3.

Each model is accompanied by figures to visualize results. To facilitate interpretation, figures report results from models estimated with unstandardized variables, expressed in grams.

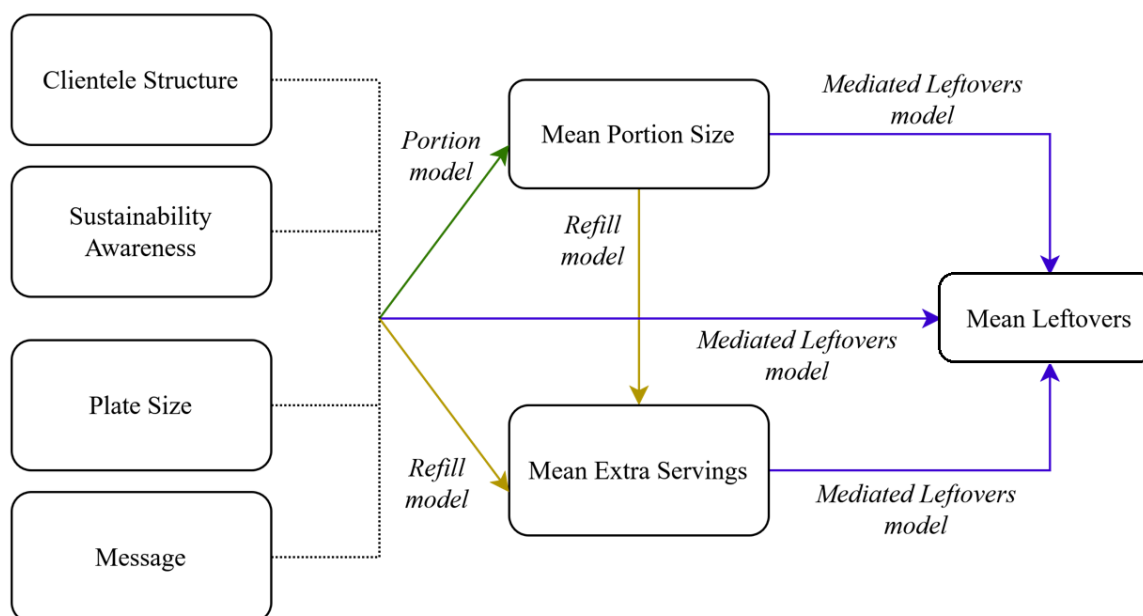


Figure 2.3: Predictor structure of the regression models. Arrows colours refer to each model pathway: Green = Portion model; Yellow = Refill model; Purple = Mediated Leftover model

2.3 Results

2.3.1 Descriptive scenario results

Each scenario represents a specific configuration of key parameters, allowing assessment of their effects on guest behaviour and PW. Full parameter settings and mean PW per guest are reported in Supplementary Table II.C.

Across the 36 simulated scenarios, average PW ranged from 9.7 g to 277 g per guest per day.

Figure 2.4 summarizes the simulation outcomes.

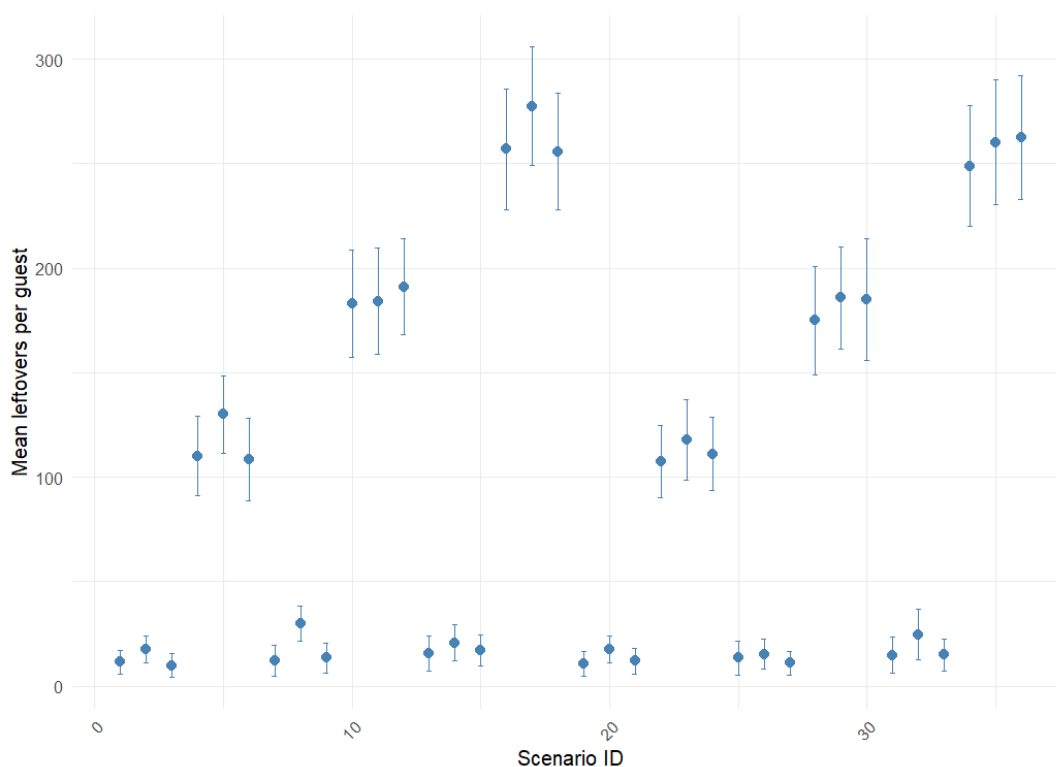


Figure 2.4: 36 simulated scenarios and PW results. Points indicate scenario-level mean PW generated by the agent-based model (based on 150 simulation runs per scenario). Error bars represent standard deviations across stochastic realizations. Results reflect model-generated behavioural outcomes under controlled variations in plate size, clientele structure, sustainability awareness, and messaging strategies.

To compare outcomes across scenarios, a Tukey HSD was applied to the simulated outputs to compare scenario-level differences. The resulting pairwise comparisons reflect variability across simulation runs rather than statistical inference on empirical data. The resulting heatmap is presented in Supplementary Figure II.D.

Figure 2.5A-D present boxplots grouping results by sustainability awareness, clientele structure, plate size, and communication strategy. Wider boxes reflect greater variability, indicating the factor's relative contribution to PW, while the red dots correspond to the mean value. Since the boxplots are based on 5400 simulations, the dispersion reflects both systematic variation due to other experimental factors and stochastic variation inherent in the ABM.

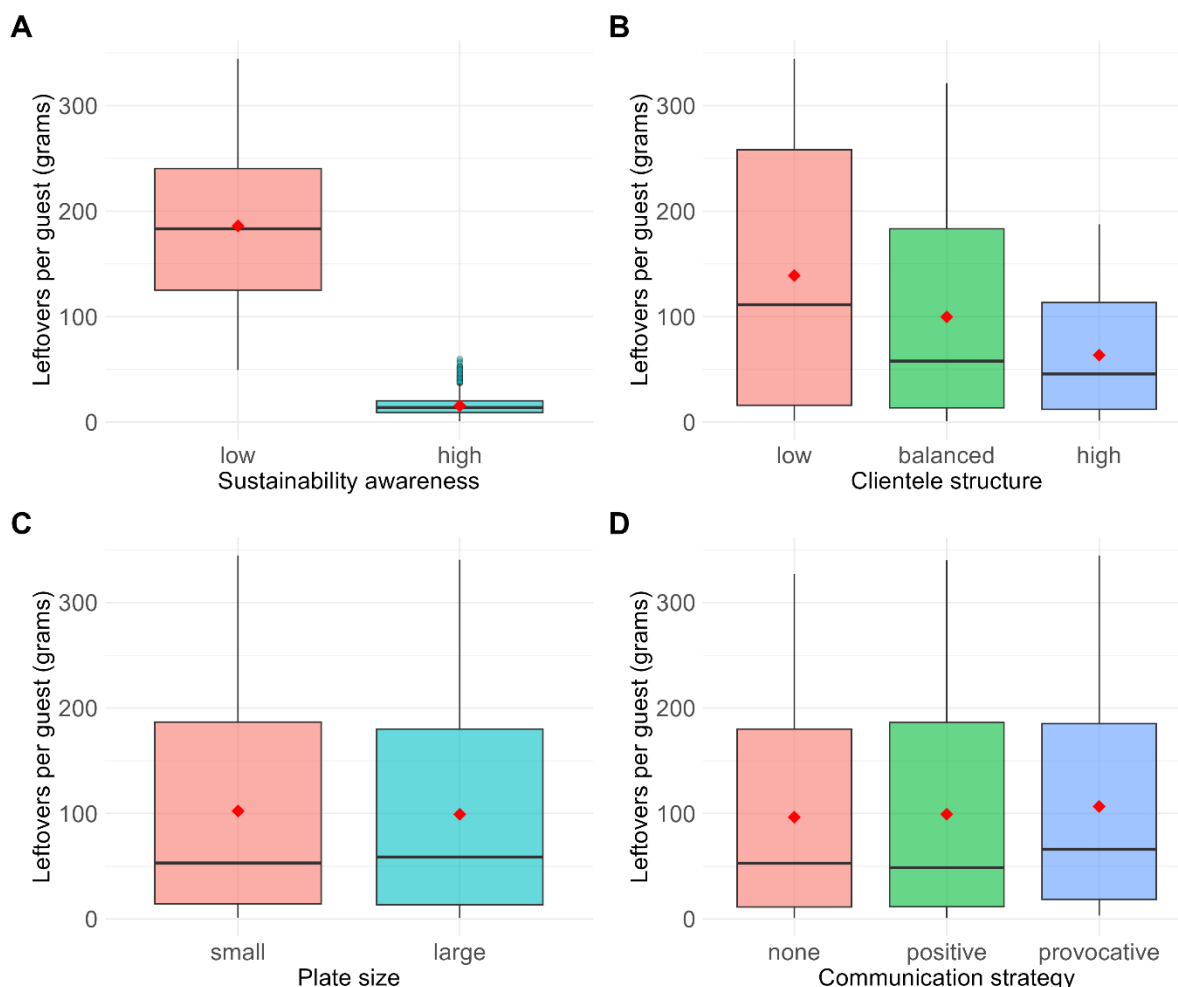


Figure 2.5: Effects of key scenario parameters on simulated leftovers per guest. Panel (A) shows the influence of sustainability awareness, (B) the proportion of business guests, (C) plate size, and (D) communication strategy. Red dots indicate the mean value.

Scenarios with high sustainability awareness consistently produce lower simulated PW (Figure 2.5A).

Scenarios with a low proportion of business show the highest mean PW and variability, whereas those with a high proportion have the lowest median PW (~50 g). Thus, within the simulated scenarios, a stronger business presence corresponds to lower simulated waste within the ABM, reflecting the behavioural rules encoded in the ABM (Figure 2.5B).

Figure 2.5C compares average PW per person across simulations featuring either small or large plate sizes. The boxplots for both sizes are almost identical, suggesting that, under the current model assumptions, plate size alone does not substantially alter simulated PW outcomes.

Provocative messages lead to slightly higher PW than either positive or no messages (Figure 2.5D).

2.3.2 Regression analysis

2.3.2.1 Portion model - Determinants of first portion decisions

Table 2.2: Portion model – Key standardized coefficients (with interactions).

Variable	Specification with interactions
	Estimate (SE)
Intercept	0.789 (0.047)***
Large plate	0.377 (0.045)***
High Sustainability Awareness	-0.178 (0.045)***
Clientele Structure Balanced	-0.407 (0.054)***
Clientele Structure High Business	-0.843 (0.056)***
Positive Message	-0.761 (0.056)***
Provocative Message	-1.832 (0.057)***
Large plate x High Sustainability Awareness	0.122 (0.043)**
Large plate x Clientele Structure Balanced	-0.358 (0.054)***
Large plate x Clientele Structure High Business	-0.919 (0.053)***
Clientele Structure Balanced x Positive Message	0.808 (0.066)***
Clientele Structure High Business x Positive Message	1.649 (0.069)***
Clientele Structure Balanced x Provocative Message	0.754 (0.069)***
Clientele Structure High Business x Provocative Message	1.747 (0.067)***
Adjusted R²	0.38

Note: Only significant coefficients ($p < 0.1$) shown. Full specification in Supplementary Table II.E.

*Significance codes: . $p < 1$; * $p < .05$; ** $p < .01$; *** $p < .001$*

Standardized coefficients (mean = 0, SD = 1). SD (original scale): Mean portion size = 8.89 g. To convert effects to grams, multiply coefficients by the SD of the dependent variable.

Table 2.2 presents standardized coefficients for the Portion model, with small plates, low sustainability awareness, low business share, and no message as baseline.

In the specification without interaction terms (Supplementary Table II.E), plate size and sustainability awareness are not significantly associated with differences in initial portions. In contrast, a higher share of business guests and the presence of provocative messages are associated with smaller simulated portions.

Including interactions between plate size, messages, and population variables improves model fit (Adjusted $R^2 = 0.38$). Figure 2.6A illustrates how the same intervention (changing plate size) can produce opposite behavioural responses within the ABM depending on clientele structure, highlighting the context-dependent nature of portioning decisions in the model.

As shown in Figure 2.6B, both message types are associated with smaller portions among leisure guests. Positive messages may produce a backfire effect in settings with a higher business clientele structure, where they are associated with larger portions rather than reductions in serving size. Sustainability awareness shows only a small direct negative effect. In summary, within the ABM simulations, business guests show more controlled portioning behaviour within the simulations, generating smaller initial servings across conditions. Provocative messages are associated with smaller portions, while positive messages and plate size interventions show effects that strongly depend on clientele structure.



Figure 2.6: Increment in mean portion size per guest changing a) small → large plate size; b) no message → positive/provocative message

Note: The figure display results from models estimated with unstandardized variables to allow interpretation in grams

2.3.2.2 Refill model – Determinants of extra serving decisions

Table 2.3: Refill model – Key standardized coefficients (with interactions)

Variable	Specification with interactions
	Estimate (SE)
Intercept	0.613 (0.019)***
Large plate	-0.920 (0.024)***
High Sustainability Awareness	-1.085 (0.018)***
Clientele Structure Balanced	-0.298 (0.024)***
Clientele Structure High Business	-0.814 (0.023)***
Positive Message	0.683 (0.025)***
Provocative Message	1.320 (0.032)***
Mean Portion Size	0.014 (0.008).
Large plate × Clientele Structure High Business	0.510 (0.030)***
Clientele Structure Balanced × Positive Message	-0.327 (0.032)***
Clientele Structure High Business × Positive Message	-0.476 (0.032)***
Clientele Structure Balanced × Provocative Message	-0.225 (0.041)***
Clientele Structure High Business × Provocative Message	-0.257 (0.038)***
High Sustainability Awareness x Positive Message	0.192 (0.024)***
High Sustainability Awareness x Provocative Message	0.612 (0.031)***
Adjusted R²	0.79

Note: Only significant coefficients ($p < 0.1$) shown. Full specification in Supplementary Table II.F.

Significance codes: . $p < 1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Standardized coefficients (mean = 0, SD = 1). SD (original scale): Mean extra servings = 0.45.

The Refill model examines the simulated mean number of extra portions taken (Table 2.3). The initial portion size was included in this model as a result of a correlation analysis (Supplementary Section II.6). In the specification without interactions (Supplementary Table II.F), larger initial portions are associated with a lower probability of refilling. Holding portion size fixed, large plates ($\beta = -0.718$, $p < .001$), high sustainability awareness ($\beta = -0.801$, $p < .001$), and business-dominant settings ($\beta = -0.812$, $p < .001$) correspond to fewer simulated extra servings. In contrast, both message types are associated with higher refill frequencies.

When interaction terms are added, the reducing main effect of large plates strengthens, but weakens in business-dominated contexts (Figure 2.7A), suggesting that within the ABM business guests are less sensitive to plate size cues. Communication effects also vary by guest shares: both message types correspond to higher refilling among leisure guests, but less so among business ones (Figure 2.7B). Figure 2.7B highlights a compensatory behavioural

pattern: messages, that are associated with smaller initial portions (as shown in Figure 2.6B), are also associated with higher refilling, illustrating a compensatory behavioural mechanism across decision stages.

Without messages, high awareness guests tend to take fewer extra servings, but both message types are associated with higher levels of refilling, consistent with a messaging-related reactance mechanism embedded in the model.

In the simulated decision environment of the ABM, refilling behaviours decrease with large plates, higher awareness, and a higher business share, but increase under message interventions, particularly among leisure-oriented audiences.

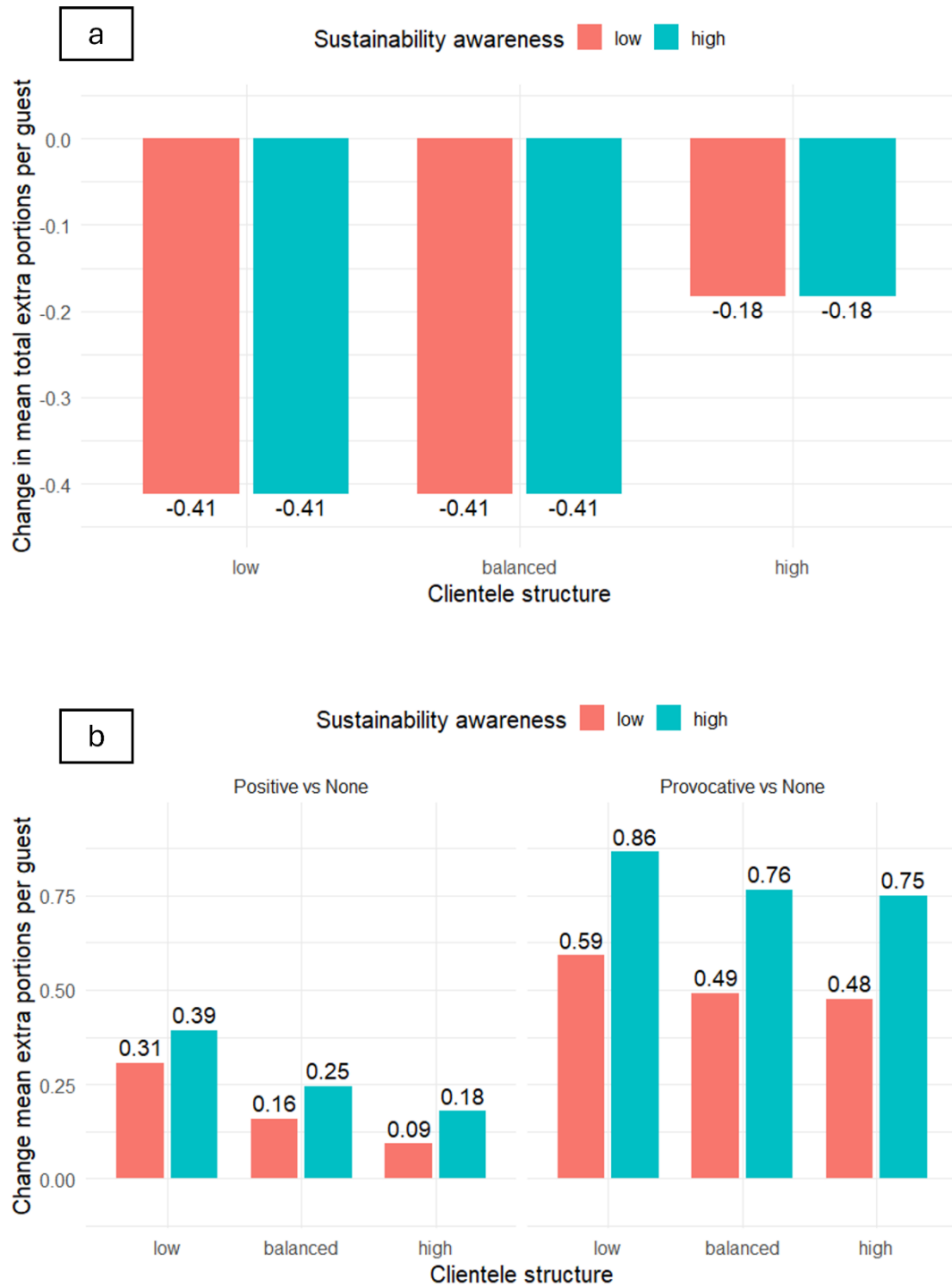


Figure 2.7: Increment in mean extra portion per guest changing a) small → large plate size; b) no message → positive/provocative message

Note: The figure display results from models estimated with unstandardized variables to allow interpretation in grams

2.3.2.3 Mediated Leftovers model – Determinants of mean leftovers

Table 2.4: Mediated Leftovers model – Key standardized coefficients (with interactions)

Variable	Specification with interactions
	Estimate (SE)
Intercept	1.067 (0.022)***
Mean Portion Size	0.065 (0.006)***
Mean Extra Servings	0.230 (0.012)***
Large plate	0.164 (0.024)***
High Sustainability Awareness	-1.456 (0.020)***
Clientele Structure Balanced	-0.318 (0.020)***
Clientele Structure High Business	-0.610 (0.025)***
Positive Message	-0.137 (0.028)***
Mean Portion Size × Mean Extra Servings	0.105 (0.007)***
Large Plate × High Sustainability Awareness	0.044 (0.018)*
Large Plate × Clientele Structure High Business	-0.094 (0.027)***
Clientele Structure Balanced × Positive Message	0.112 (0.026)***
Clientele Structure High Business × Positive Message	0.128 (0.032)***
Clientele Structure Balanced × Provocative Message	-0.086 (0.026)***
Clientele Structure High Business × Provocative Message	-0.055 (0.033).
High Sustainability Awareness × Positive Message	-0.072 (0.021)***
High Sustainability Awareness × Provocative Message	-0.264 (0.024)***
Adjusted R²	0.89

Note: Only significant coefficients ($p < 0.1$) shown. Full specification in Supplementary Table II.G.

*Significance codes: . $p < 1$; * $p < .05$; ** $p < .01$; *** $p < .001$*

Standardized coefficients (mean = 0, SD = 1). SD (original scale): Mean leftovers = 97.05 g.

The Mediated Leftovers model (Table 2.4) explores the drivers of simulated guests' wasting behaviour, including portioning and refilling variables. It shows the highest explanatory power among all models.

In the simulated outputs, larger first portions and extra servings correspond to higher levels of PW.

Within the ABM simulations, high sustainability awareness and business-oriented settings are associated with lower simulated PW, while large plates slightly increase it. Message effects are modest, but become more meaningful when interactions are considered. Figure 2.8A illustrates how sustainability awareness moderates the relationship between plate size and PW, indicating that the same intervention may produce different outcomes depending on guests' sustainability

profiles. As shown in Figure 2.8B, sustainability awareness also conditions the effectiveness of communication messages, suggesting that behavioural interventions may be more effective among sustainability-aware guests. This highlights that intervention effects are not only direct, but also depend on how behavioural traits shape decisions across the portioning-refilling-leftovers pathway.

Taken together, Figures 2.6–2.8 illustrate that plate waste emerges from interacting behavioural decisions rather than isolated effects, with compensatory dynamics across portioning and refilling stages shaping final outcomes.

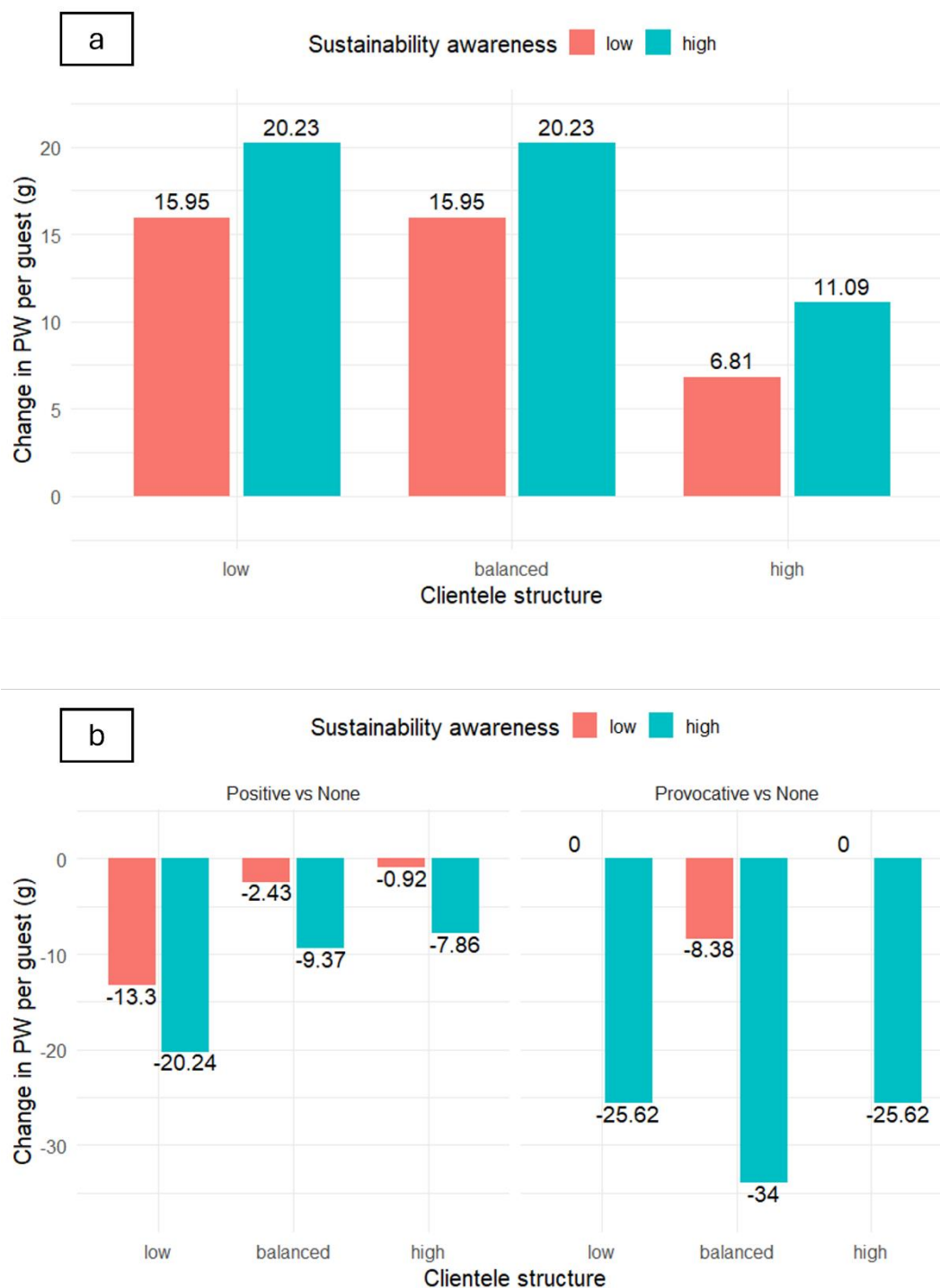


Figure 2.8: Increment in mean PW per guest changing a) small → large plate size; b) no message → positive/provocative message

Note: The figure display results from models estimated with unstandardized variables to allow interpretation in grams

2.3.2.4 Total-effect Leftovers model – Combined direct and indirect effects

The previous models decompose the pathways through which the experimental manipulations influence PW in the ABM, identifying how portioning and extra servings mediate these effects. Figure 2.9 exemplifies this by including the previous models' coefficients for plate size and sustainability awareness.

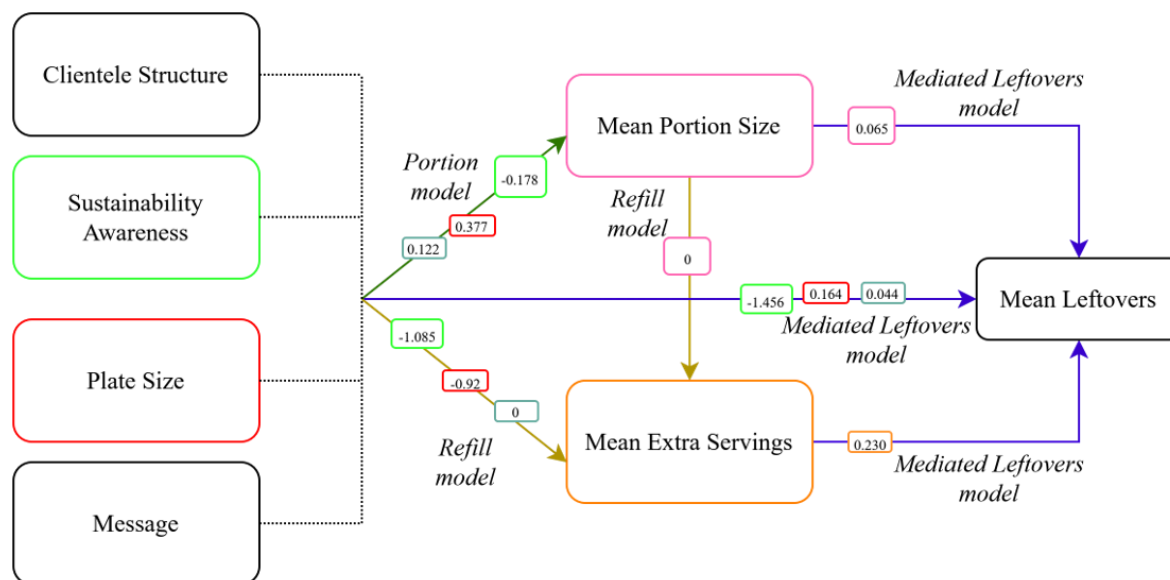


Figure 2.9: Pathway of the three regression models and example coefficients for plate size (red), sustainability awareness (light green), their interaction (dark green), mean portion size (pink) and mean extra servings (orange) across models, illustrating their in

Table 2.5: Total-effect Leftovers model - Key standardized coefficients

Variable	Estimate (SE)
Intercept	1.226 (0.022)***
Large Plate	-0.047 (0.026).
High Sustainability Awareness	-1.739 (0.020)***
Clientele Structure Balanced	-0.384 (0.020)***
Clientele Structure High Business	-0.769 (0.025)***
Provocative Message	0.161 (0.033)***
Large Plate × High Sustainability Awareness	0.034 (0.018).
High Sustainability Awareness × Positive Message	-0.056 (0.020)**
High Sustainability Awareness × Provocative Message	-0.047 (0.024).
Adjusted R²	0.88

Note: Only significant coefficients ($p < 0.1$) shown. Full specification in Supplementary Table II.H.

Significance codes: . $p < 1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Standardized coefficients (mean = 0, SD = 1). SD (original scale): Mean leftovers = 97.05 g.

The Total-effect Leftovers model (Table 2.5) estimates total effects of all manipulations on PW, excluding mediating variables.

Within the simulation outputs, high sustainability awareness shows the largest overall association with lower PW across simulated scenarios, close to two standard deviations of the

dependent variable, followed by clientele structure. In the ABM-generated data, provocative messages are associated with higher simulated PW, while positive messages are associated with lower PW only when guests have a high level of sustainability awareness. Plate size effects are small and only marginally significant.

2.4 Discussion

This study, within a simulation environment, examined how individual characteristics (sustainability awareness, social identity), external factors (plate size, message framing), and portioning behaviours interact to shape PW in hotel breakfast buffets using a validated ABM. By linking simulated behavioural data with regression analyses, the study advances a theoretical and simulation-based understanding of behavioural pathways in buffet systems, complementing but not substituting empirical research on FW interventions in hospitality. The contribution lies in identifying how micro-level behavioural rules generate macro-level patterns under controlled simulated conditions, rather than estimating real-world effects. Our findings highlight not only statistical associations, but also the behavioural mechanisms encoded in the ABM, showing how interventions act on specific steps of the portioning–refilling–leftovers pathway. Figure 2.10 summarizes the results of the four behavioural-pathway regression model, exemplifying how the simulated interventions generate compensatory dynamics within the ABM.

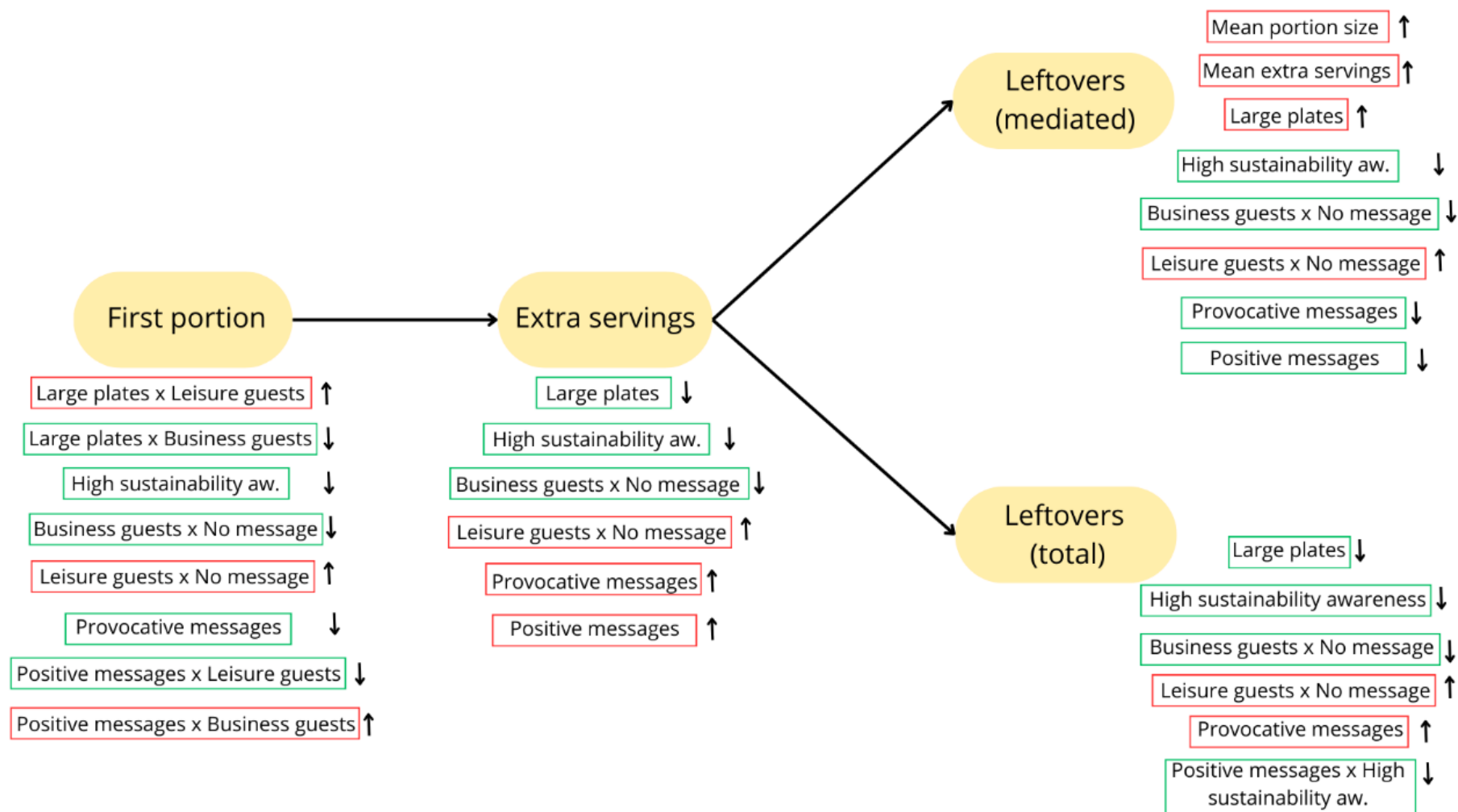


Figure 2.10: Overview of how experimental variables influence portioning, refilling, and PW outcomes

Within the ABM framework, sustainability awareness and clientele structure emerge as the strongest simulated predictors. Guests with higher sustainability awareness and in more business-oriented settings tend to serve smaller portions, take fewer refills, and generate less PW. Conversely, leisure-oriented scenarios with low sustainability awareness show less restrained portioning and higher waste outcomes. In the ABM, waste emerges from a sequence of interconnected choices rather than a single conscious decision. This aligns with the MOA framework (van Geffen et al., 2020), which conceptualises FW as the unintended outcome of iterative decisions shaped by internal drivers and external conditions.

For plate size (RQ1), the simulations indicate a multistep effect. Consistent with previous findings (Wansink & van Ittersum, 2013), larger plates induce larger initial portions because they shift the visual norms of appropriate portion upwards. This happens especially for leisure guests. Conversely, business guests partially resist the visual cue, reflecting the ABM assumption of stronger self-regulation. Larger plates reduce refills, suggesting that guests perceive their initial portion as sufficient. However, the higher overall quantity taken leads to more PW when portion size and refills are considered. When direct and indirect effects are combined (Total-effect Leftovers model), the net impact becomes small. This highlights a compensatory behavioural mechanism: interventions that reduce one waste-related behaviour (e.g., refills) may simultaneously increase another (e.g., initial portion size), ultimately limiting the net effect on PW.

Compared with earlier ABM studies that primarily focused on plate size in isolation (Ravandi & Jovanovic, 2019), our results highlight the importance of modelling multiple interacting psychological, behavioural, and contextual drivers. Rather than directly reducing waste, plate size interventions in this ABM primarily shape how and when food is taken, with downstream effects that depend on clientele structure and implemented interventions. This broader modelling perspective helps explain why apparently effective nudges may fail to produce substantial waste reductions once behavioural pathways and compensatory dynamics are taken into account.

Communication messages (RQ3) show context-dependent effects. In the simulations, provocative messages initially reduce first servings but later increase refilling and total waste. This pattern illustrates a form of psychological reactance embedded in the ABM and aligns with theoretical expectations (Brehm & Brehm, 1981). Positive messages, in contrast, show modest direct effects. Positive framing reduces PW primarily under conditions of high sustainability awareness and balanced guest mixes. This indicates that the effectiveness of communication interventions depends strongly on the sustainability profile of the guest population.

Sustainability awareness (RQ4) and clientele structure (RQ2) are the most robust predictors of responsible behaviour in the ABM. While the negative association between sustainability awareness

and PW is theoretically expected (Stancu et al., 2016; Visschers et al., 2016), the simulations highlight how awareness interacts with other behavioural drivers. Higher sustainability awareness directly and indirectly reduces waste in the model, but more importantly it moderates how agents respond to behavioural interventions. In particular, sustainability-aware agents show greater compliance with positive messages and are less prone to compensatory behaviours along the portioning–refilling pathway. Business guests waste less, an outcome that follows from the ABM’s assumptions regarding efficiency norms and time constraints (Puga-Gonzalez et al., 2025). Looking at the behavioural pathway, higher self-control and conformity lead them to choose smaller initial portions and take fewer refills. Limited time further discourages large servings, since time pressure forces more goal-directed decisions. Overall, the lower PW observed among business guests reflects not a single causal factor but the interaction of social norms (conformism), individual capacities (self-control), and contextual constraints (time pressure), all of which reduce portion sizes and increase the likelihood of finishing served food.

Portioning behaviour (RQ5) acts as a key mediator. The relationships observed in the ABM between portion size, refills, and leftovers mirror those reported in canteen and restaurant studies (Berkowitz et al., 2016; Lorenz-Walther et al., 2019), but our modelling approach shows how these behaviours are sequentially linked. Synthesizing results from the first three models allows tracing how interventions influence behaviour at different stages, while the Total-effect Leftovers model quantifies their overall impact. Comparing the models clarifies how direct and mediated effects differ: some interventions (e.g., provocative messaging) appear effective at early stages but increase final waste once downstream behaviours are considered.

These results can be interpreted through a micro–meso–macro perspective. At the micro level, the ABM represents individual behavioural decisions in the consumption pathway (i.e., how much guests serve themselves, whether they return for refills, and whether they leave PW). At the meso level, these behaviours unfold in contextual conditions such as clientele structure, plate size, and the messaging strategy, which influence how individuals interpret nudges and constraints. At the macro level, aggregate PW emerges from the interplay of these micro decisions under specific meso conditions. The ABM and the scenario analysis link these levels: micro choices drive portion size and refills; meso factors shape decision-making; macro PW emerges from their interaction across scenarios.

A key insight is the presence of behavioural compensation: interventions that reduce one PW-related behaviour (e.g., refills) simultaneously increase another (e.g., initial portions), leading to unimportant net effects. This mechanism explains why certain nudges appear promising in isolation but fail to reduce waste in aggregate. These compensatory patterns emerge from the interaction of multiple

decision rules rather than from any single model assumption, suggesting that similar dynamics may arise in real-world settings.

The model suggests that effective nudges require an integrated view of how motives, opportunities, and abilities interact over time. Plate size adjustments alone are unlikely to achieve results if not paired with other cues that influence subsequent behaviour. Communication strategies should consider tone and audience: positive, value-consistent messages engage sustainability-oriented guests, while moralizing messages may backfire.

2.4.1 Limitations and future work

Some limitations must be acknowledged. First, results rely on simulation data calibrated through aggregated empirical observations. Many behavioural parameters (e.g., reactance thresholds, sensitivity to messages) are not empirically calibrated at the individual level. Outcomes partially depend on these assumptions, and future research should incorporate individual-level empirical data to calibrate the ABM. Second, the ABM focuses on PW and excludes hotel-level operational processes, such as overproduction or buffet management practices. Integrating these operational dynamics would provide a more comprehensive view of hospitality FW.

Third, while distinguishing between business and leisure guests captures important differences, empirical evidence on how these groups differ in food-related decision-making remains scarce. Field data capturing variations in motivation and time use could improve our modelling assumptions. Additionally, other sources of heterogeneity, such as age groups, dietary preferences, and cultural differences, were not included in the ABM to maintain parsimony. Their inclusion represents potential for future work.

Fourth, the 36 scenarios explored are a selection of combinations of factors, not covering, for example, the continuous variation of sustainability awareness or alternative message framings. More extensive scenario simulation could display additional results.

Finally, as presented by Puga-Gonzalez et al. (2025), calibration data were collected in a single country, potentially limiting the generalizability of results to other cultural or regional contexts.

This work addresses conceptual and methodological issues noted by Puga-Gonzalez et al. (2025). Nevertheless, future research should continue combining empirical observation, cross-cultural data, and advanced simulation techniques to enhance external validity and theoretical integration.

2.5 Conclusions

This study investigated, within a simulation framework, how individual characteristics, contextual factors, and portioning behaviours interact to shape PW in hotel breakfast buffets, based exclusively

on outputs generated by an agent-based model. We analysed these simulated outputs through four interconnected regression analyses, used as metamodels to formally summarise and decompose behavioural pathways encoded in the model. Results show that, within the ABM, PW does not derive from a single decision but emerges from a chain of interconnected behavioural steps. These conclusions reflect patterns generated within the ABM structure and are intended to inform theoretical reasoning about behavioural interactions and compensatory mechanisms, rather than provide empirical estimates.

The primary contribution of the study is to demonstrate how behavioural pathways and compensatory dynamics emerge from the interaction of multiple drivers within a simulation framework. Within the ABM simulations, sustainability awareness and clientele structure act as structural background conditions that shape how behavioural interventions unfold. In particular, sustainability awareness moderates the effectiveness of communication strategies and influences how guests respond across the portioning–refilling pathway. Communication strategies' effectiveness is context-dependent: positive messages support conscious behaviour under the simulated conditions, while provocative messages can backfire and lead to choices that increase waste. Plate size influences when and how guests serve food, but larger plates are connected to compensatory mechanisms that reduce their overall simulated impact.

The research extends the Establishment Diner agent-based framework (Puga-Gonzalez et al., 2025) by using it as a virtual experimentation platform to explore behavioural mechanisms that are difficult to isolate empirically. The scenario-based approach highlights interactions and compensatory pathways that may remain hidden in real-world field settings due to observational constraints. By connecting micro-level decision rules with macro-level aggregate outcomes, the ABM illustrates how interventions modify behavioural pathways within a controlled simulation environment. Practically, these simulation-based findings provide indications that plate size alone may be insufficient, that messaging should be aligned with guest profiles, and that increasing sustainability awareness emerges as a robust lever within the ABM structure.

Thanks to its structure, the Establishment Diner ABM can support future exploration of operational, behavioural, and communication strategies in different hospitality contexts. Future work should integrate individual empirical data and hotel operational dynamics to guide the design of more robust, evidence-based interventions for sustainable hospitality management.

CRediT authorship contribution statement

Caterina Rettore: Writing – original draft, Writing – review/editing, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Software. **Larissa L. Lima:** Writing – original draft, Writing – review/editing, Conceptualization, Data curation, Investigation, Methodology, Software, Validation, Visualization. **Ivan Puga-Gonzalez:** Conceptualization, Investigation, Methodology, Software, Writing – review and editing. **Filippo Pini:** Conceptualization, Visualization, Investigation, Methodology, Writing – review and editing. **Paulina Szwed:** Conceptualization, Investigation, Writing – review and editing. **Patrycja Antosz:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Writing – review and editing. **Matteo Vittuari:** Conceptualization, Funding acquisition, Methodology, Project administration, Writing – review and editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Declaration of generative AI

During the preparation of this work, the authors used ChatGPT to improve the readability of the text. After using this tool, the authors carefully reviewed and edited the text generated and take full responsibility for the content of the manuscript.

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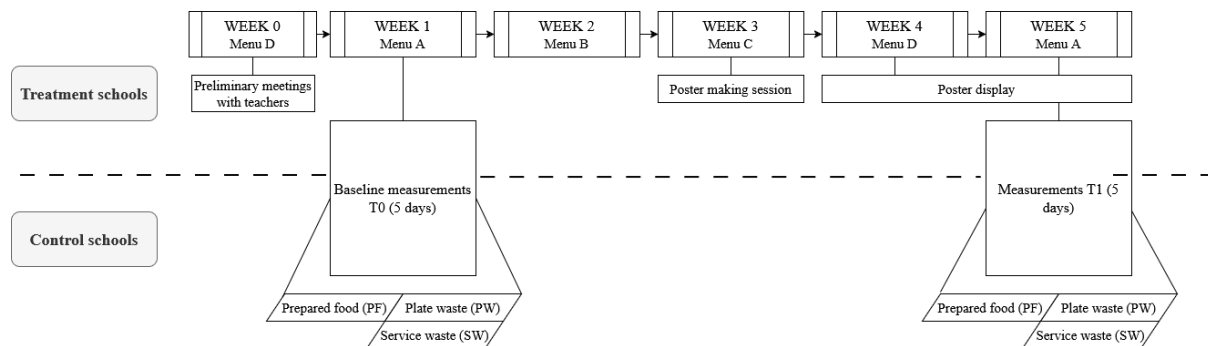
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Chapter 3

Do Social Norms Shape Food Waste Behaviour in Primary School Canteens? Experimental Evidence from a Cluster Randomized Controlled Trial

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Intervention and data collection process

Do Social Norms Shape Food Waste Behaviour in Primary School Canteens? Experimental Evidence from a Cluster Randomized Controlled Trial

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Abstract

School canteens are key settings for promoting healthy and sustainable eating behaviours among children. Increasing vegetable consumption is a central component of healthy diets and contributes to reducing the environmental and nutritional burden associated with food waste. In shared eating environments such as school canteens, social norms represent a promising behavioural lever, as children's food choices are strongly influenced by peers and perceived group behaviours. We conducted a large-scale cluster randomized controlled trial in 22 Italian primary schools to test a participatory descriptive social norm intervention aimed at reducing vegetable plate waste. The intervention combined a classroom co-design activity, in which 9-year-old pupils created posters conveying a normative message about vegetable consumption, with a two-week poster display in school canteens.

Using pre- and post-intervention measurements of plate waste, we assessed both average effects and short-term temporal dynamics under routine school canteen conditions. Results show no evidence that exposure to the social norm poster reduces vegetable plate waste on average. Instead, short-lived and context-specific deviations emerge, including increases in plate waste in some territorial areas. Exploratory analyses suggest that potential positive responses may be limited to rural schools, although these findings are non-causal and based on small subsamples. By providing one of the first large-scale randomized field evaluations of a social norm intervention targeting children's eating behaviour, this study highlights the limitations of norm-based messages when scaled up and highlights the need for more intensive,

context-sensitive, and multi-component approaches to support healthy and sustainable eating in schools.

Keywords

School canteens, Intervention, Healthy diets, Children behaviour, Descriptive norm, Food waste

3.1 Introduction

The prevalence of obesity and overweight is increasing worldwide. In 2022, 43% of adults were overweight, including 16% living with obesity. A steady rise in these figures is observable compared to 1990 data, when 25% of adults were overweight (WHO, 2020). Looking at children and adolescents aged 5-19, the prevalence of overweight and obesity has increased from 8% in 1990 to 20% in 2022. These health conditions are caused by the combined effects of excessive energy intake and insufficient energy expenditure through physical activity. Adopting healthy diets plays a pivotal role in lowering the probability of incurring in obesity and related non-communicable diseases (NCDs) as cardiovascular diseases and diabetes (Jannasch et al., 2024; Shan et al., 2020).

Addressing overweight and obesity is closely aligned with different United Nations Sustainable Development Goals (SDGs), particularly SDG 3 (“Good Health and Well-being”), which aims to ensure healthy lives and promote well-being for all at all ages. Promoting healthy diets also contributes to SDG 2 (“Zero Hunger”), by encouraging sustainable food systems and improved nutrition, and to SDG 12 (“Responsible Consumption and Production”), by fostering healthier and more sustainable dietary patterns. Additionally, reducing the burden of NCDs linked to obesity supports progress towards SDG 10 (“Reduced Inequalities”), as the prevalence of obesity disproportionately affects lower-income populations and vulnerable groups (Candio et al., 2023; WHO, 2022).

At the same time, food waste (FW) represents a major global challenge. It has been estimated that 19% of food reaching the final stages of the supply chain is wasted at the household, food service, and retail level (UNEP, 2024). The overproduction, overconsumption, and subsequent discarding of food not only exacerbate environmental pressures (Conrad et al., 2018) but also undermine efforts to achieve nutritional balance (Brennan & Browne, 2021). Tackling both unhealthy diets and FW is therefore essential to advance public health and sustainability goals.

The consolidation of healthy eating habits in children is essential to lower the probability of developing diseases during adulthood (Saavedra & Prentice, 2023; WHO, 2016). The need to educate children on healthy eating practices is recognized by the World Health Organization, which also advocates for the development of “school policies and programmes that encourage children to adopt and maintain a healthy diet” (WHO, 2020). In fact, schools have been identified as a strategic setting in which to promote the adoption of healthy eating patterns and the transition towards more healthy, sustainable, and equal food systems (MUFPP, 2024). In addition to ensuring balanced and adequate nutrition, school meals can also serve as educational tools for pupils, enhancing their awareness and comprehension of healthy diets (Oostindjer et al., 2017). At the institutional and policy level, there are several recommendations on how to improve school meal systems, such as developing dietary guidelines and adapting regulations to make healthy and sustainable diets accessible (MUFPP, 2024).

Healthy diets are characterized by a limited intake of sugars and fats, coupled with a sufficient consumption of fruit, vegetables, pulses, and cereals (Gherasim et al., 2020). Most countries have developed national nutritional guidelines to promote healthy diets, in accordance with the respective local traditions (FAO, 2025). In Italy, the national dietary guidelines provide recommendations covering all age groups, from infants to the elderly (CREA, 2019). With the identification of 13 recommendations, the national guidelines are organized into four thematic blocks, addressing dietary balance, foods to be increased (such as fruits, vegetables, and pulses), foods to be limited (including fats, salt, sugar, and alcohol), and practical guidance on how to ensure a varied, safe, healthy, and sustainable diet. Concerning fruits, vegetables, and pulses, the guidelines suggest eating at least 5 portions of fruit and vegetables per day, and 2-4 portions of pulses per week. Building on the national nutritional guidelines, additional guidelines have been developed to provide recommendations specifically for the school canteen context at the national (Ministero della Salute, 2021) and regional level (e.g., Regione Emilia-Romagna, 2023; Regione Veneto, 2021). In particular, the national school canteens guidelines recognize that school meals should be designed to provide approximately 35% of the average daily energy requirement. Based on this, they recommend using the school catering service as a mean of education and communication with families about healthy nutrition. Despite these policy efforts, a national study conducted in Italy in 2023 (OKkio alla SALUTE, 2024) highlights that 25.9% of children aged 8 years old do not consume fruits and vegetables daily, and 37% consumes pulses less than once a week. In parallel, the picture that emerges

highlights that 19% of Italian children are overweight and 9.8% are obese, including 2.6% with severe obesity.

In addition to the inadequate intake of healthy foods, FW in schools also represents a significant issue. Boschini et al. (2018) document that 22% of the food prepared is wasted by children. The most wasted dish is the side vegetables dish, as also confirmed by Petruzzelli et al. (2025), who report that 53% of the served vegetables end up wasted. FW in school canteens is influenced by a combination of factors. Studies have identified determinants such as catering provider, portion sizes, menu composition, food quality, and sensory acceptability, as well as organizational and social aspects, including the presence of teachers during meals and school policies (Boschini et al., 2020; Martins et al., 2020; Zhao et al., 2019). Addressing these factors is essential to reduce FW while ensuring adequate nutritional intake.

Despite growing interest in behavioural interventions targeting children's eating habits, evidence on social norm-based strategies in real-world school meal settings remains limited. Existing studies often rely on small samples, quasi-experimental designs, or controlled laboratory environments, limiting both causal inference and external validity. Furthermore, limited evidence exists on whether participatory approaches, such as involving children in the creation of normative messages, can enhance engagement and intervention effectiveness when implemented at scale.

To address these gaps, this study evaluates the impact of a participatory descriptive social norm intervention implemented through a large-scale cluster randomized controlled trial in Italian primary school canteens. The intervention combines a classroom co-design activity, in which pupils create posters communicating a normative message about vegetable consumption, with a subsequent exposure phase in school canteens. In recent years, the Emilia-Romagna (Italy) Regional government has been actively interested in evidence-based strategies to reduce FW and promote healthy eating behaviours within primary school canteens. To this end, a permanent regional laboratory has been established (Emilia-Romagna Region, 2023), bringing together researchers, public authorities, caterers, and educators to collaboratively design, implement, and evaluate interventions. Building on a first RCT presented in Petruzzelli et al. (2025), the Regional government supported this second large-scale RCT. The study assesses whether exposure to a co-designed social norm poster can influence children's vegetable consumption and reduce plate waste under real-life school meal conditions. Pupils in treatment schools participated in the poster design activity, with instructions to include the assigned social norm message, and the posters were subsequently displayed near class tables in school canteens.

The trial involves 22 randomly selected schools, with a final sample of 653 pupils, and adopts direct food waste weighing as the primary outcome measurement, following the methodology used in Petruzzelli et al. (2025). Direct weighing is widely recognised as one of the most accurate methods for measuring food waste (Boschini et al., 2018; Falasconi et al., 2025; Martins et al., 2014). Given that food portions served in school canteens are based on nutritional recommendations, plate waste measurements also provide an indirect assessment of whether children's intake aligns with nutritionally adequate diets.

By providing one of the first large-scale randomized field evaluations of a participatory social norm intervention in school meal settings, this study contributes to the behavioural and policy literature on promoting healthy and sustainable dietary behaviours among children.

To contextualise the study within the existing evidence base, the following section reviews previous school-based interventions aimed at promoting healthy eating and reducing food waste, with a particular focus on social norm-based approaches targeting children's dietary behaviour.

3.2 State of the art: social norm interventions in school eating contexts

Schools have long been recognised as key environments for promoting healthy dietary behaviours among children. In the past decades, school-based policy initiatives and interventions aimed at promoting healthy nutrition have multiplied. School-based interventions can take different forms: nutrition education programs targeting both teachers (Panunzio et al., 2011) and children (Jung et al., 2019; Moss et al., 2013); experiential learning approaches (Poelman et al., 2020); fruit and vegetable direct provision (Chellappah et al., 2015; Olsho et al., 2015), nutrition standards (Johnson et al., 2016), choice architecture/nudging (Marcano-Olivier et al., 2019; Petruzzelli et al., 2025); portion size modification (Smethers et al., 2019); gamification approaches (Hermans et al., 2018). In other cases, multi-component interventions combining more than one strategy were implemented (Calvert et al., 2018). These strategies have resulted in mixed results. For example, Dudley et al. (2015) found that many teaching strategies in primary schools achieved small improvements in fruit and vegetable consumption, but the overall impact on dietary behaviours was modest and varied considerably. More recently, the review by Durão et al. (2024) reported that interventions targeting the school food environment, such as nutrition standards, portion control, and nudges, showed beneficial effects on different healthy eating outcomes, but these were often small and context dependent. Further, Karpouzis et al. (2025) highlighted that programs yielding positive changes in fruit

and vegetable intake incorporated experiential components (e.g., gardening, cooking, tasting), emphasizing that the inclusion of environmental education alongside nutrition may enhance effectiveness.

In some interventions, social norm-based strategies have been tested to encourage healthier eating behaviours, but the need to further test these strategies in large scale randomized-controlled trials (RCTs) is recognized (Higgs et al., 2019). Social norms are “unwritten codes and informal understandings that define what we expect of other people and what they expect of us” (Young, 2015) and are context dependent (Rimal & Lapinski, 2015). Eating social norms guide food choices and consumption amounts within a social group and can influence what, how much, and how often people eat, as well as the willingness to try new foods (Binder et al., 2019; Sharps et al., 2021). Building on this understanding, several interventions have tested social norm-based strategies to influence eating behaviours (Robinson et al., 2014). Social norm-based interventions are designed to modify individuals’ perceptions of what behaviours are typical or socially approved within a given group. They are based on the idea that people often misperceive the prevalence or approval of certain behaviours, and that such misperceptions can lead them to a distorted norm (Lewis & Neighbors, 2006; Rhodes et al., 2020). By correcting these normative misperceptions, social norm-based interventions aim to reduce harmful behaviours (e.g., excessive alcohol drinking) or promote healthier alternatives, such as choosing fruits and vegetables or reducing FW, suggesting that these behaviours are more common and socially approved than individuals might assume.

A growing body of research has explored how social norms influence children’s eating behaviours. Experimental and observational studies have shown that children tend to model their food intake and food choices based on the eating behaviours of peers and adults in their immediate social environment (Haß & Hartmann, 2018; Lehto et al., 2016; Sharps & Robinson, 2015). Therefore, leveraging social influence through social norm-based strategies has emerged as a promising approach to encourage healthier eating in school settings. However, despite this potential, few studies have examined how social norms can be effectively activated within real-life school settings (Table 3.1).

Previous social norm-based interventions in school settings have applied a variety of strategies, from peer modelling videos (Horne et al., 2004; Lowe et al., 2004) and adult modelling (Machado et al., 2020), to in-presence delivered norm messages (Khan et al., 2022), and social norm posters (Calvert et al., 2018; Hang et al., 2020). All the identified studies relied on quasi-experimental or mixed-method designs, with schools selected through convenience sampling, group assignment not randomized, and, in one case, the absence of a control group (Machado

et al., 2020), which limits the ability to draw causal conclusions. Only Hamdi et al. (2020) include a partial randomization at the individual level. Sample sizes varied considerably, usually encompassing only one to three schools. Three interventions incorporated multiple components (Hamdi et al., 2020; Horne et al., 2004; Lowe et al., 2004), making it difficult to isolate the specific effect of the social norm element. Methods for assessing interventions' effectiveness were heterogeneous, including visual estimation (Horne et al., 2004; Lowe et al., 2004; Machado et al., 2020), self-reports (Calvert et al., 2022; Hang et al., 2020; Khan et al., 2022; Lowe et al., 2004), and occasionally weighing (Hamdi et al., 2020; Horne et al., 2004). Outcomes measured included both actual consumption (Hamdi et al., 2020; Horne et al., 2004; Lowe et al., 2004; Machado et al., 2020) and broader behavioural or attitudinal indicators such as liking, intended consumption, and perceptions of peers' norms (Calvert et al., 2022; Hang et al., 2020; Khan et al., 2022; Lowe et al., 2004). Prior research suggests that social norm-based strategies can positively influence children's dietary choices, but methodological heterogeneity and limited scale restrict generalizability. No previous study has tested social norms in a large-scale, randomized controlled trial in school canteens, leaving a research gap that our study aims to address.

Table 3.1: Previous articles implementing a social norm-based intervention to influence children's eating behaviours at school.

Article	Type of social norm-based intervention	Experimental design	Setting	Random sample selection	Group assignment randomization	Sample size	Participants age	Multi-component intervention	Measurement method	Outcome variables	Results
Horne et al. (2004)	Peer-modelling (video)	Quasi-experimental	School canteen	No	No	2 schools, 749 children	5-11	Yes (reward)	Lunchtime: visual estimation on a five-point scale; Snacktime: weighting; Home: parental recall	F&V consumption at lunchtime and fruit at snacktime	↑ F&V consumption at lunch, snack, and home during intervention and follow-up.
Lowe et al. (2004)	Peer-modelling (video)	Quasi-experimental	School canteen	No	No	3 schools, 402 children	4-11	Yes (reward)	Lunchtime and snacktime: visual estimation on a five-point scale; Home: parental recall; Survey	F&V consumption and liking	↑ F&V intake and liking during intervention; partial maintenance post-intervention.
Hang et al., 2020	Descriptive and injunctive social norms (assigned poster)	Quasi-experimental	Controlled school setting	No	N/A	3 schools, 405 children	7-16	No	Survey; binary coding (healthy/not healthy)	Healthy food: intention to eat and food choice	Descriptive and injunctive authority norms, ↑ healthy eating intentions; Descriptive norms ↑ healthy food choice.
Machado et al. (2020)	Adult-modelling	Quasi-experimental	School canteen	No	No	1 school, 797 children	4-11	No	Visual estimation	F&V consumption	↓ Complete fruit waste and ↑ full fruit consumption; ↑ full vegetable consumption and ↑ vegetable selection.
Hamdi et al. (2020)	Descriptive social	Explanatory sequential	School canteen	No for schools,	No	3 school	5-14	Yes (cafeteria decorations,	Direct weighting	F&V intake	Mixed effects: ↑ fruit and vegetable

	norming taste test	mixed- methods design		yes for children		s, 760 studen ts		creative names, and flavor station)	(Once per month)		selection in some schools/interventio n phases.
Calvert et al. (2022)	Descriptive social norm (co-designed poster)	Quasi- experimental	Class	No	No	2 school s, 258 childr en	11-12	No	Self-reported	Unhealthy snacking, related attitudes, behavioural intentions, normative perceptions	↓ Consumption and behaviour towards unhealthy; reduced misperception of peers' norms.
Khan et al. (2022)	Descriptive prescriptive, and proscriptive social norms from teachers and peers	Quasi- experimental	Class	No	No	1 school , 132 (study 1), 189 (study 2)	11-12	No	Self-reported	Healthy and unhealthy food intake	Proscriptive compliance norms lead to ↑ fruit choice vs. candy; strongest when reinforced by supportive peer conformance.
This research	Descriptive social norm (co-designed poster)	Randomized Controlled Trial	School canteen	Yes	Yes	22 school s, 653 childr en	9	No	Direct weighting	First, second, side dish plate waste	No effect of the intervention on vegetable plate waste.

3.3 Theoretical background

Food choices are particularly sensitive to social influence because they are closely related to social identity, cultural learning, and social interaction (Higgs, 2015). Social norms guide individual actions even in the absence of formal rules or coercion (Bicchieri, 2017; Cialdini & Trost, 1998). These norms operate through explicit channels, such as messages or verbal feedback (Claassen et al., 2023; Khan et al., 2022), and through implicit channels, such as observation of others' behaviours or environmental cues (Binder et al., 2019). In the context of eating, social norms act as cognitive shortcuts that simplify decision-making in uncertain settings (Higgs, 2015), particularly for children, who rely heavily on social learning to understand and internalize behavioural patterns (Hang et al., 2020; Houldcroft et al., 2014).

A central distinction within social norms theory differentiates descriptive norms, which indicate what others typically do, from injunctive norms, which communicate what others approve or disapprove of (Cialdini et al., 1990). Research shows that children and adolescents are highly responsive to descriptive norms: when they believe that others eat fruits or vegetables, they tend to increase their own consumption (Lehto et al., 2016; Sharps & Robinson, 2015). Overestimating peers' intake of unhealthy foods is associated with higher intake as well (Calvert et al., 2021; Lally et al., 2011). Injunctive norms, on the other hand, influence behaviour most effectively when they reflect approval from groups such as friends or classmates (Ragelienė & Grønhøj, 2020a). However, when perceived as overly prescriptive or controlling, normative messages may trigger psychological reactance, especially during adolescence (Stok et al., 2014). Social norms theory highlights the role of pluralistic ignorance, a process in which individuals misperceive others' attitudes or behaviours and adjust their own behaviours to these inaccurate beliefs (Miller & McFarland, 2024). In food-related contexts, children may underestimate how many classmates actually like vegetables or approve of finishing one's plate, concluding that healthy eating is less common or less valued than it is, and aligning their behaviour with this distorted norm.

Social norms shape children's eating behaviour through several underlying social and psychological processes. The first pathway involves imitation and social modeling. Grounded in social learning theory (Bandura, 1977), this process operates when children observe others eating certain foods and reproduce those behaviours. Experimental studies show that children eat more vegetables when told that peers have done so (Sharps & Robinson, 2015) and that also the exposure to videos of peers choosing healthy foods increases the selection of those foods (Horne et al., 2004). These modeling effects are especially pronounced in shared eating

contexts, such as school cafeterias, where visible behaviours and social monitoring create pressure to replicate others' intake (Herman et al., 2003; Higgs, 2015).

A second process relates to the desire for social approval and conformity. Children often align their behaviour with social norms to gain acceptance and avoid exclusion from a group (Cruwys et al., 2015; Stok et al., 2014). Group identity plays a crucial role in determining the strength of normative influence. This mechanism is more relevant during childhood and adolescence, when peer relationships become central (Foulkes et al., 2018; Ragelienė & Grønhøj, 2020b). Social norms are more powerful when they come from groups with which children identify strongly, such as classmates or friends (Cruwys et al., 2012; Liu et al., 2019). Eating together reinforces group cohesion and provides opportunities for mutual observation (Higgs & Thomas, 2016), making school mealtimes a suitable opportunity for social influence. Children who identify strongly with their class or school are also more responsive to normative messages in school settings (Giese et al., 2015).

A third pathway concerns the reduction of uncertainty. In ambiguous situations, such as when facing unfamiliar foods or novel eating contexts, individuals use social cues to guess what is appropriate to eat (Robinson et al., 2013). Observing others trying new foods can decrease food neophobia and increase willingness to taste (Addessi et al., 2005).

The relative influence of these mechanisms changes across developmental stages. In early childhood, eating practices are guided by observational learning: children tend to imitate the visible behaviours of peers and adults without distinguishing between what is common and what is socially approved (Addessi et al., 2005; Foulkes et al., 2018). As they grow up, children develop greater sensitivity to others' expectations and begin to integrate both descriptive and injunctive information in their eating choices. During adolescence, social identity and peer belonging become particularly salient, increasing sensitivity to peer-based descriptive norms and reducing it for messages that may be perceived as controlling (Stok et al., 2014).

Social norms are used to implement behavioural change strategies, to steer individuals' behaviour in the direction of a desired outcome (McAlaney et al., 2010). Interventions based on social norm theory aim at challenging pluralistic ignorance by reporting the behaviours or attitudes of a referent group (Dempsey et al., 2018). The evidence outlined above shows that social norms influence children's eating behaviour. Interventions that make healthy eating look both common and socially accepted within peer groups, rather than simply recommended by adults, are particularly promising for promoting healthy choices and reducing FW in school settings. However, social norm-based interventions must take into consideration some aspects to increase their probability of success (Berkowitz, 2005). It is important to increase the

salience of the social norms message by tailoring it to the specific target group (Cialdini et al., 1990). Then, the message should report credible information for it not to be immediately rejected as false (Dempsey et al., 2018).

Building on the theoretical and empirical literature on social norms and children's eating behaviour, we evaluate whether a descriptive social norm intervention, delivered through a participatory poster co-design activity, affects vegetable consumption in primary school canteens. Specifically, we test whether exposure to the intervention reduces the plate waste of vegetables, compared to a control group.

Given the intervention design and objectives, hypotheses are organized into primary (H1a-b, H2), secondary (H3), and exploratory (H4).

- H1: The exposure to a descriptive social norm message about vegetable consumption, through a poster co-design activity and its display in the canteen, influences side dish plate waste (SiD PW%) in treated classes, specifically:
 - a) We expect a reduction in SiD PW% on the whole sample.

Side dishes, normally composed of vegetables, constitute the primary outcome of the study. The intervention was explicitly designed to target children's vegetable consumption, which prior evidence identifies as the most wasted course in school canteens (Petruzzelli et al., 2025). As such, SiD PW% represents the most behaviourally sensitive and plausible outcome for detecting intervention effects.

- b) The effect of the intervention on SiD PW% is heterogeneous across territories.

Differences in canteen organization, menu composition, and implementation contexts across territorial areas may moderate the effectiveness of behavioural interventions, as previously observed in similar school-based RCTs (Petruzzelli et al., 2025).

- H2. Any reduction in SiD PW% induced by the intervention emerges immediately after exposure and tends to attenuate over time.

The effect of normative messages may diminish over time in the absence of reinforcement. Consistent with the logic of Ebbinghaus's forgetting curve (Murre & Dros, 2015), pupils' reaction to the intervention is expected to be stronger immediately after exposure and to weaken afterwards.

- H3. The intervention does not have a direct effect on PW% for:
 - a) First dishes (FD)
 - b) Second dishes (SeD).

First and second dishes were not targeted by the intervention. Any observed changes in FD or SeD PW% would therefore reflect indirect spillover effects rather than direct behavioural responses to the social norm message.

- H4. Receiving a second serving is positively associated with plate waste across different courses.

Second servings may reflect over-serving relative to children's actual appetite or induce incomplete consumption, leading to higher PW. Post hoc analyses related to second servings are exploratory and aimed at providing insight into potential behavioural mechanisms underlying observed patterns of PW.

3.4 Methods

3.4.1 Sampling and participants

The study was conducted in a statistically representative sample of primary schools in the Emilia-Romagna Region (Italy). Schools are the sampling units, considering that each school's canteen practices are organized at that level. To strengthen our sampling approach and ensure territorial heterogeneity, we constructed samples representative at regional level. The Emilia-Romagna Region is divided into three so-called Vast Areas (hereafter, Areas), i.e. supra-local administrative groupings within the Regional Health Service designed to coordinate healthcare provision. Within each Area (A), schools were sampled proportionally to the number of eligible schools in each Local Health Authority (AUSL), which constituted the stratification level for the selection process (Supplementary Table III.A). By following the CONSORT guidelines (Moher et al., 2012), this study adopts a cluster RCT design in which the population is defined at the Area level, AUSLs serve as stratification units, schools constitute the randomization units, and fourth-grade classes represent the measurement units (Table 3.2).

Table 3.2: Sampling structure in the study

Level	Role	Description
Area (A)	Population level	A random sample of schools was drawn within each of the three regional Areas.
Local Health Authority (AUSL)	Stratification level	Each AUSL served as a stratification layer for school selection, ensuring proportional representation within Areas.
School	Cluster (randomization unit)	Schools were the units randomized into intervention and control groups.
Fourth-grade class	Measurement unit	Outcomes were measured at the class level within each selected school.

In this work, 964 primary schools were assessed for eligibility. The sample size was determined through a power analysis for cluster randomized designs using the command *power twomeans* in Stata 17, which estimates the number of clusters required given cluster size, minimum detectable effect, statistical power, and the intraclass correlation coefficient (ICC). Parameter values were derived from previous evidence on FW in primary schools (Antón-Peset et al., 2021; Iaia et al., 2016; Petruzzelli et al., 2025; Vidal-Mones et al., 2022). Specifically, we assumed: (i) an average per-capita vegetable-waste generation between 130 and 150 g/day; (ii) a minimum detectable reduction of 10–30 g; (iii) an ICC ranging from 0.01 to 0.05; and (iv) an average cluster size of 35–50 students (considering only fourth-grade classes). Under these assumptions, a sample of 30 schools, 10 per Area, was determined to provide adequate statistical power for detecting the expected intervention effects. Eligible schools were required to have at least one fourth-grade class, a full-time schedule including five days/week canteen services. Fourth-grade classes not using the canteen from Monday to Friday were excluded from the study. Schools with mixed-age classes were excluded. Schools were randomly allocated to either the treatment group, where the social-norm co-design activity and poster exposure were implemented, or the control group, which received no intervention. The group assignment was not masked. Sampled schools were contacted between December 2024 and February 2025 to confirm eligibility and participation. Because complete information on school characteristics was not available before sampling, 10 sampled schools identified ex post as non-eligible were replaced through re-sampling within the same stratum (AUSL). 9 schools refused to participate and were then resampled. While this procedure preserves the randomized design, it may marginally reduce the representativeness of the original sample, as replacement was not random with respect to participation willingness. There was one protocol deviation, related to 7 randomly selected schools which did not confirm participation within the required timeframe.

Given the tight operational schedule of the intervention, it was not feasible to resample additional schools to replace them. All 7 schools belonged to the same Area (A2) and AUSL. Consequently, the final sample for A2 fell below the intended target and is not fully representative of the population, while samples for A1 and A3 remained unaffected. Our final sample counted 22 primary schools and 37 fourth-grade classes. In the treatment (control) group, 23 (14) fourth-grade classes from 11 (11) schools received the intervention (Supplementary Figure III.A, Supplementary Table III.B). The sampling process is presented in Figure 3.1.

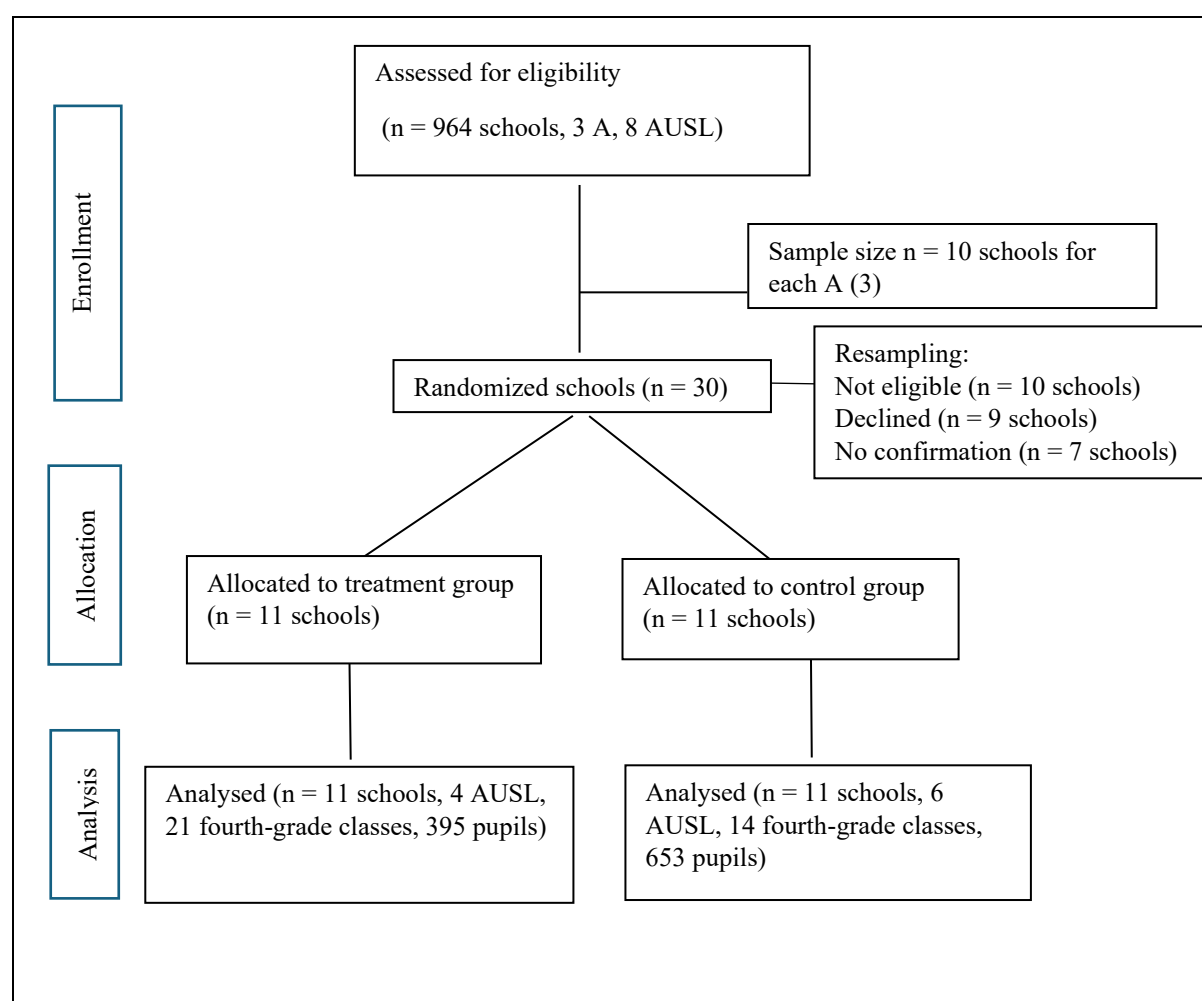


Figure 3.1: Sampling process based on CONSORT guidelines (Moher et al., 2012)

3.4.2 Intervention co-design

The intervention followed a systematic co-design process embedded in the Regional Laboratory for Sustainable School Catering (LaRiSo), whose characteristics are described in Petruzzelli et al. (2025). Stakeholders included nutrition experts, public health professionals, and academic researchers. Stakeholder engagement took place through three preliminary meetings held between October 2024 and February 2025. The first meeting introduced the

concept of social norms and initial intervention proposals, which were evaluated by stakeholders; the second meeting presented a more advanced intervention design incorporating stakeholders' feedback; and the third focused on methodological and operational aspects. A key outcome of this process was the identification of fourth-grade classes as the target group. Stakeholders agreed on this choice for two reasons. First, developmental considerations indicate that sensitivity to peer behaviour and social norms becomes more important with age. Second, fifth-grade classes were excluded for feasibility reasons: in the Italian school system, the final year of primary school is typically characterized by intensified curricular activities and multiple end-of-cycle projects, which limit classes' capacity to engage in additional activities. Following these collective meetings, a series of individual ones were conducted with representatives from each AUSL to adapt the intervention to local organizational contexts and to collect all practical information required for implementation (e.g., school-specific menus, meal-service arrangements). Then, food catering services were contacted to inform them of the intervention and ensure their logistical support (e.g., provide separate trays for fourth-grade classes, weight prepared food).

Following consensus on the theoretical framework and intervention design, a descriptive social norm message, positively framed and referring to same-age peers as the normative source, was selected. Message design followed a semiotic analysis: we analyzed the symbolic representations children associate with vegetables, reconstructed the underlying value system using Floch's valorization square (Floch, 2001), and identified persuasive modalities (e.g., seduction, temptation) to enhance the motivational salience of the social norm (Supplementary Section III.7). The final normative message, defined by the research team, stated:

“Explorers and athletes have a secret: vegetables!

At school, children eat vegetables to have more energy and enjoy their day. Eat them too and discover their superpowers!”

The creative elements (slogan and drawings) were decided and included in the poster directly by children during the classroom co-design activity, ensuring participatory ownership and contextual relevance.

3.4.3 Procedure

The intervention was implemented between March and May 2025, preceded by a one-day pilot test in February 2025 to ensure operational feasibility. In treatment schools, teachers first attended two online training sessions. The first session provided an overview of healthy eating

principles. The second session introduced the co-design activity through an interactive simulation, with the active participation of teachers to collect their feedback.

The co-design activity with children followed standardized guidelines to ensure homogeneous implementation across classes (Supplementary Section III.8). It lasted approximately 120 minutes and entailed two complementary parts: first, teachers were asked to conduct an introductory module on healthy eating. This part aimed to engage children and provide basic knowledge on healthy nutrition. Using the Harvard Healthy Eating Plate (Harvard Health Publishing, n.d.), teachers explained the main food groups and the principles of composing a nutritionally balanced meal. Children were then assigned a dish each, asked to identify the main ingredients, and collocate them within the Healthy Eating Plate categories. Second, teachers guided children in producing the poster, providing them with the social norm message and inviting them to complete the poster with drawings and slogans reflecting their interpretation of the message. Teachers were encouraged to stimulate creativity and to ensure that the mandatory message was clearly incorporated. Guidance materials, including example posters, were available to support the activity (Supplementary Section III.8). The structure of the activity, including the introduction and creative production, was designed to both increase children's awareness of healthy eating and foster ownership of the intervention material to engage them with the social norm message, following the example of Calvert et al. (2018).

After completion, posters were displayed in the school canteen for two weeks. Control schools conducted no classroom activities and displayed no materials. Teachers and school staff were instructed not to disclose the aim of the study to children to avoid additional influences external to the intervention. To verify implementation fidelity, teachers were required to send photographs of the completed posters to the research team. Following the fidelity check, 4 classes did not include the assigned social-norm message on their posters. These classes were therefore exposed to an incomplete version of the intervention. In the main analysis, these classes were retained in the treatment group, while a robustness check excluding them is presented in the Supplementary Material.

3.4.4 Data collection

Measurement of FW was carried out during the first week (T0) for five consecutive days to collect baseline data. Following baseline, treatment classes implemented the co-design poster activity, during which children created the visual components of the social-norm poster (slogan and drawings) under teachers' guidance. The poster incorporated the researcher-defined normative message presented in Section 3.2. Teachers were instructed to implement the co-

design activity during the third week (i.e., two weeks before T1), and to display the poster in the school canteens for the fourth and fifth weeks. The post-intervention data collection took place during the fifth week (T1) for 5 consecutive days in both treatment and control schools. The intervention process is represented in Figure 3.2.

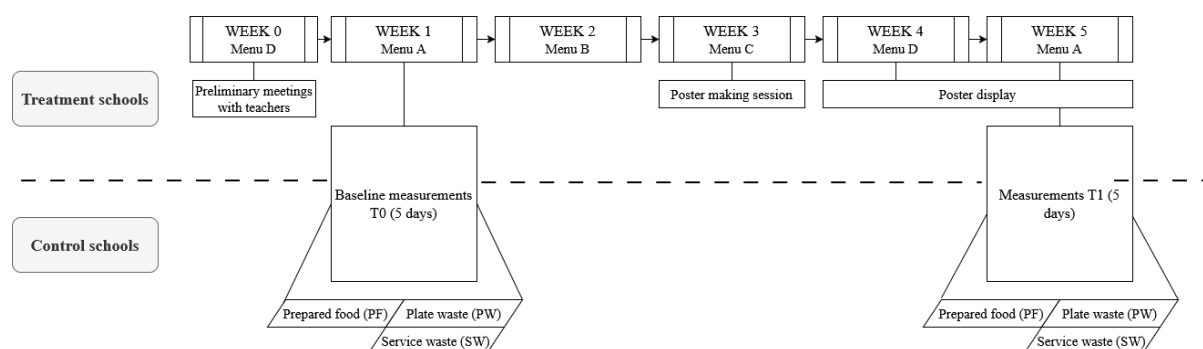


Figure 3.2: Intervention and data collection process in an exemplifying school with a 4-week menu rotation

To ensure comparability between baseline (T0) and post-intervention (T1) measurements, the measurement weeks and, consequently, the timing of the intervention, were defined separately for each school. The objective was to maximize similarity between the dishes served at T0 and T1, to reduce the chance that observed differences in FW could be induced by food preferences rather than by the intervention. Because menu rotation cycles differed across territories (ranging from 4-week rotating menus to annual menus, indicated in the figure as menu A, B, C, and D), this process led to variable time intervals between T0 and T1 across schools. Detailed timelines and menu seasonality for each school are provided in Supplementary Table III.C.

The data collection process followed the procedure detailed in Petruzzelli et al. (2025). For each fourth-grade class, prepared food (PF) was weighed before meals by the catering service operating in each school. After lunch, PW (edible food left uneaten) (Chapman et al., 2019) and service waste (SW, prepared but not distributed to children) (García-Herrero et al., 2021) were weighed separately for each dish and for each class. Children were asked to empty their plates into five bins dedicated to their specific class. Hence, five food categories were distinguished: first dish (FD), second dish (SeD), side dish (SiD, i.e., vegetables), bread, and fruit. During data cleaning, a deviation from the RCT protocol was introduced. In most schools, children were allowed to take bread and fruit home, and field operators reported substantial operational difficulties in distinguishing what portion of these items had been consumed or taken away. This issue generated non-systematic measurement errors, therefore the bread and

fruit categories were excluded from the analytical dataset. All analyses hence focus on FD, SeD, and SiD. Measurements were obtained through commercial digital scales and recorded in kilograms to three decimal digits. Depending on the catering system (class-level trays, school-level trays, or single-portion service), specific calculation rules accounted for tare weight and allowed to estimate served food $w_{c,SF}^{u,d}$ and consumed food $w_{c,CF}^{u,d}$ at the class level through Eq. 3.1 and 3.2, respectively:

(3.1)

$$w_{c,SF}^{u,d} = w_{c,PF}^{u,d} - w_{c,SW}^{u,d}$$

(3.2)

$$w_{c,CF}^{u,d} = w_{c,SF}^{u,d} - w_{c,PW}^{u,d}$$

where w represents the weight in kg per dish $c \in \{\text{FD, SeD, SiD}\}$ for each measurement (i.e. SF, SW, PW). For each class $u \in \{1, 2, \dots, 37\}$ daily $d \in \{1, 2, \dots, 10\}$ measurements were completed. In 18 classes, 9 days of measurement (instead of 10) were completed because of unplanned school closures due to strikes or field trips. In 6 schools (14 classes), meal distribution practices did not allow separation of trays for fourth-grade classes, preventing operators from weighing prepared food at the class level. In these cases, a single portion for each course was weighed, and the total class-level prepared food was estimated by multiplying the portion weight by the number of children. Service waste could not be estimated for these schools.

In addition to these measurements, data operators observed the number of children that asked for a second serving for each dish.

Data collection was implemented by field operators (i.e., researchers and dieticians), who were responsible for the delivery of blank posters and activity guidelines to teachers, the positioning of bins, and the weighing operations. Field operators attended a preliminary meeting and received guidelines explaining the data collection procedure.

The data collection protocol was reviewed and approved by the Ethics Committee of the University of Bologna on 30 January 2025 (Prot. N. 0048345).

3.4.5 Outcome measures

For each fourth-grade class, and for each serving day, the following quantities were measured at the aggregated class level: prepared food (PF), plate waste (PW), and service waste (SW) for the first dish (FD), second dish (SeD), and side dish (SiD). These measurements resulted in nine weight observations per class per day.

Then, each FD, SeD, and SiD was assigned to the standardized food categories adopted in Emilia-Romagna school menus (Regione Emilia-Romagna, 2023). This classification captures heterogeneity in preparation modes and perceived palatability, dimensions known to influence children's acceptance of foods (Donadini et al., 2022; Zanoni et al., 2026). Dummy variables were created for each dish category.

To assess intervention effects, we use the share of PW in the amount of food served to each class. For each course c , the outcome is defined in Eq. 3.3 as:

(3.3)

$$PW\%_c^{u,d} = \frac{w_{c,PW}^{u,d}}{w_{c,PF}^{u,d} - w_{c,SW}^{u,d}} \times 100$$

This measure normalizes PW with respect to the volume of food effectively received by children, thus allowing comparison across different menu items and service systems. Because recommended portion sizes and mass differ across food categories (e.g., soup is not comparable with pasta), absolute PW in grams would not provide a meaningful basis for comparison. 4.7% of measured weights³ fell outside the feasible range for PW% (i.e., <0% or >100%). The correction procedure for these data collection errors is detailed in Supplementary Section III.3

3.4.6 Data analysis

Data were analyzed in several steps, each corresponding to a specific set of hypotheses. The analytical strategy combines descriptive analyses, overall difference-in-differences (DiD) models, and dynamic event-study DiD to assess average treatment effects, temporal dynamics, spillover effects, and exploratory behavioural mechanisms.

First, descriptive statistics of sampled schools and classes were computed for treatment and control groups to assess baseline comparability and internal validity. To ensure comparability of menus between T0 and T1 periods, we examined the frequency distribution of standardized food categories (Supplementary Table III. D) within each course type. For each class, a food category was classified as a match if it appeared the same number of times at T0 and T1, and as a non-match otherwise. This procedure was conducted separately for FD, SeD, and SiD and serves to check menu consistency before estimating treatment effects.

Second, we computed descriptive statistics (mean, median, standard deviation, interquartile range) for plate waste percentages (PW%) for FD, SeD, and SiD across both groups before and

³ 2.48% FD, 2.52% SeD, 8.63% SiD

after the intervention. These statistics were calculated both at the level of each Area (A1 and A3) and for the full sample. The three schools located in A2 are included in the full-sample statistics, but we do not report separate A2 estimates because this subgroup is too small to be considered representative of that territorial area.

Third, to estimate average treatment effects on the treated (ATT) and address H1a-b and H3a-b, we employed a difference-in-difference (DiD) design. We used the augmented inverse probability weighting (AIPW) estimator implemented through the *xthdidregress* command in STATA 17 (Glynn & Quinn, 2010). Although treatment assignment was randomized, we adopted a DiD framework estimated via AIPW as a conservative robustness choice. Given the real-world implementation of the intervention and minor deviations from the experimental protocol (e.g., schools' refusal and resampling), AIPW helps reduce residual imbalance while preserving experimental identification, particularly in a short panel with strong class and day fixed effects. This approach provides a more robust estimator, which remains consistent if at least one of the propensity score models for treatment assignment or the outcome model is correctly specified, offering robustness advantages over traditional two-way fixed effects (TWFE) models (Kurz, 2021). We specified a model with individual fixed effects at the class level (α_u) and temporal fixed effects at the day level (λ_d), estimated on the full sample using plate waste percentages for each course separately (FD, SeD, SiD). Standard errors are clustered at the school level. The estimating equation (Eq. 3.4) is:

(3.4)

$$PW\%_c^{u,d} = \alpha_u + \lambda_d + \beta D_{ud} + \varepsilon_{ud}$$

where:

- $PW\%_c^{u,d}$: outcome variable (PW%) for class u at time d for each course $c = \{\text{FD, SeD, SiD}\}$
- α_u : class fixed effects
- λ_d : temporal (day) fixed effects
- D_{ud} : DiD indicator (treatment group $\times$ post-intervention period)
- β : average causal effect of the treatment
- ε_{ud} : idiosyncratic error

This overall AIPW analysis was conducted on the full sample of 35 classes ⁴ (H1a) and separately on each Area, to check for potential territorial heterogeneity of the effects (H1b).

⁴ Two classes that skipped the first day of measurement due to unexpected school closures were excluded to avoid complications from staggered treatment timing.

Estimates for FD and SeD allow us to assess hypothesis H3a-b regarding the absence of spillover effects on non-targeted dishes. Additionally, we performed a robustness check on the full sample excluding A2 schools. Another robustness check on the full sample involved the exclusion of the 4 classes with incorrect posters.

As an additional exploratory analysis, we investigated whether ATT differs across school contexts characterized by different levels of population density and settlement size (high-density vs low-density municipalities) within each Area. To do so, we estimated DiD models (Eq. 3.4) interacting the treatment indicator with a municipality density dummy (higher vs lower density) and, where feasible, conducted separate comparisons between treated and control classes within the same context. The sample was not stratified by municipality density, leading to small and unbalanced samples.

Fourth, to examine the temporal dynamics of treatment effects, test hypothesis H2, and complement the testing of H3a-b, we implemented a panel event-study analysis. In the overall model described in Eq. 3.4, we assume that the ATT is stable over time and that there are no differences between treatment and control classes before the intervention. With the panel event study, we verified the existence of parallel trends, we observed if and how the effect evolves at T1, and we identified potential anticipated or delayed effects and adaptive dynamics (e.g., learning or fatigue) (Callaway & Sant'Anna, 2021). We used the *eventdd* command in STATA (Clarke & Tapia-Schythe, 2021). The model was estimated using high-dimensional fixed effects (HDFE) (Correia, 2017), absorbing class and day fixed effects. Standard errors were clustered at the school level.

This approach estimates treatment effects period-by-period relative to the day before intervention exposure, transforming the time variable into relative distance from the start day ($event_time = treat_day - 6$, where $treat_day$ ranges from 1 to 10)⁵, yielding leads and lags from -5 to +4 (with $k=0$ as the first treatment day)⁶. The model (Eq. 3.5) compares the outcome variable evolution between treatment and control groups, estimating:

(3.5)

$$PW\%_c^{u,d} = \alpha_u + \lambda_d + \sum_{k \neq -1} \beta_k 1(EventTime_{ud} = k) + \varepsilon_{ud}$$

where:

⁵ Treat_day represents the days of data collection, thus pre-intervention (T0) = $1 < treat_day \leq 5$, while post-intervention (T1) = $6 \leq treat_day \leq 10$.

⁶ Thus: $k < 0$: T0 (leads), $k = 0$: first day of treatment, $k > 0$: T1 (lags)

- $PW\%_c^{u,d}$: outcome variable (PW%) for class u at time d for each course $c = \{FD, SeD, SiD\}$
- α_u : class fixed effects
- λ_d : time fixed effects
- $1(EventTime_{ud} = k)$: dummy for relative time k ($k < 0$: leads; $k = 0$: first day of treatment; $k > 0$: lags)
- $k = -1$: reference period (omitted)
- β_k : treatment effect k periods relative to the event
- ε_{ud} : error (clustered at the school level)

Each β_k measures the average treatment effect relative to the reference period ($k = -1$) (Eq. 3.6):

(3.6)

$$\beta_k = E[PW\%_c^{u,1} - PW\%_c^{u,0} \mid EventTime = k]$$

This specification tests pre-trends (leads are expected to be non-significant under parallel trends) and traces post-treatment trajectories for PW% across the three courses (FD, SeD, SiD). Analyses were replicated on the full sample of 35 classes and on each Area. A robustness check was performed, excluding classes with incorrect posters.

Finally, to explore potential additional mechanisms underlying average effects (H4), we conducted a set of post hoc analyses focusing on second servings. These analyses use stratified event-study DiD specifications based on pre-treatment levels of SiD PW% and second serving propensity. All analyses in this step are exploratory and intended to generate hypotheses rather than test pre-specified effects.

3.5 Results

3.5.1 Sample characteristics and baseline conditions

The treatment group and the control group in the full sample show similar characteristics in terms of the number of schools and classes, as illustrated by Table 3.3. Characteristics at the Area level are reported in Supplementary Table III. E.

Table 3.3: Descriptive statistics for the two experimental groups (full sample)

Variable	Control group	Treatment group
Number of AUSL	6	4
Number of schools	11	11
Number of classes	14	23
Min. students per class	12	11
Max. students per class	24	24
Mean students per class	19.4	19.4
Total students	272	447
Number of observations	132	225
Total meals weighted	2347	3924

To assess baseline comparability between control and treatment groups, we compared class size and average PW% for each course at T0 using Welch two-sample t-tests (Supplementary Table III.F). Class-level averages of PW were used to account for within-class aggregation. We also estimated linear models with standard errors clustered at the school level to account for potential intra-school correlation. At baseline, the treatment and control groups were well balanced. The average class size was similar between groups. PW% were also comparable across all courses: FD ($p = 0.615$), SeD ($p = .718$), and SiD ($p = .307$). Cluster-robust linear regressions confirmed these results (Supplementary Table III.G), showing no statistically significant differences at baseline and supporting the internal validity of subsequent causal analyses. The same tests are replicated at the Area level (Supplementary Table III.H-I). As presented in Table 3.4, schools serve a large variety of dishes, although with very different frequency.

Table 3.4: Frequency of dish categories across courses in all classes during T0 and T1

FD Category	Frequency (absolute)	%	SeD Category	Frequency (absolute)	%	SiD Category	Frequency (absolute)	%
Pasta with vegetables	119	32.16	White meat (fresh)	64	21.84	Mixed salad and raw vegetables	168	44.56
Soups	76	20.54	Fish (processed)	57	19.45	Carrots	50	13.26
Rice	73	19.73	Eggs	33	11.26	Potatoes	42	11.14
Pasta with oil	25	6.76	Cakes (pies, salty cakes)	29	8.95	Mixed cooked vegetables	26	6.9
Pizza	23	6.22	Cheese (fresh)	27	9.22	Green beans	24	6.37
Pasta with meat	17	4.59	Red meat (beef, fresh)	22	7.51	Fennel	15	3.98
Pasta with fish	13	3.51	Fish (fresh)	22	7.51	Broccoli	16	4.24
Others	14	3.78	Pulses (processed)	20	6.83	Cauliflower	11	2.92
Pasta with pulses	3	0.81	Meat (processed)	13	4.44	Zucchini	10	2.65
Fresh pasta	6	1.62	No SeD	12	4.10	Cabbage	8	2.12
No FD	1	0.27	Red meat (pork, fresh)	12	4.10	Peas	4	1.06
			Others	11	3.75	Spinach	3	0.80
			Fish (canned)	2	0.62			
TOTAL	370	100	TOTAL	324	100	TOTAL	377	100

Note: SiD results in a higher number of observation counts because schools did not serve FD and SeD in some cases. In these cases, it happened that two SiDs were served.

The FD category is dominated by pasta variants (49.5%), with pasta with vegetables as the most served FD. Rice and soups provide variety, while the serving of pizza is limited to 6%. Looking at SeD, a balance in protein sources (white meat, red meat, eggs, fish) is present. However, pulses were served 20 times, or 23 considering pasta with pulses, falling below the regional dietary guidelines for school services that recommend at least 1-2 servings per week (Regione Emilia-Romagna, 2023). Variability is also observable for the SiD, with a clear prominence of salads and mixed fresh vegetables, which is also in line with the regional guidelines. This heterogeneity underscores the relevance of using plate waste shares, rather than absolute quantities.

Menu consistency between T0 and T1 varies across food categories (Supplementary Table III.J). Second dishes (SeD) show the highest stability across measurement periods, particularly

fish (88.4% match) and meat (82.0%). First dishes (FD) exhibit more heterogeneous patterns, with high consistency for items such as pasta with fish (85.7%), pizza (76.9%), and rice (73.8%), but no continuity for categories such as pasta with pulses or fresh pasta. Side dishes (SiD) display the greatest variability, with relatively high consistency for mixed salads and raw vegetables (71.4%) and carrots (61.3%), but no continuity for several vegetable categories such as cauliflower, peas, and zucchini. This discrepancy can be explained by the intervention implementation period: all schools change menus according to seasonality, which influences the availability of certain vegetables. For several schools, pre-intervention and post-intervention measurements took place with different seasonal menus (Supplementary Table III.C). While menu consistency between T0 and T1 is imperfect, this variation reflects seasonal menu rotations typical of real-life school canteen operations. As such, the observed menu heterogeneity enhances the external validity of the study, albeit at the cost of reduced experimental control.

3.5.2 Descriptive patterns of plate waste

Across all territorial levels, Table 3.5 shows that SiD consistently exhibits the highest PW%, with 40.5% wasted across experimental groups before and during the intervention. Both SeD (28%) and FD (23.9%) waste shares are significantly lower.

SiD displays a homogeneous PW% across the Areas, as well as SeD. FD has the lowest PW% overall, though Area 3 displays a slightly higher waste compared to Area 1. This pattern further confirms SiD as the most critical course in terms of PW and the primary target for behavioural change.

Table 3.5: Descriptive statistics of PW% per dish, for Areas and full sample

Territorial level	Mean (SD)	Median [IQR]
First dish		
Area 1	21.0 (12.0)	19.0 [21.8]
Area 3	29.3 (13.2)	26.5 [16.4]
Full sample	23.9 (13.1)	21.8 [20.9]
Second dish		
Area 1	26.1 (12.9)	25.9 [18.9]
Area 3	28.2 (10.3)	28.9 [14.5]
Full sample	28.0 (12.7)	27.5 [17.7]
Side dish		
Area 1	39.6 (15.2)	40.0 [17.9]
Area 3	41.7 (14.3)	41.6 [15.4]
Full sample	40.5 (15.0)	40.7 [18.9]

Figure 3.3 shows PW% for FD, SeD, and SiD in control and treatment classes at baseline (T0) and post-intervention (T1), separately by Area and for the full sample (detailed summary

statistics of PW% at the aggregate territorial level available in Supplementary Table III.K). Visual inspection of Figure 3.3 reveals modest modifications between T0 and T1 within groups, with a substantial overlap of interquartile ranges, already signaling the absence of significant modifications in PW% in FD, SeD, SiD before and after the intervention, both at the Area and full sample levels.

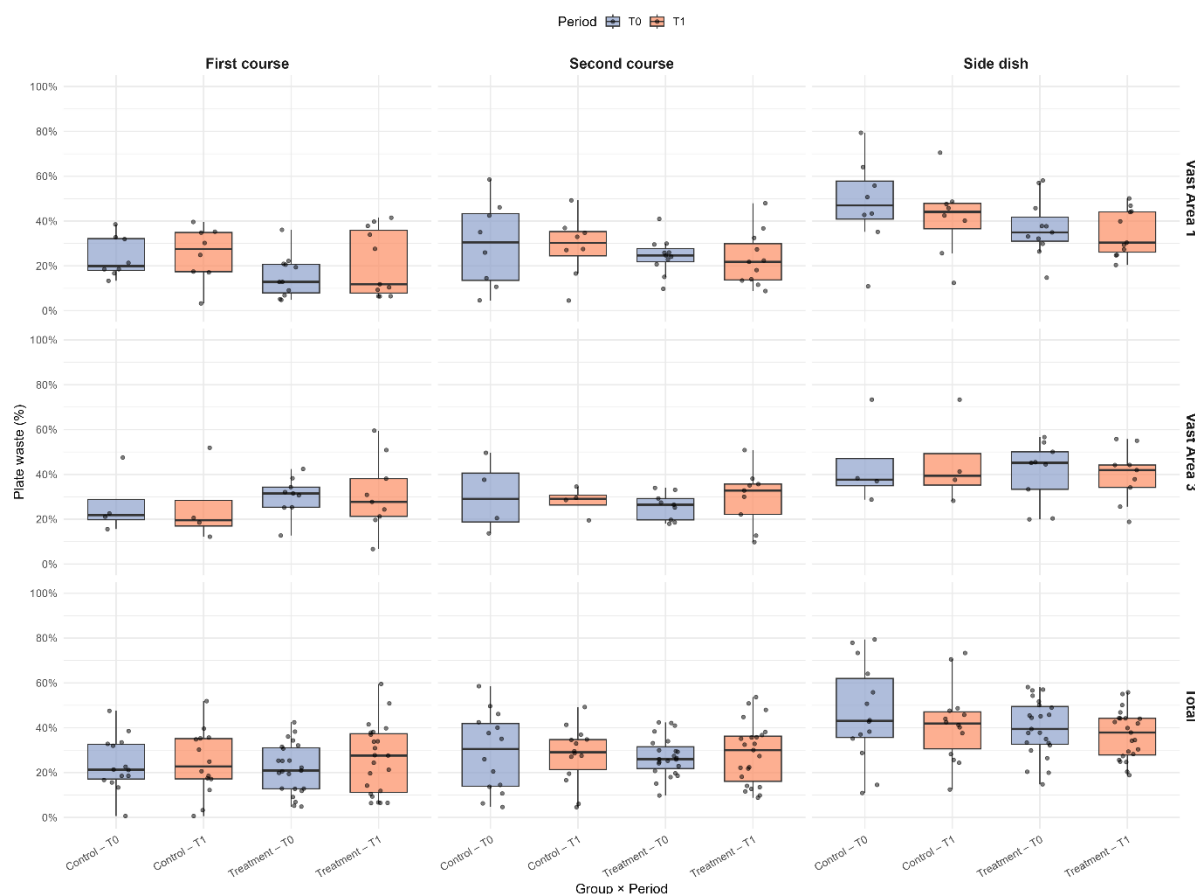


Figure 3.3: Distribution of PW% by meal course, experimental group, sample, and measurement period.

3.5.3 Average treatment effect on SiD PW

To test hypotheses H1a and H1b, we estimated the average treatment effect on the treated (ATT) using an overall difference-in-differences model (Eq. 3.4). The analysis focused on SiD PW%, the primary outcome of the intervention. Estimates are reported for the full sample and separately by Area (Table 3.6).

Table 3.6: Average treatment effect for the full sample, for each Vas, and for urban/rural segmentation

	Full sample	Area 1	Area 3	Higher-density municipalities (full sample)	Lower-density municipalities (full sample)
FD PW%	6.550 (4.56)	5.873 (5.38)	2.283 (4.29)	3.435 (3.56)	12.534* (7.49)
SeD PW%	7.668 (6.73)	1.049 (10.69)	18.438** (8.86)	7.518 (8.64)	8.394 (13.02)
SiD PW%	3.260 (8.37)	23.946*** (7.71)	-12.647 (9.62)	11.069 (9.44)	-10.070 (10.07)
Observations	FD: 338, SeD: 338, SiD: 335	FD: 183, SeD: 183, SiD: 181	FD: 116, SeD: 116, SiD: 115	FD: 233, SeD: 233, SiD: 234	FD: 105, SeD: 105, SiD: 101

Significance codes: . $p < 1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Note: Values in percentage points (pp), standard errors in brackets. The 3 A2 schools are included in the Full sample model. Results without A2 schools are available in Supplementary Table III.L.

Across the full sample, the intervention does not produce a statistically significant reduction in SiD PW%. The estimated coefficient is positive in sign (+3.3pp) but small in magnitude and statistically insignificant. This result provides no evidence in support of H1a, indicating that, on average, exposure to the descriptive social norm intervention did not reduce SiD PW. We conducted a robustness check by removing from the sample the 4 schools that did not include the correct social norm message in the poster. Main results are confirmed by the robustness check (Supplementary Table III.M).

Disaggregating results by Area reveals heterogeneous patterns in line with H1b. In A1, the intervention is associated with a large and statistically significant increase in SiD PW% (+23.9 pp, $p < .001$). In A3, the estimated effect on SiD PW% is negative (-12.7 pp) but does not reach statistical significance. These findings suggest that the intervention did not generate average beneficial effects in any territorial context and, in some cases, may have led to adverse behavioural responses.

As an additional contextual disaggregation, Table 3.6 reports estimates for schools located in higher- versus lower-density municipalities⁷. This split is not part of the primary analysis but aims to explore whether contextual differences in population density and settlement structure are associated with heterogeneous responses to the intervention. Results show no statistically significant effects of the intervention on SiD PW% in either group, thus confirming the main finding of no average treatment effect.

Table 3.6 also reports estimated effects for FD and SeD. Across the full sample, no statistically significant effects are observed for these dishes. Some significant coefficients emerge in

⁷ Schools were classified based on the degree of urbanization (DEGURBA) of the municipality in which they are located, following the Eurostat classification. This categorization captures differences in population size and density, distinguishing between cities, towns and suburbs, and rural areas. For the purpose of the analysis, cities and towns/suburbs were grouped into a single category representing higher-density and more populated contexts, while rural areas capture lower-density and smaller communities.

specific subgroups, such as an increase in SeD PW% in A3 and an increase in FD PW% among schools in lower-density municipalities. However, as these dishes were not targeted by the intervention, such patterns are interpreted as indirect spillover effects rather than direct behavioural responses to the social norm message.

To further investigate potential structural differences across contexts, we conducted an additional exploratory analysis estimating the ATT separately for classes in higher- and lower-density municipalities within each Area. This specification interacts the DiD indicator with a density-based dummy, comparing treated and control classes within the same context and Area. It is important to note that the sample was not stratified by municipality density at the design stage. Results should therefore be interpreted with caution due to small and unbalanced subsamples. In A1, the number of schools in lower-density municipalities is too limited to support inference.

Table 3.7: DiD variable interacted with municipality density (higher vs lower) within Area

	A1	A3
Higher-density municipalities		
FD PW%	7.208** (4.045)	-2.911 (5.762)
SeD PW%	-0.103 (10.734)	26.833*** (7.087)
SiD PW%	23.365*** (8.702)	-5.752 (18.898)
Observations	FD: 155, SeD: 155, SiD: 156	FD: 58, SeD: 58, SiD: 58
Lower-density municipalities		
FD PW%	-	-1.394 (4.068)
SeD PW%	-	14.722 (15.813)
SiD PW%	-	-13.797** (7.083)
Observations	-	FD: 58, SeD: 58, SiD: 57

Significance codes: . $p < 1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Dashes (-) indicate comparisons not feasible due to insufficient observations. Note: For A1 higher-density municipalities, estimates differ slightly from overall A1 (Table 6) due to exclusion of the observations for the few rural schools ($N=28-25$), altering sample composition.

To further investigate potential structural differences across contexts, we conducted an additional exploratory analysis estimating the ATT separately for classes in higher- and lower-density municipalities within each Area. This specification interacts the DiD indicator with a density-based dummy, comparing treated and control classes within the same context and Area. It is important to note that the sample was not stratified by municipality density at the design stage. Results should therefore be interpreted with caution due to small and unbalanced subsamples. In A1, the number of schools in lower-density municipalities is too limited to support inference.

Table 3.7 presents the estimated ATTs by course, Area, and location of the schools. In classes located in higher-density municipalities, statistically significant effects emerge: in A1, the PW increasing effect of the intervention for FD and SiD is driven by these classes. The same can

be observed for classes in higher-density municipalities in A3, which are the main driver of the significant increase in SeD PW% already observed in Table 3.6. In classes in lower-density municipalities, for which we only have estimates for A3, the intervention is associated with a statistically significant reduction in SiD PW%. This exploratory evidence suggests that the association between the intervention and PW may vary according to the territorial context.

The overall DiD results do not provide evidence of a systematic effect of the intervention on SiD PW. Some differences emerge at the smaller territorial levels. These findings motivate the dynamic event-study analysis presented in the next section, aimed at assessing the temporal evolution of treatment effects and validating the parallel trends assumption.

3.5.4 Dynamic effects and time evolution

To provide an initial descriptive overview of daily PW dynamics, Supplementary Figure III.B plots class-day average PW% by meal course and experimental group relative to the start of the post-intervention period.

To assess hypothesis H2, we estimated a dynamic DiD model tracing the evolution of treatment effects on SiD PW% over time. Figure 3.4 displays the estimated differences in PW% between treatment and control classes for each day before and after the intervention, using the last day before implementation as the reference point. Each point in the figure represents the difference in SiD PW% between treated and control classes at a given time relative to the intervention. Values above zero indicate higher PW% in treated classes, while values below zero indicate lower PW%. The vertical bars represent 95% confidence intervals, showing the statistical uncertainty around each estimate. Estimates before the intervention provide a visual check that treatment and control classes followed similar trends prior to exposure, while estimates after the intervention illustrate whether and how the effect changed over time. The robustness check removing 4 classes with incorrect posters is available in Supplementary Figure III.C.

Pre-treatment leads are not statistically different from 0, confirming the validity of the parallel trends assumption for SiD. Post-treatment estimates reveal no significant reduction in SiD PW%. While a positive deviation is observed at the first post-treatment lag, none of the post-treatment coefficients are statistically significant, nor do they display a monotonic or persistent trajectory. Subsequent lags return close to the reference level.

The event-study evidence provides no support for H2. These dynamic results are consistent with the overall DiD estimates reported in Section 3.5.3, reinforcing the conclusion that the intervention did not produce systematic effects on SiD PW% in the full sample.

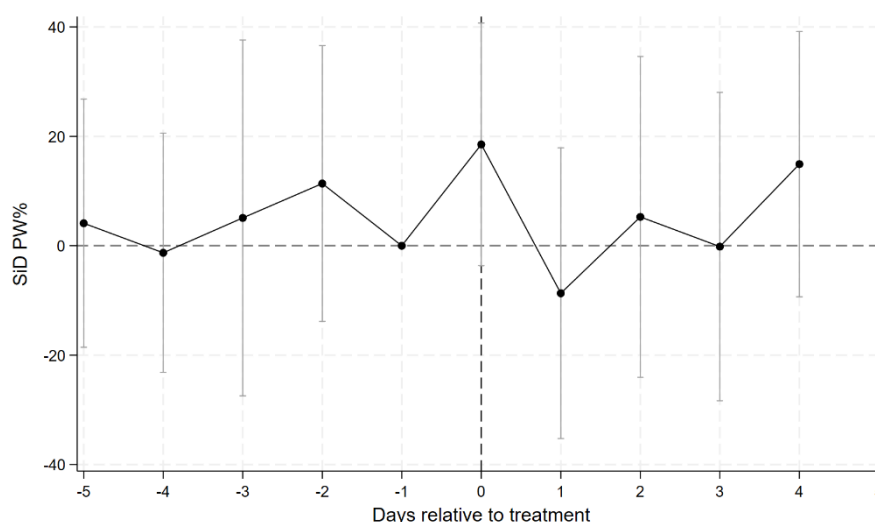


Figure 3.4: Dynamic treatment effects on SiD PW%: event-study estimates, full sample.

Figure 3.5 presents event-study estimates disaggregated by Area, showing the territorial heterogeneity underlying the null average effect and supporting hypothesis H1b. In both A1 and A3, pre-treatment trends remain parallel. In A1, post-treatment coefficients become positive and statistically significant at selected lags ($k+1$, $k+3$, and $k+4$), indicating an increase in SiD PW%. Importantly, this pattern does not conform to the temporal dynamics hypothesized in H2: effects are not immediate, not decreasing over time, and move in the opposite direction of the intended outcome. Conversely, A3 shows post-treatment coefficients that gradually decline over time but remain non-statistically significant. This pattern indicates the absence of any detectable intervention effect in A3.

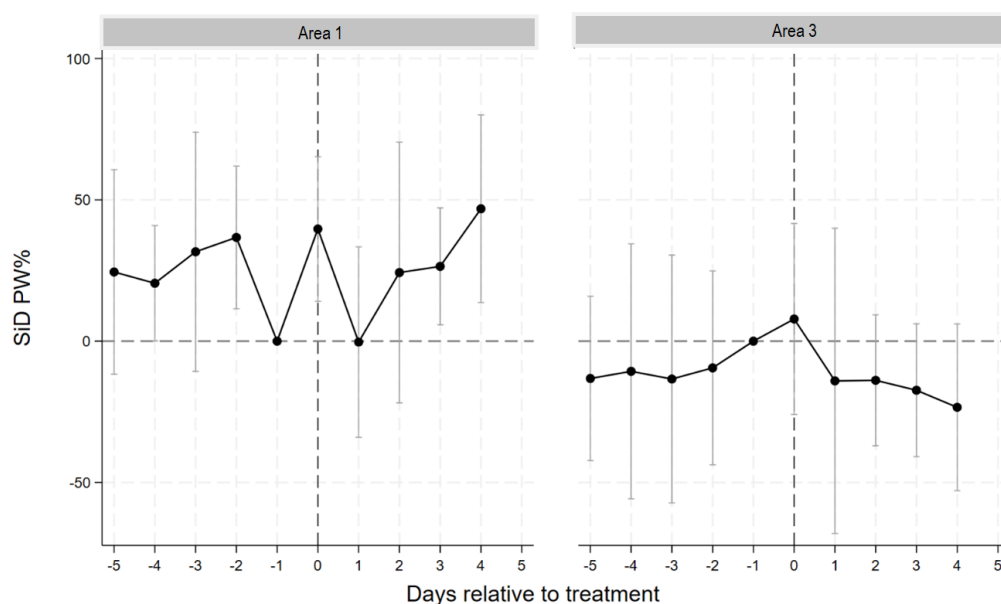


Figure 3.5: Dynamic treatment effects on SiD PW% by Vast Area

3.5.5 Spillover effects on FD and SeD

H3a-b hypothesizes that the intervention does not have a direct effect on PW% of FD and SeD, which were not targeted by the social norm message. Therefore, any observed changes in these dishes would reflect indirect spillover effects and non-intentional behavioural responses. In line with H3a-b, overall DiD estimates (Table 3.6) reveal no statistically significant average treatment effects on FD or SeD PW% in the full sample. While some statistically significant coefficients emerge in specific subgroups, these effects are heterogeneous in sign and magnitude and do not display a coherent pattern.

Dynamic event-study analyses confirm the absence of systematic spillover effects (Figure 3.6 and Figure 3.7). For both FD and SeD, pre-treatment trends are parallel and post-treatment coefficients fluctuate around 0, suggesting that the intervention did not produce systematic effects in other dishes. Robustness checks are available in Supplementary Figure III.D-E.

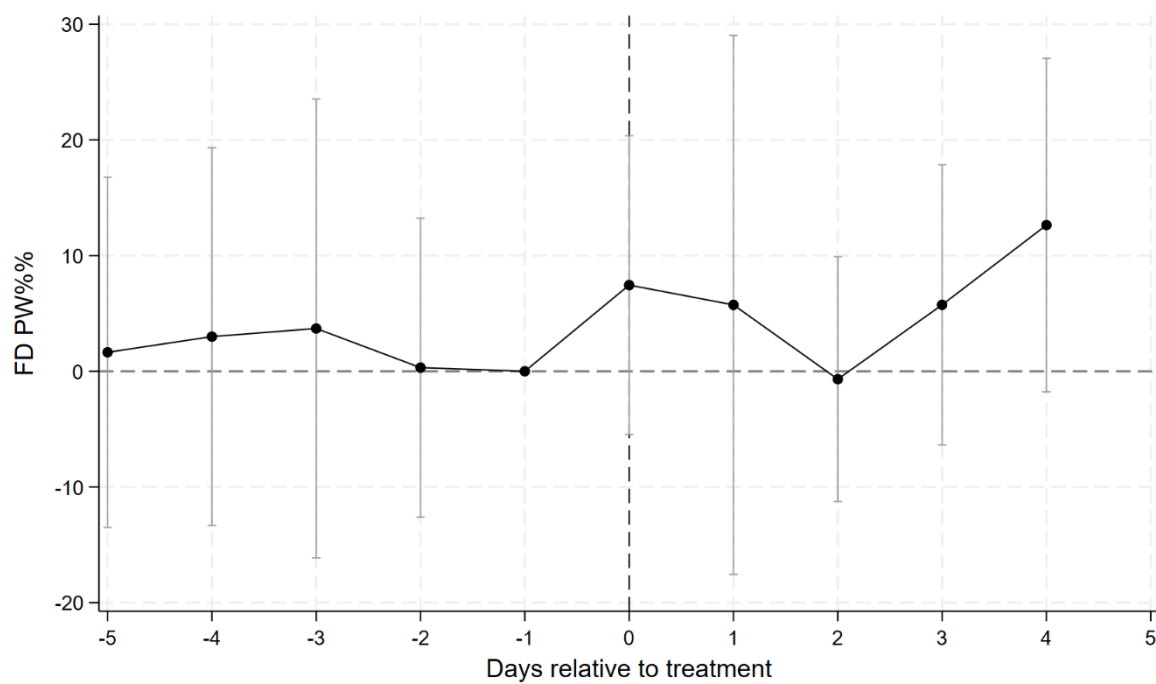


Figure 3.6: Dynamic treatment effects on FD PW%

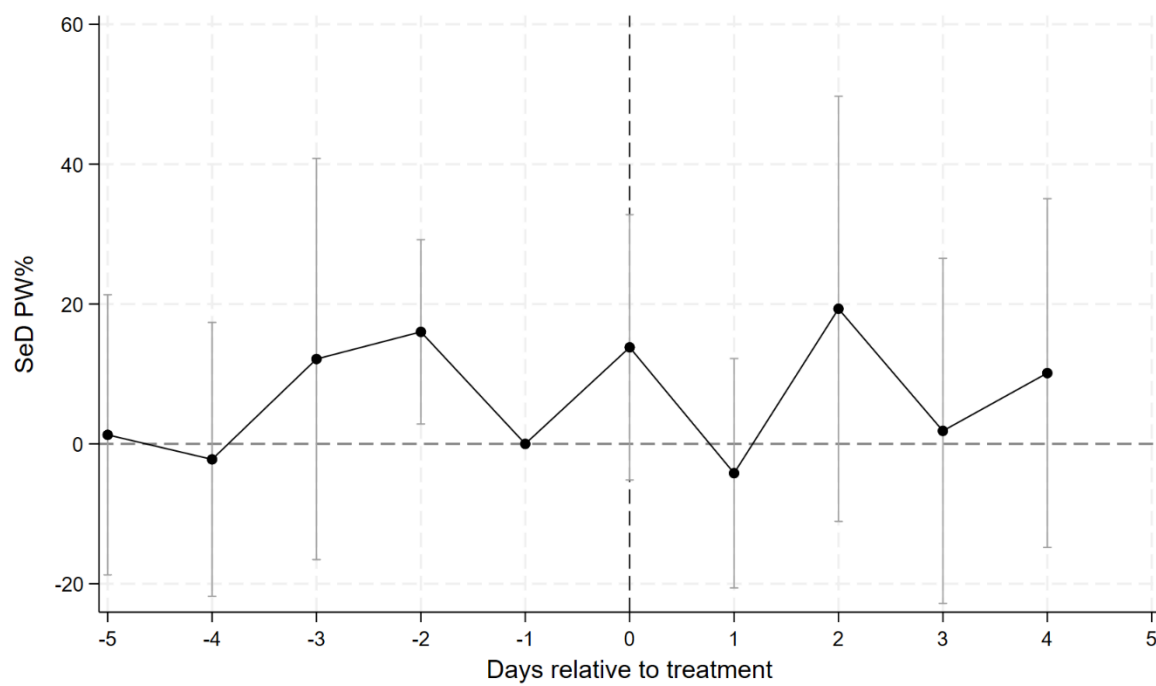


Figure 3.7: Dynamic treatment effects on SeD PW%

3.5.6 Exploratory mechanisms: second servings

To explore potential behavioural mechanisms, we conduct a set of post hoc analyses focusing on second servings of SiD (H4). All analyses in this section are exploratory and intended to generate hypotheses rather than test pre-specified effects. Second servings may capture differences in appetite, engagement with vegetables, or willingness to consume additional portions, and thus provide insight into heterogeneous behavioural responses to the norm message. Figure 3.8 presents event-study estimates of SiD PW% stratified by pre-treatment SiD second serving propensity, calculated as the share of second servings on the total number of children. Classes are divided based on whether their baseline frequency of second servings is above or below the sample median in the pre-treatment period.

Classes with low pre-treatment second servings propensity show systematically higher levels of SiD PW% compared to high second servings propensity classes. In both cases, results indicate no responses to the intervention.

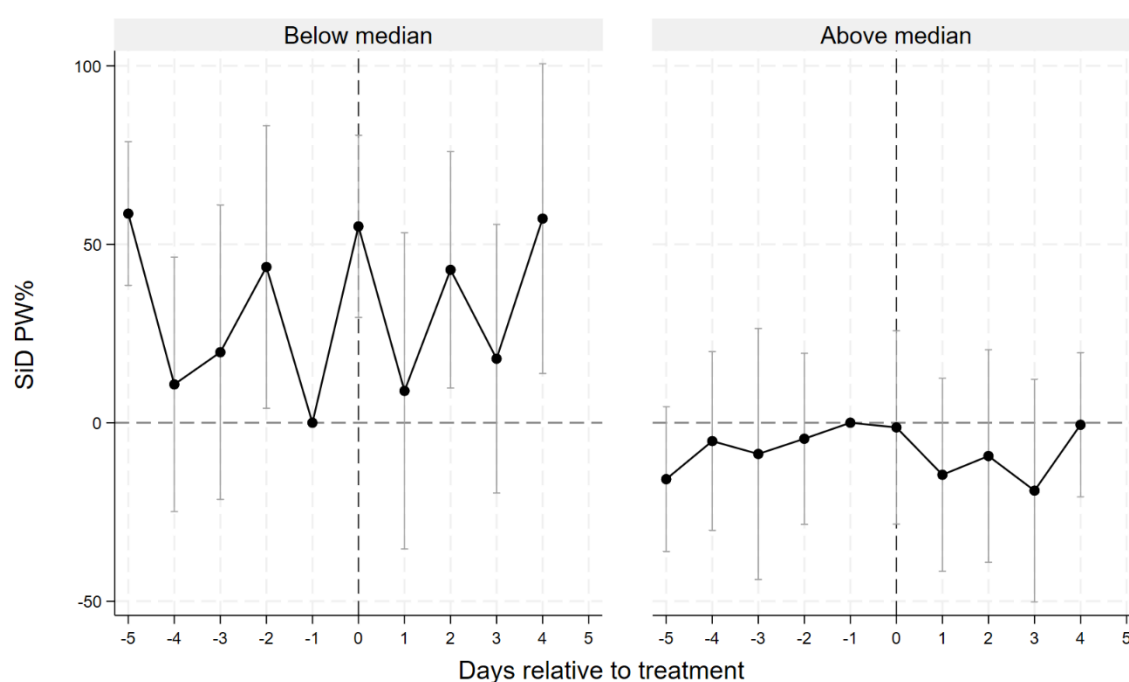


Figure 3.8: Dynamic treatment effects on SiD PW% stratified by pre-treatment SiD second serving propensity

Figure 3.9 and Figure 3.10 examine whether second servings act as a complementary behaviour to SiD waste. Figure 3.9 reports event-study estimates of second serving propensity stratified by SiD PW% in the pre-treatment phase, while Figure 3.10 shows the corresponding dynamics for SiD PW%.

Among classes with high baseline SiD PW%, the intervention is associated with a short-lived increase in second servings immediately after treatment exposure (Figure 3.9), without a corresponding increase in PW% (Figure 3.10). This pattern suggests a temporary increase in SiD intake via refills. However, this effect does not persist across the measurement week. Classes with low baseline SiD PW% show stable patterns in second servings (Figure 3.9) and a small non-significant decrease in SiD PW% (Figure 3.10), potentially indicating limited responsiveness to the intervention among efficient groups.

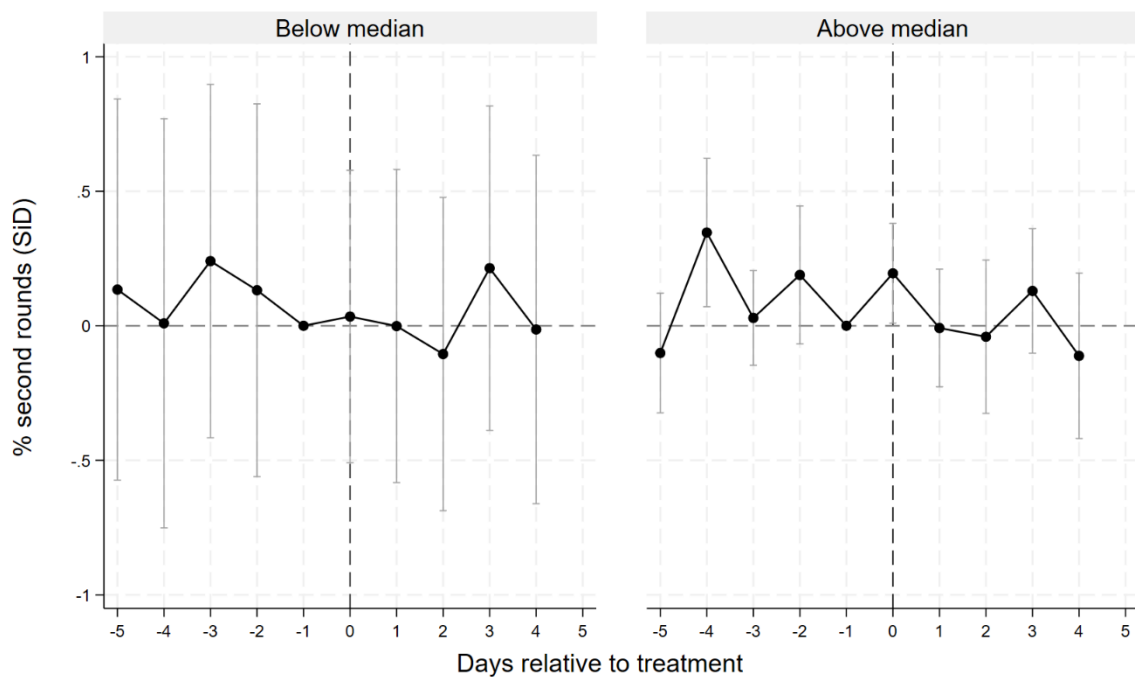


Figure 3.9: Dynamic treatment effects on SiD second serving propensity stratified by baseline SiD PW%

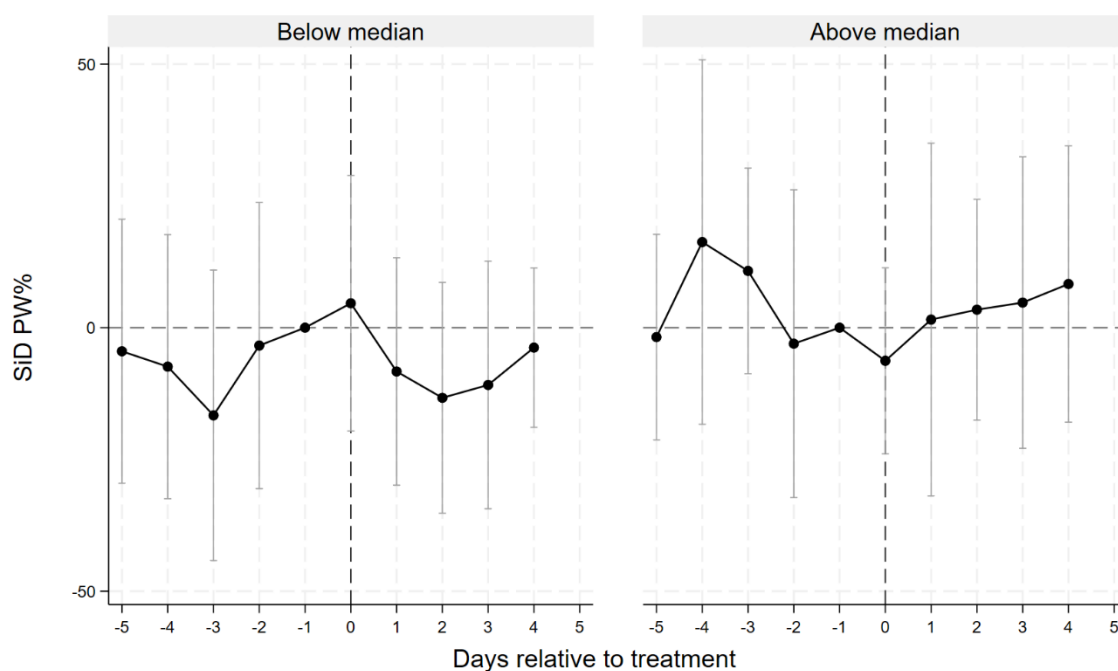


Figure 3.10: Dynamic treatment effects on SiD PW% stratified by baseline SiD PW%.

These exploratory analyses suggest that second servings may mediate heterogeneous and short-lived responses to the intervention, particularly among vegetable-averse classes. However, statistical significance is limited, and any initial effects diminish over time. These findings should therefore be interpreted cautiously and are consistent with the absence of aggregate treatment effects reported in previous sections.

3.6 Discussion

3.6.1 Main findings

This study evaluated the effectiveness of a participatory descriptive social norm intervention aimed at reducing vegetable PW among 9-year-old pupils in primary school canteens. With respect to H1a, we find no evidence that exposure to a social norm message included in a poster co-designed by children reduces SiD plate waste shares on average. The heterogeneous effects observed across Areas suggest that the effectiveness of the social norm intervention may be context-dependent, consistent with H1b. This heterogeneity in results may partly reflect differences in the territorial composition of schools. Area 1 includes a higher share of schools located in higher-density municipalities, while Area 3 includes a larger proportion of schools in lower-density contexts. Exploratory analyses along this dimension indicate that in Area 3 the intervention is associated with a statistically significant reduction in SiD PW% in lower-

density municipalities, while no effect emerges in higher-density contexts. Although these results cannot be interpreted causally, they suggest that the effectiveness of descriptive social norm messages may depend on local social and institutional environments. In lower-density contexts, social interactions may be more stable and repeated, potentially strengthening the salience and enforcement of social norms (Berger, 2024). In contrast, in more densely populated settings, greater heterogeneity and more fragmented social interactions (Hofferth & Iceland, 1998; Moss et al., 2023) may weaken the influence of normative messages. Additionally, these patterns may reflect differences in canteen organization, meal service practices, or baseline consumption habits across contexts. Future research should explicitly account for these contextual dimensions in the experimental design.

Turning to H2, dynamic analyses indicate that the lack of an average treatment effect does not mask delayed responses. Instead, estimated treatment effects fluctuate over the post-intervention period and do not display a stable trajectory. In line with H3a-b, the intervention does not generate systematic changes in plate waste for first or second dishes, which were not targeted by the normative message. Finally, exploratory analyses addressing H4 suggest that second servings are systematically associated with plate waste patterns but do not alter the main conclusions. Classes with a lower propensity to take second servings exhibit higher levels of SiD plate waste, but no intervention effect is observed.

3.6.2 Methodological insights from large-scale RCT field experiments

Although previous research suggested that descriptive social norms are associated with children's vegetable intake and that interventions leveraging social norms have the potential to increase healthy eating habits among children, the current study does not support this hypothesis. A potential explanation for the divergence of our findings from previous evidence may be related to issues of external validity and statistical inference related to study scale and sampling strategies. Much of the existing literature supporting the role of social norms in influencing children vegetable intake is based on correlational studies (Haß & Hartmann, 2018; Lehto et al., 2016), laboratory or highly controlled school-based experiments (Hang et al., 2020; Khan et al., 2022; Sharps & Robinson, 2015), and small scale field studies with convenience samples (Calvert et al., 2018; Hamdi et al., 2020; Horne et al., 2004; Lowe et al., 2004; Machado et al., 2020). While these studies provide important proof of concept evidence, limited sample sizes and non-random selection substantially confine their generalizability and increase the risk of overestimating treatment effects. From a statistical perspective, small and convenience samples are more likely to yield unstable estimates and statistically significant

results driven by contextual characteristics rather than by behavioural changes influenced by the intervention (Button et al., 2013; Gelman & Carlin, 2014; Oakes, 2014). On the other hand, larger and more heterogeneous samples provide more conservative but reliable estimates. In this sense, our study does not contradict prior evidence but rather refines it. The present study employs a cluster randomized controlled design with random school selection across multiple territorial areas, involving 22 schools and over 650 pupils. This design enhances both statistical power and population representativeness, allowing us to test whether effects observed in smaller and more controlled settings persist when exposed to real-world variability. The absence of significant average effects thus suggests that previously reported positive findings may not scale up when social norm interventions are implemented at policy-relevant levels.

Another key explanation relates to differences in ecological validity between our study and prior laboratory or highly controlled school-based experiments. Experimental studies have shown that children increase vegetable intake when exposed to manipulated descriptive norms under controlled conditions, such as hypothetical choice tasks in supervised school experiments (Hang et al., 2020; Khan et al., 2022; Sharps & Robinson, 2017). These designs maximize internal validity by isolating social norm cues and minimizing confounding influences. In contrast, eating behaviour in school canteens is shaped by multiple concurrent factors, including time pressure, food preferences, portion sizes, menu composition, appetite, and peer interactions (Petruzzelli et al., 2025). In such complex environments, descriptive norm messages may compete with stronger situational drivers of behaviour and fail to translate into actual consumption changes. More broadly, our findings illustrate the trade-off between internal and external validity: while controlled experiments may detect behavioural effects, field studies with high ecological validity are essential to assess their real-world relevance (Dannenberg et al., 2024). Our study prioritizes ecological validity by implementing the intervention in routine school canteen operations, allowing for seasonal menu variation, heterogeneous service systems, and natural peer and teacher-children dynamics. While this approach reduces experimental control, it provides a more realistic test of whether descriptive social norms can meaningfully alter children's eating behaviour in everyday conditions. Therefore, the lack of observable effects suggests that descriptive norms alone may be insufficient to overcome contextual drivers to vegetable consumption in real-life school food environments. This is particularly relevant given the central role of healthy eating in childhood for preventing NCDs later in life and for consolidating long-term dietary habits.

Spanning beyond children's behaviour, on which no previous RCT experiments have been conducted, our findings are consistent with a broader literature on social norm interventions

with adult participants. RCT field experiments in eating contexts showed null (Çoker et al., 2022, 2025) or modest immediate effects that disappear over time (Thorndike et al., 2016), particularly in the absence of reinforcement mechanisms or complementary interventions. In contrast, Daker et al. (2025) found a substantial reduction in PW using a descriptive social norm poster in corporate dining settings. Unlike our intervention, their targeted adults and calibrated the norm message based on participants' actual perceptions of peers' waste behaviours, derived from a preliminary survey, which may have enhanced its credibility.

3.6.3 Mechanisms and boundary conditions of social norm interventions

Several theoretical and methodological factors may explain our null results. First, the credibility of the descriptive norm may have been limited. Social norm interventions rely on correcting misperceptions about others' behaviour, yet our message, while theoretically grounded and crafted through a semiotic analysis, was not pre-tested against children's baseline misperceptions of vegetable intake norms. If pupils did not perceive vegetable consumption as uncommon to begin with, the normative message may have lacked informational value. Second, our intervention bolsters message salience through a participatory poster co-design activity, aimed at engaging children with the message and increasing the likelihood that they remember it. However, we did not include reinforcement mechanisms such as peer modeling or repeated social feedback to remind children about the message content. Descriptive norms are more likely to influence behaviour when participants identify with the group represented by the norm referent (Louis et al., 2007) and when the norm is supported by visible behaviours of salient in-group members (Higgs et al., 2019; Liu et al., 2019). Even though the message was crafted to resonate with children's interests, the referent group remained generic ("many children"), and no classmates or aspirational peers were explicitly involved as models. In a school environment, salience and credibility could be enhanced by engaging peer models or school-level champions (Robinson et al., 2013), although the logistical complexity of doing so at large scale should be carefully considered in future trials.

Third, the intervention did not account for children's pre-existing eating habits, which were not directly measured. Children's eating behaviours are embedded in broader routines shaped by family food environments, cultural norms, and repeated exposure over time (Scaglioni et al., 2011). Habits are typically resistant to change (Shepherd, 2002) and moderate the impact of behavioural change interventions (Stok et al., 2016; Verhoeven et al., 2012). With these respects, our exploratory analysis reports that baseline vegetable-averse classes show a temporary increase in vegetable intake through second servings, in the direction of the evidence

provided by Horne et al. (2004) and Robinson et al. (2014). Fourth, social norms operate by changing what individuals perceive as typical or appropriate, but an additional step is required for behaviour change. Altering norm perceptions may not necessarily translate into actual consumption (Templeton et al., 2016), especially in constrained environments such as school canteens, where time pressure, fixed menus, appetite, and strong food preferences limit children's behavioural flexibility. Collecting data on both perceived norms and motivation (e.g., willingness to try vegetables) would help clarify whether descriptive norm messages may shift perceptions and motivations even though they are not effective enough to overcome the intention-behaviour gap (Sheeran & Webb, 2016).

3.6.4 Limitations and future research

Some experimental design limitations deserve attention. The intervention and observation period was short, while the modification of eating habits may require longer exposure and follow-up. Menu composition was not perfectly identical between pre- and post-intervention periods, potentially introducing noise in plate waste measures despite efforts to match menus. One territorial area was underpowered (Area 2) and had to be removed from the analysis. Finally, although the co-design activity was intended to ensure engagement with the message, the study did not include a manipulation check to verify whether children noticed, understood, or remembered the poster, nor did it measure baseline identification with the reference group. The risk of participants not recalling the poster is particularly present in field settings where multiple inputs co-exist (Mollen et al., 2013). These gaps suggest that future research should combine social norm interventions with measures of factors known to moderate normative influence (Chen et al., 2024; Stok et al., 2016) as in-group identification and manipulation checks. Importantly, future research should also include measures of perceived norms before and after the intervention, evaluating norm perception as a key outcome together with behavioural indicators such as plate waste. Additionally, future studies should systematically incorporate measures of habit strength and examine whether social norm messages are more effective among children with stronger or weaker pre-existing vegetable consumption habits. Building on our exploratory results across municipality density, future research is needed to explicitly investigate contextual heterogeneity across local environments. Future works should also test multi-component interventions that integrate descriptive norms with peer modeling or repeated reinforcement. In doing so, collaboration among regional authorities, schools, caterers, and teachers becomes crucial, as these interventions entail relevant coordination costs but can also create opportunities for shared learning and more coherent school food policies.

Particular attention should therefore be paid to balancing ecological validity with both the practical burden placed on researchers and schools and the potential benefits of sustained multi-stakeholder engagement. From a broader sustainability perspective, school canteens remain a critical arena for preventing FW and promoting healthy diets among children. Although this intervention did not reduce vegetable plate waste, the study contributes to ongoing efforts to identify strategies that can more effectively support progress toward SDG 2, SDG 3, and SDG 12.

3.7 Conclusions

This study provides the first large-scale field evaluation of a participatory descriptive social norm intervention aimed at reducing vegetable plate waste among primary school children. By randomizing schools and implementing the intervention within routine canteen operations, the study offers robust evidence on the real-world effectiveness of norm-based strategies in school food environments.

The results show that, when implemented at scale, a descriptive social norm message delivered through a poster does not lead to systematic reductions in vegetable plate waste, even if supported by a poster co-design activity. This finding suggests that interventions that appear effective in laboratory or small-scale settings may not be sufficient to generate meaningful behavioural change in complex, everyday food environments such as school canteens.

The observed heterogeneity across Areas and municipality density suggests that the effectiveness of social norm interventions may depend on local social characteristics, school environments, and institutional arrangements. Although exploratory, the identified patterns suggest that “one-size-fits-all” behavioural interventions are unlikely to be optimal. Policy-makers should therefore consider tailoring norm-based strategies to specific contexts or combining them with reinforcing mechanisms such as peer modeling or repeated feedback. From a policy perspective, results highlights the limits of low-intensity, information-based nudges when applied without additional behavioural interventions and organizational support. These actions require substantial costs (schools’ engagement, teacher training, class time, regional coordination) for negligible behavioural impact, particularly if the goal is to meaningfully contribute to healthier diets and reduce food waste.

Beyond its main findings, this study demonstrates the feasibility and value of implementing rigorous experimental evaluations of food waste reduction interventions within public school systems when all actors are engaged. Building on earlier work by Petruzzelli et al. (2025), this

intervention further strengthened the engagement of the Emilia-Romagna regional authorities with science-based approaches. Such institutional learning is a crucial outcome of large-scale field experimentation designed and implemented through participatory approaches, and represents an important step toward more effective, science-based strategies to promote sustainable and healthy eating in schools.

CRedit authorship contribution statement

Caterina Rettore: Writing – original draft, Writing – review/editing, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization. **Maria Teresa Trentinaglia:** Writing – original draft, Writing – review/editing, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization. **Marina Fridel:** Writing – review and editing, Conceptualization, Project administration. **Matteo Vittuari:** Writing – review and editing, Conceptualization, Methodology, Project administration, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Declaration of generative AI

During the preparation of this work, the authors used ChatGPT to improve the readability of the text. After using this tool, the authors carefully reviewed and edited the text generated and take full responsibility for the content of the manuscript.

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Conclusions

The thesis investigated how social influences shape eating behaviours along the continuum from food consumption to plate waste, and under which conditions norm-based interventions can effectively support healthier and more sustainable eating behaviours. Building on behavioural theory and previous food systems research, and by explicitly taking into consideration the differences among food environments, the work addressed three interconnected research questions: whether and under which conditions social norms influence eating behaviours (RQ1), how social norms and contextual drivers interact to shape plate waste in food service environments (RQ2), and whether a descriptive social norm-based intervention can reduce vegetable plate waste in primary school canteens (RQ3).

To address these questions, the thesis adopted a progressive and integrated research design, combining a systematic review and meta-analysis (Chapter 1), scenario-based simulation modelling (Chapter 2), and a large-scale randomized controlled trial in a real-world school setting (Chapter 3). Rather than providing isolated answers, the three studies collectively contribute to a coherent understanding of social norms and eating behaviours as context-dependent, dynamic, and interaction-sensitive.

Summary of evidence

Taken together, the findings of the three chapters provide a coherent and progressive answer to the thesis research questions by examining the role of social norms across different food environments. By analysing eating behaviours across organizational food environments such as hospitality buffets and school canteens, the thesis illustrates how social influence operates at the interface between individual decision-making and broader food system outcomes. With respect to RQ1, the systematic review and meta-analysis in Chapter 1 confirms that social norms exert a small but statistically significant positive influence on eating behaviours. Importantly, the analysis demonstrates that this influence is highly conditional. Stronger effects emerge among younger individuals (particularly those under 26 years of age), when messages are framed in a proscriptive manner, when norms refer to majority behaviours, and when eating behaviours are observable. Chapters 2 and 3 extend this evidence by showing that normative influences also operate along the food consumption-plate waste continuum, but that their

effectiveness becomes increasingly context-dependent in complex food environments. The agent-based scenario modelling results reveal the potential emergence of behavioural reactance and compensatory responses, while the field randomized controlled trial shows that norm-based interventions may fail to produce measurable average effects when implemented within complex institutional food environments such as school canteens. These findings challenge simplified narratives according to which social norms are universally effective nudges and instead position them as behavioural levers whose influence depends on contextual and design features.

Regarding RQ2, Chapter 2 provides evidence by embedding social norms within the MOA framework and simulating their interaction with structural and behavioural determinants of food waste. The results reveal that plate waste is shaped by sequential behavioural pathways linking portioning, refilling, and leftovers generation. Within these pathways, social norms interact with sustainability awareness and opportunity structures, such as plate size and time constraints. The simulations demonstrate that interventions targeting single decision points may trigger compensatory mechanisms, potentially offsetting expected reductions in waste. For example, nudges yielding reductions in initial portion sizes may be offset by increased refilling, leading to limited or even counterproductive net effects on plate waste. These findings address important gaps in the literature, which has traditionally examined food waste drivers in isolation and has paid limited attention to behavioural interactions and adaptive responses.

Finally, in relation to RQ3 and moving from simulation to field testing, Chapter 3 provides rigorous causal evidence through a large-scale cluster randomized controlled trial conducted in an organizational food environment characterised by strong institutional routines, peer interaction, and structured meal provision. Contrary to expectations derived from previous experimental literature, the intervention did not produce significant average reductions in vegetable plate waste. However, the results reveal meaningful heterogeneity, including differences across territorial contexts. Importantly, dynamic analyses show that the absence of an average effect does not mask delayed treatment impacts. Rather than contradicting the existing literature, these findings are consistent with the meta-analytic evidence of small average effects. These insights suggest that stand-alone normative nudges may have limited effectiveness in complex, real-world food environments, particularly when not reinforced by broader educational or structural interventions.

Together, the three studies suggest that the effectiveness of social norms cannot be adequately assessed through single interventions or average treatment effects alone. Instead, their

influence must be understood as conditional, mediated by behavioural pathways, and influenced by characteristics of specific food environments.

Contributions to the state of the art

Methodological contributions

From a methodological perspective, this work demonstrates the analytical and policy relevance of combining complementary research designs to study behavioural change in complex food environments. The integration of meta-analysis, agent-based modelling, and large-scale field experimentation represents an innovative mixed-methods strategy that allows investigation of behavioural mechanisms across different levels of evidence generation.

Each methodological approach contributes to different analytical strengths. The meta-analysis synthesizes fragmented empirical findings and identifies systematic moderators of normative influence. Agent-based scenario modelling enables the exploration of behavioural pathways, interaction effects, and counterfactual intervention scenarios that would be difficult to observe directly in real-world settings. Randomized field experiments provide causal inference under ecological conditions, allowing evaluation of interventions' effectiveness within complex institutional food environments.

In particular, Chapter 3 contributes methodologically by providing one of the first large-scale cluster randomized controlled trials assessing a social norm intervention targeting children's eating behaviour in school canteens. Importantly, the study also demonstrates the scientific value of null findings generated through ecologically valid field experimentation, highlighting their role in refining behavioural theory, improving intervention design, and advancing evidence-based policy development.

Empirical and policy-relevant contributions

Empirically, the work presented provides robust evidence that low-intensity, stand-alone social norm interventions are unlikely to influence eating behaviours and generate systematic reductions in plate waste when implemented in complex, real-world food environments. From an applied perspective, these findings highlight the limitations of relying on single behavioural levers and emphasise the importance of mechanism-based intervention design.

These results have important implications for policymakers and practitioners designing behaviourally informed interventions. Rather than treating social norms as a universally applicable and low-cost solution, the findings suggest that norm-based strategies should be

embedded within multi-component interventions that simultaneously address multiple behavioural determinants. In the context of school food policy, the results indicate that participatory and educational components, while valuable for increasing engagement and awareness, are unlikely to produce sustained behavioural changes when implemented in isolation. From an intervention design perspective, participatory approaches may instead function as reinforcement mechanisms that increase intervention acceptability, salience, and internalization of desired behaviours when integrated with environmental and organizational changes. For intervention designers and policymakers, these findings suggest that social norm interventions are more likely to be effective when combined with structural and environmental modifications that reduce behavioural frictions and reinforce desired practices. In school canteens, for example, normative messages encouraging vegetable consumption or waste reduction could be combined with experiential learning activities, curriculum integration, changes in food presentation, smaller default portions with the possibility of refills, repeated tasting opportunities, or peer modelling activities. In hospitality and buffet settings, normative communication may be more effective when integrated with portion guidance strategies, smaller plate sizes, optimized buffet layouts, or feedback mechanisms providing real-time information on food waste generation.

More broadly, the findings indicate that behavioural interventions should be designed as integrated behavioural pathways rather than isolated nudges targeting single decisions. Interventions that simultaneously address motivation, opportunity, and ability dimensions of behaviour may reduce the risk of compensatory responses and increase the persistence of behavioural change over time. Future policy experimentation should therefore test multi-component intervention packages combining normative cues, environmental restructuring, and educational or participatory elements across different organizational food environments.

The thesis highlights the importance of adopting theory-informed and context-sensitive policy design. Behavioural interventions targeting eating behaviours should be tailored to the characteristics of specific populations and organizational food environments, accounting for baseline habits, social interaction patterns, and institutional constraints. The findings also suggest that policy design should incorporate iterative evaluation and adaptive implementation strategies, allowing interventions to be refined in response to behavioural responses and contextual variability.

Limitations and implications for future research

Despite the methodological and empirical contributions of this thesis, several limitations should be acknowledged, which also indicate directions for future research.

First, all empirical analyses conducted in this thesis rely primarily on quantitative approaches. While this allows for robust effect estimation, causal inference, and behavioural modelling, it limits the ability to capture how individuals interpret and internalize social norms' messages. Qualitative and mixed-method research could provide valuable insights into the mechanisms through which social norms influence eating behaviours, including how individuals perceive norm credibility, interpret reference groups, and experience potential reactance or reinforcement processes. Moreover, individual eating behaviours are not shaped within a single food environment but emerge from the interaction among multiple environments that individuals navigate in their daily lives, including households, schools, workplaces, and food service settings. The exposure to potentially conflicting norms, routines, and constraints across these environments may influence how individuals interpret and respond to normative messages. Qualitative approaches could therefore provide important insights into how individuals negotiate and integrate these overlapping environmental influences, helping to explain variability in behavioural responses that may not be fully captured through quantitative designs alone.

Second, and related to the point outlined above, the findings highlight the importance of heterogeneity and context dependence, but the thesis is only able to partially capture these dimensions. Across the meta-analysis, simulation modelling, and field experimentation, social norm effectiveness appears to vary according to individual characteristics, territorial contexts, and institutional food environments. Future research should therefore move beyond average treatment effects and systematically investigate distributional impacts, subgroup-specific responses, and cross-cultural variability. In particular, stronger empirical attention should be devoted to the role of habit strength, cultural norms, and food environment characteristics as moderators of normative influence.

Third, the temporal dimension of behavioural responses to social norms remains insufficiently explored. The short duration of field observation and the static representation of some behavioural parameters in the simulation model limit the ability to fully examine processes such as learning, adaptation, fatigue, or habit formation. Longitudinal designs combining repeated behavioural observations and perception measures would help clarify whether normative interventions produce delayed, cumulative, or decaying effects.

Fourth, the research primarily evaluates relatively low-intensity, stand-alone norm-based interventions. While this choice allows for the isolation of normative mechanisms, it does not fully capture how social norms interact with other behavioural and environmental drivers. Future research should therefore systematically test multi-component interventions targeting multiple dimensions of the MOA framework. In particular, combining social norms messages with peer modelling, repeated social feedback, experiential education, or structural food environment modifications may help overcome other behavioural drivers and strengthen intervention effectiveness.

From a methodological perspective, this thesis demonstrates the potential of combining experimental and modelling approaches, but further integration remains necessary. Agent-based models would benefit from calibration using individual-level behavioural data, including measures of norm perception and habit strength. Expanding simulation scenarios to incorporate broader forms of heterogeneity, including cultural and dietary differences, could further improve external validity and theoretical realism. Conversely, experimental research could use modelling results to anticipate unintended behavioural responses and optimize intervention design prior to large-scale implementation.

Another potential development for future research concerns participatory approaches. The findings from the school-based intervention suggest that participatory activities may enhance engagement and acceptability but may not be sufficient to produce systematic behavioural change when implemented in isolation. Future studies should investigate how participatory approaches can function as co-design and co-implementation tools that strengthen intervention ownership, facilitate social diffusion processes, and support institutional adaptation over time. In this regard, research should explore how schools, hospitality organizations, and public institutions can integrate behavioural interventions into routine practices and use monitoring and feedback mechanisms to iteratively refine intervention strategies.

Finally, expanding high-quality field experimentation in diverse collective catering settings remains essential to strengthen the external validity and policy relevance of behavioural research. Future trials should test different types of normative messaging, paired with other intervention tools, across heterogeneous food environments such as households, schools located in different territorial contexts, and workplace catering. Particular attention should be paid to designing scalable interventions that balance ecological validity with operational feasibility, allowing behavioural insights to be effectively translated into real-world food system transformation strategies.

Concluding remarks

The work presented in this thesis shows that social norms are neither ineffective nor universally powerful. Their influence on eating behaviours is modest, conditional, and highly sensitive to the characteristics of the food environments in which choices occur. By systematically integrating evidence synthesis, behavioural modelling, and field experimentation, this work clarifies when social norms are likely to succeed and why they may fail to produce large average effects to promote healthy and sustainable eating. More broadly, the thesis highlights the need to understand behavioural change as an adaptive process emerging from the interaction between individuals, social influences, and institutional food environments. In doing so, the thesis contributes to advancing behavioural research and informs the design of interventions capable of supporting food system transformation at the intersection of public health and sustainability.

Declaration of generative AI and AI-assisted technologies in the writing process

The author used AI-assisted tools (ChatGPT, OpenAI) exclusively for language editing, formatting, and minor stylistic refinement. All conceptual content, analyses, and interpretations are entirely the author's own responsibility.

Supplementary Materials

List of Supplementary Materials

Supplementary Materials I.....	159
Section I.1 - Theoretical framework underlying the selected moderators	159
Section I.2 - Methods.....	162
Section I.3 - Results	169
Section I.4 - References	176
Supplementary Materials II.....	179
Section II.1 - Model calibration	179
Section II.2 - Messages calibration.....	179
Section II.3 - Message mechanisms and modulators' functions definition	180
Section II.4 - Descriptive scenario results	185
Section II.5 - Scenario differences using Tukey's Honest Significant Difference test	186
Section II.6 - Correlation between first portions and extra servings	186
Section II.7 - Models' multicollinearity.....	188
Section II.8 - Full specifications of Portion model, Refill model, Mediated Leftovers model, Total-effect Leftovers model	189
Section II.9 - References.....	192
Supplementary Materials III	193
Section III.1 – Sampling results.....	193
Section III.2 – Intervention timeline.....	195
Section III.3 - Correction of inconsistent measurements.....	197
Section III.4 – Food categorization.....	198
Section III.5 – Descriptive results.....	198
Section III.6 – Event-study robustness checks	203
Section III.7 - Social norm message semiotic analysis.....	205
Section III.8 - Teacher's guidelines for the in-class activity	211

Section III.8.1 - ANNEX 1: The healthy eating plate: what it is and how it is composed	214
Section III.8.2 - ANNEX 2: Material for the game “Let's complete the Healthy Eating Plate”	216
Section III.8.3 - ANNEX 3: Poster examples	219
Section III.8.4 - ANNEX 4: Dishes figures for the game “Let’s complete the Healthy Eating Plate”	220

List of Supplementary Figures

Supplementary Figure I.A: Boxplots of effect sizes across the three effect categories (-1 = negative, 0 = non-significant, 1 = positive). Outliers (beyond $1.5 \times \text{IQR}$ from the first or third quartile) are highlighted in red.....	169
Supplementary Figure I.B: Funnel plot of 88 estimated effect sizes (sub-sample).....	170
Supplementary Figure I.C: Leave-one-out change in the pooled estimate (delta)	172
Supplementary Figure I.D: Cook's distance plot	172
Supplementary Figure I.E: COVRATIO plot.....	173
Supplementary Figure II.A: Parametric modulator curve for varying agent's thresholds	183
Supplementary Figure II.B: Amount of leftovers per person (g) for level of choice threat: $\rho = 0.8$	184
Supplementary Figure II.C: Amount of leftovers per person (g) for level of choice threat: $\rho = 0.6$	184
Supplementary Figure II.D: Heatmap of pairwise differences in mean PW across the 36 simulated scenarios. Each cell represents the mean difference between two scenarios (Group 1 – Group 2), with red indicating higher and blue indicating lower leftovers for Group 1...	186
Supplementary Figure II.E: Correlation between the number of guests taking a small first portion and the total number of extra portions taken across simulations	187
Supplementary Figure II.F: Correlation between the number of guests taking a normal first portion and the total number of extra portions taken across simulations	187
Supplementary Figure II.G: Correlation between the number of guests taking a large first portion and the total number of extra portions taken across simulations	187
Supplementary Figure III.A: Map of the 22 schools included in the sample. Red = Control, Yellow = Treatment.....	194
Supplementary Figure III.B: Means and 95% CIs PW% dynamics over time by course, full sample. Notes: the horizontal lines indicate the pre-treatment average PW% for control (blue) and treatment (orange) groups, the vertical red line indicates the first day of post-treatment measu	202
Supplementary Figure III.C: Robustness check, dynamic treatment effects on SiD PW%: event-study estimates on the full sample, removing 4 classes with incorrect posters	203
Supplementary Figure III.D: Robustness check, dynamic treatment effects on FD PW%: event-study estimates on the full sample, removing 4 classes with incorrect posters	203

Supplementary Figure III.E: Robustness check, dynamic treatment effects on SeD PW%: event-study estimates on the full sample, removing 4 classes with incorrect posters	204
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List of Supplementary Tables

Supplementary Table I.A: Database and Search query	162
Supplementary Table I.B: Bibliography of articles included in the review	163
Supplementary Table I.C: Data Extraction coding scheme	165
Supplementary Table I.D: Example of the standardized spreadsheet used to extract data from publications	168
Supplementary Table I.E: Leave-one-out (LOO) influence diagnostics.....	170
Supplementary Table I.F: Sensitivity analysis fitting the meta-analytic model after removing Hang et al. (2020)	173
Supplementary Table I.G: Formal Tests of Subgroup Differences (Single-predictor Meta-Regression Models)	174
Supplementary Table I.H: Robustness check Model from Eq. 1.2 and Model from Eq. 1.3.	175
Supplementary Table II.A: Parameters used for model calibration by Puga-Gonzalez et al. (2025)	179
Supplementary Table II.B: Leftovers generated during the experiments	180
Supplementary Table II.C: Parameter setting and average results for the 36 simulated scenarios.....	185
Supplementary Table II.D: Generalized Variance Inflation Factors for the three models	188
Supplementary Table II.E: Full specification for the Portion model, without interactions (Column 1) and with interactions (Column 2).....	189
Supplementary Table II.F: Full specification for the Refill model, without interactions (Column 1) and with interactions (Column 2).....	190
Supplementary Table II.G: Full specification for the Mediated Leftovers model, without interactions (Column 1) and with interactions (Column 2)	191
Supplementary Table II.H: Full specification for the Total-effect Leftovers model.....	192
Supplementary Table III.A: Correspondence of Vast Areas and AUSLs, and number of schools sampled for each VAs based on the number of schools per AUSL	193
Supplementary Table III.B: Final sample of schools divided by VA and AUSL	194
Supplementary Table III.C: Measurement and intervention timeline. Yellow cells = T0 measurement, Red cells = co-design activity suggested week, Blue cells = T1 measurements, P = poster displayed. Menu seasonality: A/W= Autumn/Winter, S/S= Spring/Summer	195
Supplementary Table III. D: Food categories	198

Supplementary Table III. E: Descriptive statistics for the two experimental groups at the Vast Area level	198
Supplementary Table III.F: Differences at T0, Welch two-sample t-test, full sample	199
Supplementary Table III.G: Cluster-robust linear regressions to test the baseline comparability of treatment and control groups, full sample	199
Supplementary Table III.H: Differences at T0, Welch two-sample t-test, Vast Areas level ..	199
Supplementary Table III.I: Cluster-robust linear regressions to test the baseline comparability of treatment and control groups, Vast Area Level.....	199
Supplementary Table III.J: Matching of food categories at T0 and T1, class level.....	200
Supplementary Table III.K: Summary statistics of PW% (total sample), divided by group, dish, and measurement period.....	201
Supplementary Table III.L: Robustness check, average treatment effect for the full sample after removing VA2 schools.....	201
Supplementary Table III.M: Robustness check, average treatment effect for the full sample after removing 4 classes with incorrect posters	202
Supplementary Table III.N: Floch's valorization square (Floch, 2001)	206
Supplementary Table III.O: Floch's valorization square – Adaptation for children	206

Supplementary Materials I

Chapter 1

Framing the influence of eating social norms on eating behaviours: a systematic literature review and meta-analysis of the moderators

Section I.1 - Theoretical framework underlying the selected moderators

As outlined by the Focus Theory of Normative Conduct (Cialdini et al., 1990) and the Theory of Normative Social Behavior (Lapinski & Rimal, 2005), the relationship between social norms and behavioural outcomes is influenced by several moderating conditions also called moderators. This section provides a brief outline of the main groups of moderators analyzed in this work. We focused on moderators that have been previously discussed in the literature and for which consistent information was available across the studies included in our review. Drawing on theories of social norms and prior empirical evidence, four main categories of moderators that may influence the strength of social norms' effects on eating behaviour can be identified: (1) experimental setting characteristics, (2) participants' characteristics, (3) social norm characteristics, (4) referent of the norm characteristics, (5) outcome behaviour characteristics.

Moderators relating to experimental setting characteristics include the setting where social norms are put in place, and the familiarity of the participants with this setting. Previous reviews have noted substantial diversity in the settings in which normative influence is tested (Rhodes et al., 2020), reflecting different social and contextual environments in which norms operate. Three types of setting are mostly reported in empirical studies testing the influence of social norms - and are therefore included in our analysis. Laboratory settings provide controlled conditions but may reduce ecological validity, while in field experiments participants act in a naturally occurring social context, whose features are not controlled by researchers. Online settings, on the other hand, may elicit different levels of engagement. The familiarity of the setting - also known as ambiguity - refers to how familiar or unfamiliar the environment is to individuals. In unfamiliar settings, people are more likely to rely on social cues to decide how

to behave (Lapinski & Rimal, 2005). Conversely, in familiar settings, individuals can rely on prior experience, making social norms less influential. Previous literature supports the statement that social norms are more relevant when ambiguity is high both with regards to descriptive (Cialdini et al., 1991; Goldstein et al., 2008; Higgs, 2015) and injunctive norms (Chen et al., 2024).

Social norms have also shown to moderate eating behaviours across different participants characteristics. Both age groups and gender can moderate the social norm effects in influencing eating behaviours (Cruwys et al., 2015; Ragelienė & Grønhøj, 2020; Stok et al., 2016; Vartanian et al., 2015), but the extent and magnitude of this influence does not yet have common agreement.

Next, social norms specifications can vary across several dimensions that may influence their effect on eating behaviours. A first distinction concerns the type of norm: descriptive norms indicate what others do, while injunctive norms describe what others approve (Cialdini et al., 1991; Rimal & Real, 2005). Evidence is mixed, but several studies suggest that descriptive norms exert a stronger effect on eating behaviours (Cruwys et al., 2015; Melnyk et al., 2022). Another relevant dimension is the message type. Norm messages can be positively framed (prescriptive: what people do/approve) or negatively framed (proscriptive: what people do not do/disapprove) (Bergquist & Nilsson, 2019; Staunton et al., 2014). Rhodes et al. (2020) found that prescriptive norms are more effective at influencing behaviour compared to proscriptive norms. Conversely, Bergquist & Nilsson (2019) conclude that proscriptive norms strongly influenced participants behaviour.

The level of the norm i.e., whether it reflects a majority or a minority norm also plays an important role. While social learning theories suggest that individuals tend to imitate majority behaviours (Laland, 2004), Binder et al. (2019) found that majority norms did not increase healthy food choices, while minority ones decreased them. Therefore, we include the level of the norm as a moderator to test whether majority and minority norms differentially affect eating behaviours. Finally, the mode of norm delivery may influence the extent to which individuals follow the normative message. Rhodes et al. (2020) highlighted the wide methodological variability in the mode of norm delivery across studies, including written texts, videos, images, or face-to-face communication. This factor represents a meaningful moderator, as the medium through which a message is conveyed may alter its perceived credibility, social presence, and emotional engagement. In this study, we distinguish between physical and virtual norm delivery, and include them in the analysis to explore whether the mode of communication moderates the influence of social norms on eating behaviours.

The characteristics of the norm referent may also shape the influence of social norms on eating behaviours. A relevant factor concerns the source authority. Social norms can originate from authority figures (e.g., teachers) or peers (e.g., classmates). This distinction corresponds to compliance (authority-driven) and conformance (peer-driven) mechanisms (Cialdini & Goldstein, 2004). Another factor involves the age and gender of the norm referent, which may affect how strongly individuals identify with the reference group. According to Rimal & Real (2005), group identity reflects both the perceived similarity - the extent to which people see themselves as alike to referent others - and aspiration, intended as the desire to emulate them. Drawing on Social Identity Theory (Hogg et al., 1995), individuals are more influenced by models they perceive as similar or belonging to their in-group. Chen et al. (2024) suggest that descriptive norms have stronger effects when referents share target individuals' demographic characteristics, such as age or gender. An additional dimension is related to the familiarity of the referent, meaning whether the norm source is socially close (friends, family) or distant (strangers, general population). Evidence is mixed, as in some cases the social influence on eating behaviour does not differ among familiar or unfamiliar referents (Cruwys et al., 2015; Vartanian et al., 2015), while in other cases it is a significant moderator (Ruddock et al., 2019).

The influence of social norms on eating behaviour may also depend on specific characteristics of the investigated outcomes. First, diverse types of food have been tested, both high-energy dense (e.g., snacks, cookies) and low-energy dense (e.g., fruits and vegetables). Results about how food type moderates the effect of social norms on eating behaviour are often mixed (Ruddock et al., 2019; Stok et al., 2016).

Another relevant aspect involves the type of outcome. Behavioural intentions and actual behaviours are distinct constructs: intentions are proximal predictors of behaviour (Ajzen, 1991; Webb & Sheeran, 2006), yet the intention-behaviour gap shows that intentions do not always translate into action (Hassan et al., 2016; Sheeran & Webb, 2016). Therefore, we examine whether the effects of social norms differ depending on whether the outcome refers to eating intentions or actual eating behaviours.

Finally, outcome observability may play a crucial moderating role. This moderator refers to whether eating behaviour occurs publicly or privately. Public behaviours are more observable, increasing social pressure and normative influence (Lapinski & Rimal, 2005; Rimal et al., 2011). Therefore, we expect social norms to exert a stronger influence in public than private settings.

Section I.2 - Methods

Supplementary Table I.A: Database and Search query

Database	Search query
Scopus	(TITLE-ABS-KEY ("social norm*") OR TITLE-ABS-KEY ("normative influence*") OR TITLE-ABS-KEY ("social influenc*") OR TITLE-ABS-KEY ("descriptive norm*") OR TITLE-ABS-KEY ("injunctive norm*") OR TITLE-ABS-KEY ("group pressur*") OR TITLE-ABS-KEY ("peer pressur*") OR TITLE-ABS-KEY ("group influenc*")) AND (TITLE-ABS-KEY (behavior*) OR TITLE-ABS-KEY (behaviour*)) AND (TITLE-ABS-KEY ("food habit*") OR TITLE-ABS-KEY ("eating choice*") OR TITLE-ABS-KEY ("food choice*") OR TITLE-ABS-KEY ("dietary habit*") OR TITLE-ABS-KEY ("eating behaviour*") OR TITLE-ABS-KEY ("eating behavior*") OR TITLE-ABS-KEY ("food wast*")) AND NOT TITLE-ABS-KEY (ill*) AND NOT TITLE-ABS-KEY (diseas*) AND NOT TITLE-ABS-KEY (syndrom*) AND NOT TITLE-ABS-KEY (nurs*) AND NOT TITLE-ABS-KEY (disorder*) AND NOT DOCTYPE (bk) AND NOT DOCTYPE (ch) AND NOT DOCTYPE (ed) AND NOT DOCTYPE (re) AND NOT DOCTYPE (cp) AND LANGUAGE (english) AND NOT SUBJAREA (vete) AND NOT SUBJAREA (dent) AND NOT SUBJAREA (bioc) AND NOT SUBJAREA (immu) AND NOT SUBJAREA (phar) AND NOT SUBJAREA (ceng) AND NOT SUBJAREA (chem) AND NOT SUBJAREA (comp) AND NOT SUBJAREA (cart) AND NOT SUBJAREA (ener) AND NOT SUBJAREA (engi) AND NOT SUBJAREA (mate) AND NOT SUBJAREA (math) AND NOT SUBJAREA (phys)
Web of Science	(ALL=("social norm*" OR "normative influence*" OR "social influenc*" OR "descriptive norm*" OR "injunctive norm*" OR "group pressur*" OR "peer pressur*" OR "group influenc*")) AND (ALL=(behavior* OR behaviour*)) AND (ALL=("food habit*" OR "eating choice*" OR "food choice*" OR "dietary habit*" OR "eating behaviour*" OR "eating behavior*" OR "food wast*")) NOT (ALL=(ill*) OR ALL=(diseas*) OR ALL=(syndrom*) OR ALL=(nurs*) OR ALL=(disorder*)) NOT (DT=(Book OR Book Chapter OR Book Review OR Proceedings Paper OR Review)) AND LA=(English) NOT (WC=(Zoology OR Medical Informatics OR Neurosciences OR Biology OR Computer Science Interdisciplinary Applications OR Dentistry Oral Surgery Medicine OR Biochemistry Molecular Biology OR Cell Biology OR Developmental Biology OR Energy Fuels OR Engineering Environmental OR Entomology OR Pharmacology Pharmacy OR Substance Abuse OR Veterinary OR Surgery))
ProQuest	((NOFT(("social norm" OR "social norms") OR ("normative influence") OR ("social influence" OR "social influences") OR "descriptive norm*" OR "injunctive norm*" OR ("group pressure") OR ("peer pressure") OR ("group influence" OR "group influenced" OR "group influences"))) AND NOFT(behavior* OR behaviour*) AND (NOFT(("food habit" OR "food habits" OR "food was*") OR "eating choice*" OR ("food choice" OR "food choices") OR ("dietary habits") OR ("eating behaviour") OR ("eating behavior" OR "eating behaviors")))) NOT (NOFT(ill*) OR NOFT(diseas*) OR NOFT(syndrom*) OR NOFT(nurs*) OR NOFT (disorder*))) NOT (at.exact("Review" OR "Conference Proceeding" OR "Commentary" OR "Report" OR "Editorial" OR "General Information" OR "Literature Review") NOT stype.exact("Dissertations & Theses" OR "Newspapers" OR "Working Papers" OR "Wire Feeds" OR "Conference Papers & Proceedings" OR "Trade Journals" OR "Books" OR "Magazines" OR "Reports") NOT la.exact("POR" OR "FRE" OR "POL" OR "SPA")))) NOT (stype.exact("Dissertations & Theses" OR "Newspapers" OR "Working Papers" OR "Wire Feeds" OR "Conference Papers & Proceedings" OR "Trade Journals" OR "Books" OR "Magazines" OR "Reports") NOT la.exact("POR" OR "FRE" OR "POL" OR "SPA") AND PEER(yes))

Supplementary Table I.B: Bibliography of articles included in the review

- Aldoh, A., Sparks, P., & Harris, P. R. (2021). Dynamic norms and food choice: Reflections on a failure of minority norm information to influence motivation to reduce meat consumption. *Sustainability*, 13(15), 8315. <https://doi.org/10.3390/su13158315>
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Supplementary Table I.C: Data Extraction coding scheme

Category	Variable	Description	Type of Data/Code
Bibliographic characteristics	article_id	Unique identifier for the article in the dataset	Numeric
	study_id	Identifier for a specific study within the article (if multiple studies)	Numeric
	effect_id	Identifier for a specific effect size within the study	Numeric
	Authors	Article authors	Text
	Title	Article title	Text
	Doi	Digital Object Identifier	Text (DOI format)
	Year	Year of publication	Numeric
	location_country	Country where study was conducted	1=Australia 2=US 3=UK 4=Germany 5=Pakistan 6=Canada 7=France 8=Netherlands 9=China 10=Switzerland 11=Singapore 12=Other Eu countries
	setting_code	Setting in which the study was conducted	1=Real life eating context 2= Laboratory/Non-eating

Experimental setting characteristics			context 3= Online
	setting_familiarity	Familiarity of the eating setting	1=Low 2=Medium
Participants' characteristics	sample_size	Number of participants	Numeric
	mean_sample_age	Mean sample age	Numeric
	sd_sample_age	Standard deviation of sample age	Numeric
	sample_gender	Gender distribution (male/female/mixed)	1= Sample composed of more than 80% males 2= Sample composed of more than 80% females 3= Sample composed by mixed gender participants
	sample_gender_perc	% of female participants	Numeric
	sn_target	Age of participants	1= Children (under 12 years old) 2= Adolescents (under 18 years old) 3= Young adults (under 26 years old) 4= Adults (above 26 years old)
Social norm Characteristics	sn_type	Norm type (descriptive/injunctive)	0=Injunctive 1=Descriptive
	sn_message	Type of message: prescriptive (the social norm describes what is done or what should be done) or proscriptive (the social norm describes what others refraining from doing or what should be avoided)	0 = proscriptive 1 = prescriptive
	minority_majority	Reference group: minority (e.g., "30% of students eat sufficient vegetables") or majority (e.g., 70% of Australians are trying to reduce meat consumption, or a confederate is present)	0 = majority 1 = minority;
	sn_delivery	Mode of delivery: physical, the norm is communicated in-person or through real-world interaction. Includes oral communication, live observation, or written signs in a real-	0 = virtual 1= physical

		life context.; or virtual, the norm is communicated virtually or remotely, such as in online surveys, videos, digital text, or through remote confederates.	
Referent of the norm characteristics	source_authority	Norm referent has authority (e.g., teacher) or does not have authority on the participants.	0 = peer 1 = referent with authority
	referent_age	Age of referent group similar to participants or not	0 = different 1 = similar
	referent_gender	Gender of referent group similar to participants or not	0 = different 1 = similar
	referent_familiarity	Participants already knew the norm referent before the experiment (classmate, teacher, friend)	0 = no 1 = yes
Outcome behaviour characteristics	food_type	Type of food involved in the study	Text
	food_code	Coding scheme for food type	0 = unhealthy 1 = healthy 2 = other
	outcome_type	General category of outcome measured (intake, choice, liking, preference, waste)	Text
	outcome_behaviour	The investigated behaviour is an actual behaviour or an intended one.	0 = Intention 1 = Behaviour
	outcome_observability	Participants' behaviour was observed during the experiment or participants acted in anonymity (e.g., online survey) or they were not observed by others during the experiment	0 = behaviour not observable 1 = observable behaviours
Effects	effect_cat	Category of effect (positive/negative/null)	-1 = if the effect estimated was less than 0 and statistically significant ($p < 0.05$) 0 = if the effect estimated is not statistically significant 1 = if the effect estimated was greater than 0 and statistically significant ($p < 0.05$)
	effect_size	Numeric effect size	Numeric
	effect_size_type	Type of effect size (Cohen's d, OR, r, etc.)	Text

	ci_lower	Lower confidence interval bound	Numeric
	ci_upper	Upper confidence interval bound	Numeric
	se	Standard error	Numeric

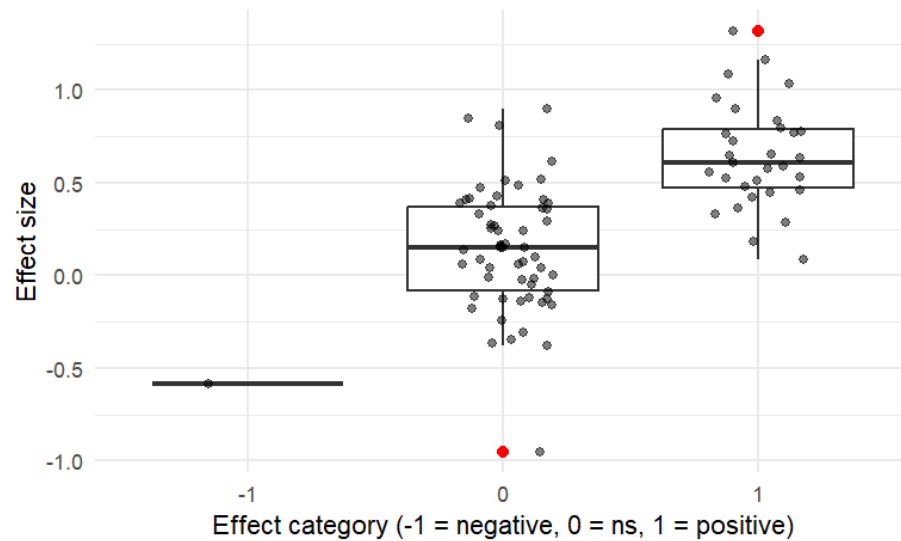
Supplementary Table I.D: Example of the standardized spreadsheet used to extract data from publications

arti- cle- id	stu- dy- id	effe- ct- id	authors	title	doi	y e a r	sam- ple- size	settin- g- co- de	locatio- n- coun- try	mean.s ample- age	sd.s ample- age	sn.t arg- et	sampl- e- gen- der	sample- gender- perc	sn- type	sn- mess- age	minorit- y- majority	source- author- ity	refer- ent- age	refer- ent- gen- der	referent- familia- rity	sn.d elive- ry	food- type	food- co- de	outco- me- type	outcome- behavi- our	outcome- observabi- lity	setting- familiar- ity	effe- ct- at	effe- ct- size	effect- size- type	ci.l owe- r	ci. upp- er	se
1	1	1	Khan, H. and Lee, R. and Khan, Z.	The interaction of social influence and message framing on children's food choice	10.1108/EJ M-07-2021- 0505	2022	84	2	5	11.5		1	3	44	0	1	0	1	0	0	1	0	fruit	1	Choice	0	1	2	0	0.08 600	hedges	- 0.38 560	0.5 576	0.2 406
1	1	2	Khan, H. and Lee, R. and Khan, Z.	The interaction of social influence and message framing on children's food choice	10.1108/EJ M-07-2021- 0505	2022	86	2	5	11.5		1	3	44	0	0	0	1	0	0	1	0	candy	0	Choice	0	1	2	0	0.48 630	hedges	- 0.00 590	0.9 785	0.2 511
2	2	3	Gumussoy, M. and Rogers, P.J.	A social norm intervention increases liking and intake of whole crickets, and what this tells us about food disgust	10.1016/j.ap pet.2023.106 768	2023	60	2	3	20.8	2.8	3	1	82	1	1	0	0	1	0	0	0	insects	2	Intake	1	0	1	1	0.58 8	hedges	0.07 78	1.0 987	0.2 604
3	3	4	McLeod, C.J. and Thomas, J.M.	Does social-norm messaging influence expected satiety and ideal portion-size selection?	10.1016/j.ap pet.2023.107 157	2024	235	3	3	26	10	4	3	77.5	1	1	0	0	0	0	0	1	past	2	Intake	0	0	0	0	0.15 430	hedges	- 0.10 110	0.4 096	0.1 303
3	4	5	McLeod, C.J. and Thomas, J.M.	Does social-norm messaging influence expected satiety and ideal portion-size selection?	10.1016/j.ap pet.2023.107 157	2024	200	3	3	20	4	3	1	82	1	1	0	0	0	0	0	1	past	2	Intake	0	0	0	0	0.00 290	hedges	- 0.27 330	0.2 792	0.1 409

Data were extracted at the observation level (i.e. for each effect identified). In some cases, multiple effects could be extracted from the same study, as visible in Khan et al. (2022) (article_id 1, study_id 1), from which two effects were identified (effect_id 1 and effect_id 2).

In other cases, multiple studies - or experiments - were presented in the same article. This example is shown in the Table by McLeod et al. (2024) (article_id 3), which included study_id 3 and study_id 4. Each of these studies provided one effect (effect_id 4 and effect_id 5).

Section I.3 - Results



Excluded outliers:

article_id	study_id	effect_id	Reference
36	46	114	Feeney et al. (2011)
40	51	220	Pliner & Mann (2004)

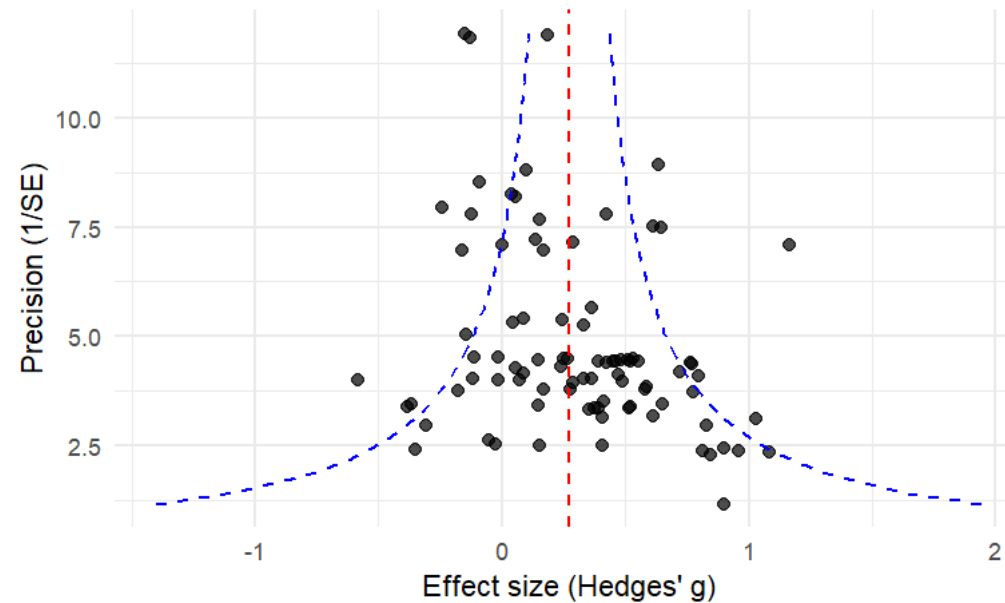
Supplementary Figure I.A: Boxplots of effect sizes across the three effect categories (-1 = negative, 0 = non-significant, 1 = positive). Outliers (beyond $1.5 \times \text{IQR}$ from the first or third quartile) are highlighted in red.

Publication bias assessment

We conducted a publication bias assessment, using the *funnel* function of the *metafor* package in R. Due to the characteristics of the observations included, we could perform this analysis only on the sub-sample of effects for which we have a quantitative estimated measure.

Publication bias is defined as “occur[ing] when the published literature reports results that systematically differ from those of all studies and statistical tests conducted” (Rothstein et al., 2006) and can have an influence on the estimated effects (Sadeghi, 2025). The funnel plot shows the

Hedges's g effect sizes on the x-axis, plotted against their precision (i.e. as the inverse of the standard error) on the y-axis. A meta-analysis without publication bias should produce a funnel plot in which most of the effects fall within the funnel and are symmetrically distributed with the most precise one closer to the mean effect, and the less precise ones towards the bottom of the funnel and farther from the mean (Borenstein et al., 2021). The funnel plot inspection (Supplementary Figure I.B) does not show visible asymmetry.



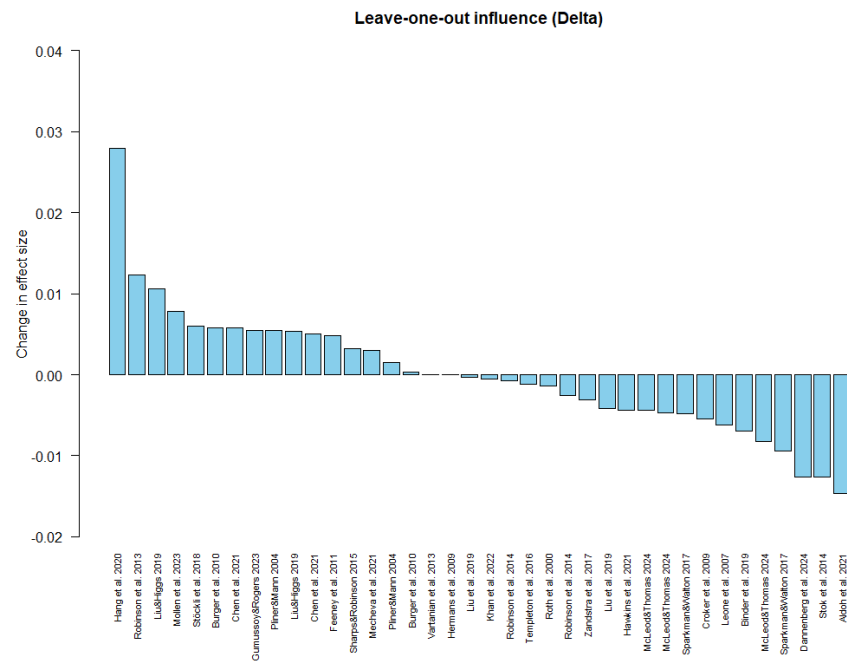
Supplementary Figure I.C: Funnel plot of 88 estimated effect sizes (sub-sample)

Supplementary Table I.E: Leave-one-out (LOO) influence diagnostics

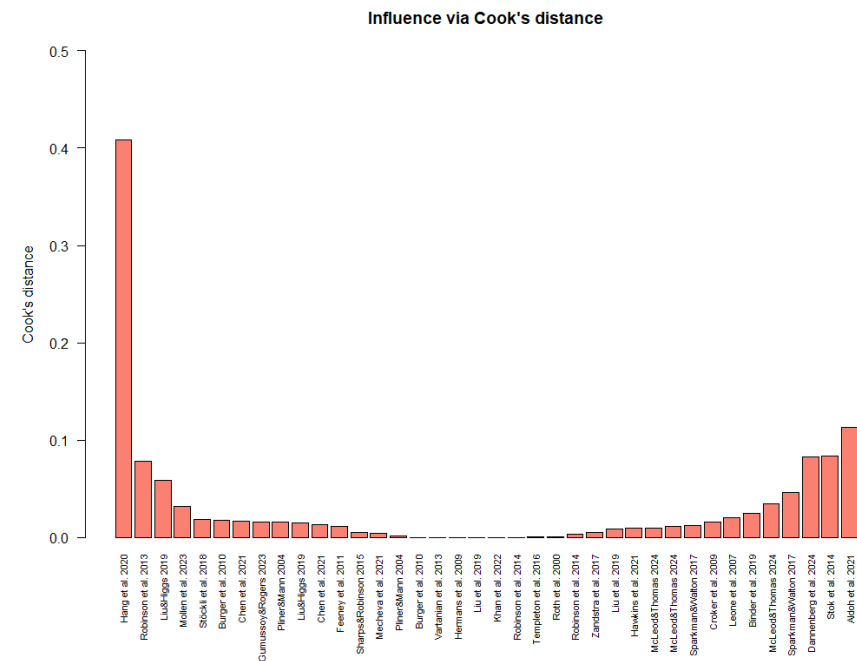
Study	Study ID	Estimate LOO	Cook's Distance	CovRatio
Khan et al. (2022)	1	0.2730806	0.00014	1.0514449
McLeod & Thomas (2024)	3	0.2769802	0.01015	1.0581870
McLeod & Thomas (2024)	4	0.2807721	0.03512	1.0322044

McLeod & Thomas (2024)	5	0.2773156	0.01175	1.0548043
Mollen et al. (2023)	6	0.2647112	0.03227	1.0372571
Hawkins et al. (2021)	7	0.2769275	0.00991	1.0680951
Zandstra et al. (2017)	8	0.2756876	0.00507	1.0633365
Liu & Higgs (2019)	9	0.2619868	0.05852	0.9922510
Liu & Higgs (2019)	10	0.2672626	0.01472	1.0223314
Templeton et al. (2016)	11	0.2736975	0.00066	1.0726577
Binder et al. (2019)	13	0.2794970	0.02505	1.0301745
Sharps & Robinson (2015)	14	0.2693136	0.00555	1.0430422
Liu et al. (2019)	15	0.2729113	0.00006	1.0596535
Liu et al. (2019)	16	0.2766953	0.00888	1.0711722
Hang et al. (2020)	17	0.2446045	0.40855	0.8267641
Stok et al. (2014)	18	0.2852178	0.08353	0.9578008
Leone et al. (2007)	21	0.2788280	0.02044	1.0281112
Crocker et al. (2009)	23	0.2780797	0.01585	1.0654492
Burger et al. (2010)	24	0.2721943	0.00007	1.0495571
Burger et al. (2010)	25	0.2667798	0.01752	1.0231096
Aldoh et al. (2021)	27	0.2872804	0.11299	0.9450928
Vartanian et al. (2013)	28	0.2725430	0.00000	1.0544230
Robinson et al. (2014)	31	0.2732982	0.00028	1.0380404
Robinson et al. (2014)	32	0.2750967	0.00333	1.0446519
Mecheva et al. (2021)	35	0.2695938	0.00463	1.0655625
Stöckli et al. (2018)	38	0.2666144	0.01854	0.9978495
Chen et al. (2021)	39	0.2668207	0.01728	1.0192302
Chen et al. (2021)	40	0.2675843	0.01299	1.0234410
Dannenberg et al. (2024)	42	0.2851627	0.08280	0.9942352
Sparkman & Walton (2017)	44	0.2820248	0.04667	1.0308106
Sparkman & Walton (2017)	45	0.2774120	0.01224	1.0561922
Feeney et al. (2011)	46	0.2677895	0.01195	1.0020057
Roth et al. (2001)	47	0.2739258	0.00096	1.0583778
Hermans et al. (2009)	48	0.2725836	0.00000	1.0516139
Robinson et al. (2013)	49	0.2602883	0.07881	0.9710768
Pliner & Mann (2004)	50	0.2671050	0.01561	1.0249196
Pliner & Mann (2004)	51	0.2710223	0.00125	1.0025740

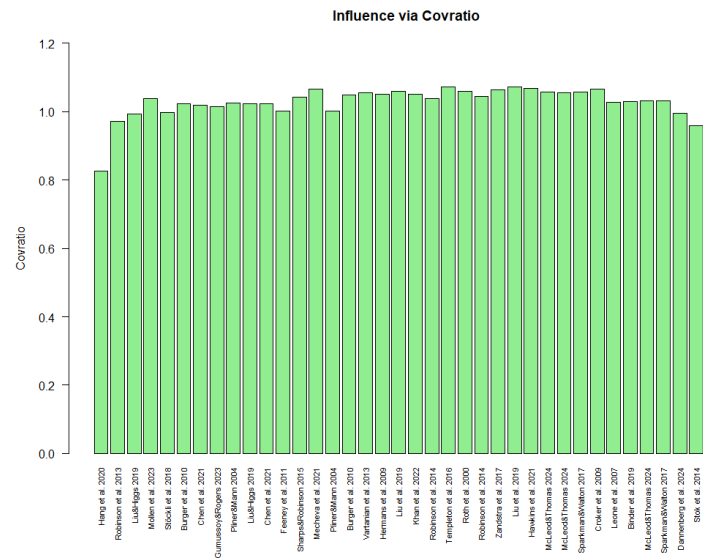
Note: Estimate LOO refers to the effect size estimate obtained when the corresponding study is removed from the meta-analysis (leave-one-out analysis). Cook's Distance is a measure of the influence of each study on the overall model estimate; higher values indicate greater impact of that study on the model. Covariance Ratio (COVRATIO) indicates the influence of each study on the precision of the model estimates; values considerably different from 1 suggest that removing the study largely changes the covariance of the model.



Supplementary Figure I.D: Leave-one-out change in the pooled estimate (delta)



Supplementary Figure I.E: Cook's distance plot



Supplementary Figure I.F: COVRATIO plot

Supplementary Table I.F: Sensitivity analysis fitting the meta-analytic model after removing Hang et al. (2020)

Model	Observations (effects)	Grand mean effect size estimate (SE)	95% CI	τ^2 (between-study variance)	Q
Meta-analytic full model	88	0.273 (0.044) ***	[0.187, 0.358]	0.045	275.89
Excluding Hang et al. (2020)	85	0.245 (0.040)***	[0.167, 0.323]	0.032	207.28

Supplementary Table I.G: Formal Tests of Subgroup Differences (Single-predictor Meta-Regression Models)

Moderator	Contrast	β (SE)	95% CI	QM (p-value)
Laboratory setting	Laboratory vs Online	0.160 (0.085) .	[-0.007, 0.327]	3.516 (0.061)
Low familiarity setting	Low vs Medium	0.131 (0.088)	[-0.042, 0.304]	2.192 (0.139)
Participants' age	Children vs Adults	0.349 (0.123) **	[0.107, 0.591]	QM overall = 10.545 (0.005)
	Young adults vs Adults	0.249 (0.090) **	[0.074, 0.425]	
Participants' gender	Female vs Mixed	0.017 (0.080)	[-0.140, 0.174]	0.044 (0.834)
Social norm type	Descriptive vs Injunctive	0.008 (0.083)	[-0.155, 0.170]	0.009 (0.925)
Type of message	Prescriptive vs Proscriptive	-0.164 (0.060) **	[-0.282, -0.045]	7.351 (0.007)
Level of the norm	Minority vs Majority	-0.107 (0.074)	[-0.253, 0.040]	2.036 (0.154)
Norm delivery	Physical vs Virtual	-0.235 (0.079) **	[-0.391, -0.080]	8.807 (0.003)
Source authority	-	-	-	-
Source age	Similar vs Different	0.027 (0.081)	[-0.131, 0.185]	0.114 (0.736)
Source gender	Same vs Different	0.248 (0.094) **	[0.063, 0.433]	6.882 (0.009)
Source familiarity	-	-	-	-
Food type	Healthy vs Unhealthy	-0.042 (0.068)	[-0.175, 0.092]	2.990 (0.224)
Outcome observability	Observable vs Private	0.184 (0.075) *	[0.037, 0.330]	6.047 (0.014)
Outcome type	Behaviour vs Intention	0.149 (0.090) .	[-0.027, 0.325]	2.772 (0.096)

Note: Each row reports the results of a single-predictor meta-regression testing whether subgroup differences are statistically significant. These models include a single moderator at a time and a random intercept for study. Results for Source Authority and Source Familiarity are omitted since one of the levels are represented by less than 10 observations.

*Significance codes: . $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$*

Supplementary Table I.H: Robustness check Model from Eq. 1.2 and Model from Eq. 1.3

Variable	Robustness check Model from Eq.2: Sign and Significance for 88 observations Estimate (SE)	Robustness check Model from Eq.3 Estimate (SE)
Intercept	0.231 (0.203)	0.038 (0.204)
Experimental setting characteristics		
Field	0.855 (0.279) **	0.271 (0.294)
Laboratory	0.097 (0.304)	0.098 (0.256)
Low familiarity setting	0.219 (0.268)	0.138 (0.255)
Participants' characteristics		
Children	0.984 (0.300) **	0.469 (0.264) .
Adolescents	-	-
Young adults	0.830 (0.238) ***	0.282 (0.174)
Female	-0.229 (0.182)	-0.139 (0.115)
Social norm characteristics		
Social norm type	0.210 (0.175)	0.135 (0.096)
Type of message	-0.296 (0.205)	-0.175 (0.072)*
Level of the norm	-0.263 (0.155) .	-0.081 (0.080)
Norm delivery	-0.139 (0.174)	-0.051 (0.148)
Referent of the norm characteristics		
Source authority	-0.562 (0.321) .	0.436 (0.219)*
Source age	-0.359 (0.186) .	-0.120 (0.156)
Source gender	0.045 (0.266)	0.286 (0.174).
Source familiarity	-0.333 (0.280)	-0.520 (0.245) *
Outcome behaviour characteristics		
Healthy food	0.212 (0.207)	0.038 (0.088)
Mixed food	-0.056 (0.242)	0.177 (0.160)
Outcome type	-0.558 (0.154)***	-0.146 (0.178)
Outcome observability	0.036 (0.157)	0.038 (0.109)
Model fit	Adjusted R ² =0.34	Model fit: k = 88 effect sizes, REML log-likelihood = -22.15, AIC = 84.30; BIC = 128.98 Random effects: Between-study variance: $\tau^2 = 0.041$ (SD = 0.201) Residual heterogeneity: $Q_E(69) = 132.799, p < .0001$ Test of moderators: $Q_M(18) = 40.74, p = .0017$

Section I.4 - References

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Supplementary Materials II

Chapter 2

A Bite Too Much: Scenario-Based Analysis of Simulated Plate Waste Behaviour at a Hotel Breakfast Buffet

Section II.1 - Model calibration

Supplementary Table II.A: Parameters used for model calibration by Puga-Gonzalez et al. (2025)

Parameter	Value	Standard deviation
Average weight control	0.5	0.01
Average fullness	0.3	0.01
Average hunger	0.7	0.01
Average indulgence (non-business guests)	0.7	0.01
Average indulgence (business guests)	0.6	0.01
Choosing ability	0.6	0.01
Female proportion	0.5	0.01
Food diversity	0.156	0.01
Leftover percentage	0.1	0.01
Self-control	0.446	0.01
Average conformism (non-business guests)	0.1	0.01
Average conformism (business guests)	0.25	0.01
Number of agents	250	

Section II.2 - Messages calibration

Data from eight Norwegian hotels, collected by Strawberry Hotels, include daily counts of business and non-business guests and buffet breakfast food waste. These data were gathered during an experiment testing how different buffet messages about food waste influenced daily leftovers (see Alonso Miquélez et al., 2024).

From March to September 2023, each hotel rotated through three treatments: no message (control), a positive message, and a provocative message. Daily food waste and guest numbers were recorded throughout. While Puga-Gonzalez et al. (2025) used the control data to calibrate the model, here we used the positive and provocative messages experiments to calibrate the model with a corresponding function. The calibration was performed by comparing the experimental data regarding days with positive or provocative messages and the model. The results are displayed in Supplementary Table II.B.

Supplementary Table II.B: Leftovers generated during the experiments

	Control (no message)	Positive message	Provocative message
N° of observations (days)	493	348	109
	Grams of leftovers per guest per day		
Mean	27.940007	22.80533	32.46264
Standard deviation	15.411966	12.77173	17.61744
Min	0	1.434426	4.83871
25%	16.777042	13.54897	19.19643
50%	26.315789	20.05666	29.95951
75%	36.431227	29.02588	46.15385
Max	104.268293	81.08108	100

Section II.3 - Message mechanisms and modulators' functions definition

When agents are serving themselves, they see a message being displayed. It was considered that each agent has an individual tolerance to the message threat level. Tolerance value is drawn from a beta distribution ($a=3$, $b=3$) and correlated (0.5) with self-control (Gaussian $\mu = 0.5$, $\sigma = 0.05$), meaning that guests with higher self-control also have higher tolerance. It was assumed that self-control can moderate reactance by allowing people to approach the message with a more considered perspective. On the other hand, each type of message has a threat level. The ABM incorporates two distinct decision-making routes, which apply to choices about portioning and leftovers. An agent's route depends on how their tolerance compares with the message's threat level. When the message threat level exceeds an agent's tolerance, reactance occurs, and the decision routes diverge.

When deciding on the size of the portion, an agent can follow Route 1 (no reactance) or 2 (reactance). In both cases, the agent's motives change based on a modulator.

The modulator is defined as a function of both the agent's tolerance threshold and the level of message threat. To illustrate this relationship, consider a graph in which either the message threat level or the agent's tolerance threshold is placed on the x-axis, while the modulator value is represented on the y-axis (Supplementary Figure II.A). The point message threat level = 0.5 corresponds to the condition of no communication.

The modulator is computed using a linear interpolation function. Specifically, the modulator value y_3 is obtained from Eq. II.A:

(II.A)

$$y_3 = y_1 + \left(\frac{y_2 - y_1}{x_2 - x_1} \right) * (x_3 - x_1)$$

The higher the message threat level (more provocative), the higher the chances of the agent reacting to it. Route 1: if the message threat level is lower than the agent's tolerance. In this case, the agent does not feel that the message is instigating reactance. The likelihood of conforming to perceived social standards (conformism) regarding FW increases. The importance of sustainability also increases, since the message has a positive effect on the agent, while the importance of indulgence decreases.

The importance of the motives changes based on a modulator (M1) given by Eq. II.B. This modulator represents how much importance increases or decreases (i.e., if M1=0.2, that means an increase or decrease of 20% in that importance).

For the case in which the message threat level is lower than the agent's tolerance threshold, the points are defined as:

$$P_1 = (x_1, y_1) = (0, 1)$$

$$P_2 = (x_2, y_2) = (\text{agent tolerance threshold}, 0)$$

$$P_3 = (x_3, y_3) = (\text{message threat level}, 0)$$

Substituting into the linear equation yields the formula to calculate modulator 1:

$$y_3 = 1 + \left(\frac{0 - 1}{\text{agent threshold} - 0} \right) * (\text{message threat level} - 0)$$

$$y_3 = 1 + \left(\frac{-1}{\text{agent threshold}} \right) * (\text{message threat level})$$

$$(II.B) \quad y_3 = 1 + \left(\frac{-\text{message threat level}}{\text{agent threshold}} \right)$$

Route 2: if the message threat level is higher than the agent's tolerance. In this case, there is reactance to the message, and the agent tends to do the opposite of what the message says. In this case, the importance of conformism, of the desire to control weight, and of indulgence all decrease.

The importance of the motives changes based on a modulator given by Eq. II.C.

When the message threat level exceeds the agent's threshold, the points are instead defined as:

$$P_1 = (x_1, y_1) = (1, 1)$$

$$P_2 = (x_2, y_2) = (\text{agent threshold}, 0)$$

$$P_3 = (x_3, y_3) = (\text{message threat}, 0)$$

In this case, modulator 2 is computed as:

$$y_3 = 1 + \left(\frac{0 - 1}{\text{agent threshold} - 1} \right) * (\text{message threat level} - 1)$$

$$y_3 = 1 + \left(\frac{-1}{\text{agent threshold} - 1} \right) * (\text{message threat level} - 1)$$

$$(II.C) \quad y_3 = 1 - \left(\frac{\text{message threat level} - 1}{\text{agent threshold} - 1} \right)$$

Supplementary Figure II.A displays how the modulators' values change according to the agent's threshold and the message threat level.

In both Routes, when the message threat level equals the agent's threshold, the message does not exert any influence on the agent as the modulator's value is 0.

Concerning the decision to leave leftovers, it was assumed that, as guests were exposed to the message at the beginning of the mealtime, their reaction to the message gradually diminishes in proportion to the time between serving and finishing their meal. This assumption is based on Ebbinghaus's forgetting curve theory, which hypothesizes that information is lost over time when there is no recall (Murre & Dros, 2015). In the model, the importance of motives changes proportionally to the time the agent spends eating. This reduction is given by Eq. II.D:

(II.D)

$$I_t = I_t \pm \rho * |I_{t=0} * e^{-1 * \gamma * \text{breakfast time}}|$$

Where I_t is the importance of the motive at time t , the parameter γ was set to 0.0001 and governs the rate at which the exponential term decays as breakfast time increases. The parameter ρ acts as an adjustment coefficient. We tested the model using $\rho=0.8$ and $\rho=0.6$, with the results shown in Supplementary Figure II.B and Supplementary Figure II.C. We selected $\rho=0.6$ for all subsequent simulations, as it exhibits lower variability and better reflects the assumed temporal behavior of the motive's importance.

Route 1: if the message threat level is lower than the agent's tolerance.

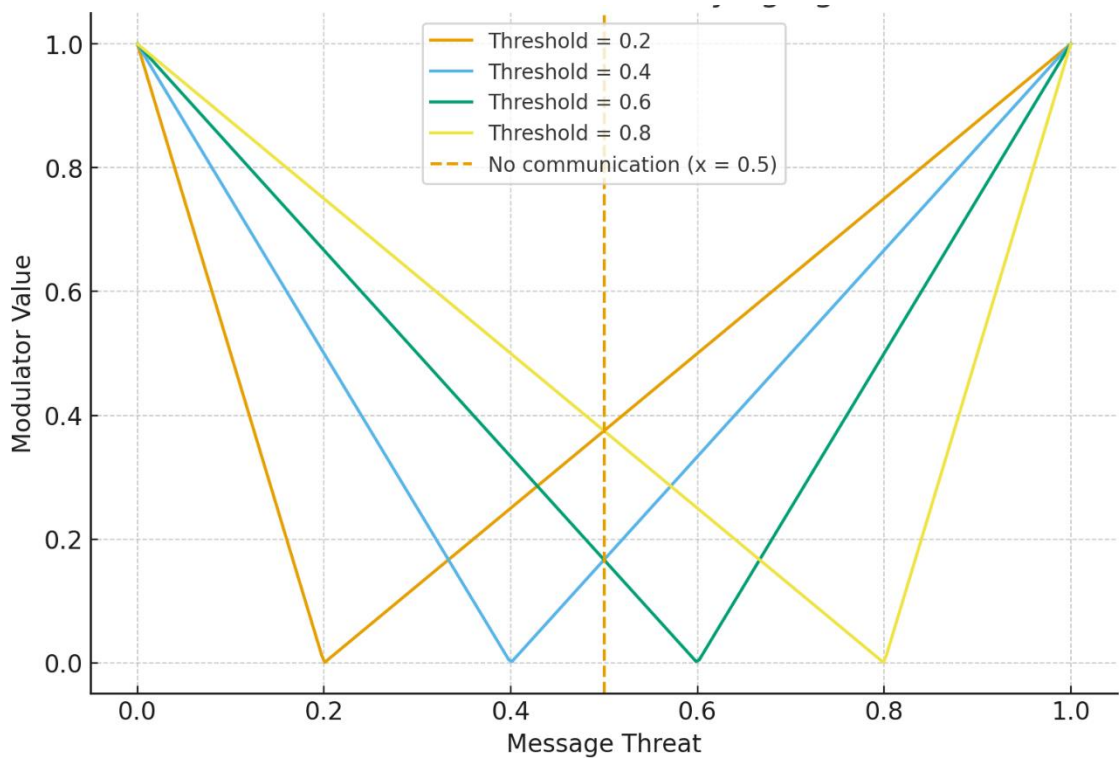
When the message is not perceived as threatening, the increased importance of conformism (raised during the portion size decision) gradually decreases as the agent eats. However, it never drops below its original baseline, that is, the value before the message was shown. In other words, conformism remains equal to or higher than the initial level, but lower than the heightened level triggered by the message. The same pattern applies to sustainability. However,

the importance of indulgence returns to its original baseline, since it does not influence the plate waste decision.

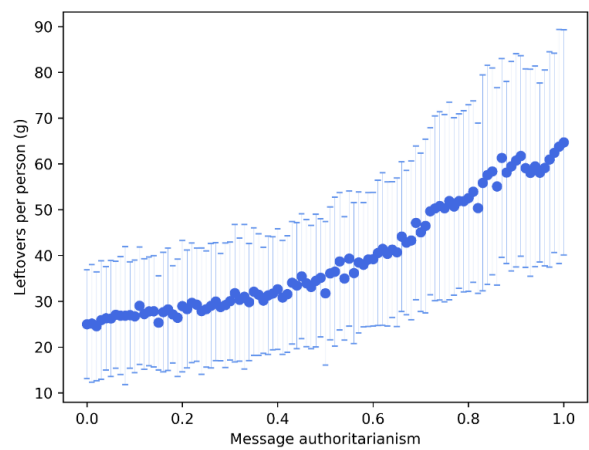
Route 2: if the message threat level is higher than the agent's tolerance.

When the message is perceived as threatening and reactance occurs, the reduced importance of conformism (lowered during the portion size decision) gradually increases while eating. However, it never exceeds the original baseline value from before the message was shown, meaning conformism remains equal to or lower than the initial level, but never higher than the pre-message level. The same logic applies to sustainability. The importance of the desire to control weight returns to its baseline. Fullness, however, does matter: its importance is first adjusted upward using the moderator in Eq. II.A, and then Eq. II.C is applied to account for its decrease over time. The resulting value of fullness is never lower than its level before the message was introduced.

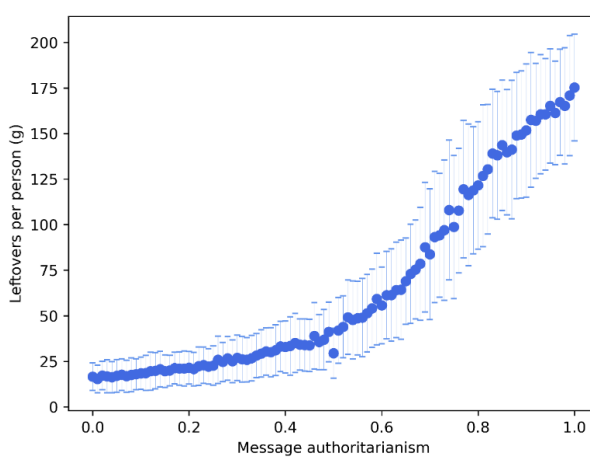
Motive importance values remain between 0 and 1.



Supplementary Figure II.A: Parametric modulator curve for varying agent's thresholds



Supplementary Figure II.B: Amount of leftovers per person (g) for level of choice threat: $\rho = 0.8$



Supplementary Figure II.C: Amount of leftovers per person (g) for level of choice threat: $\rho = 0.6$

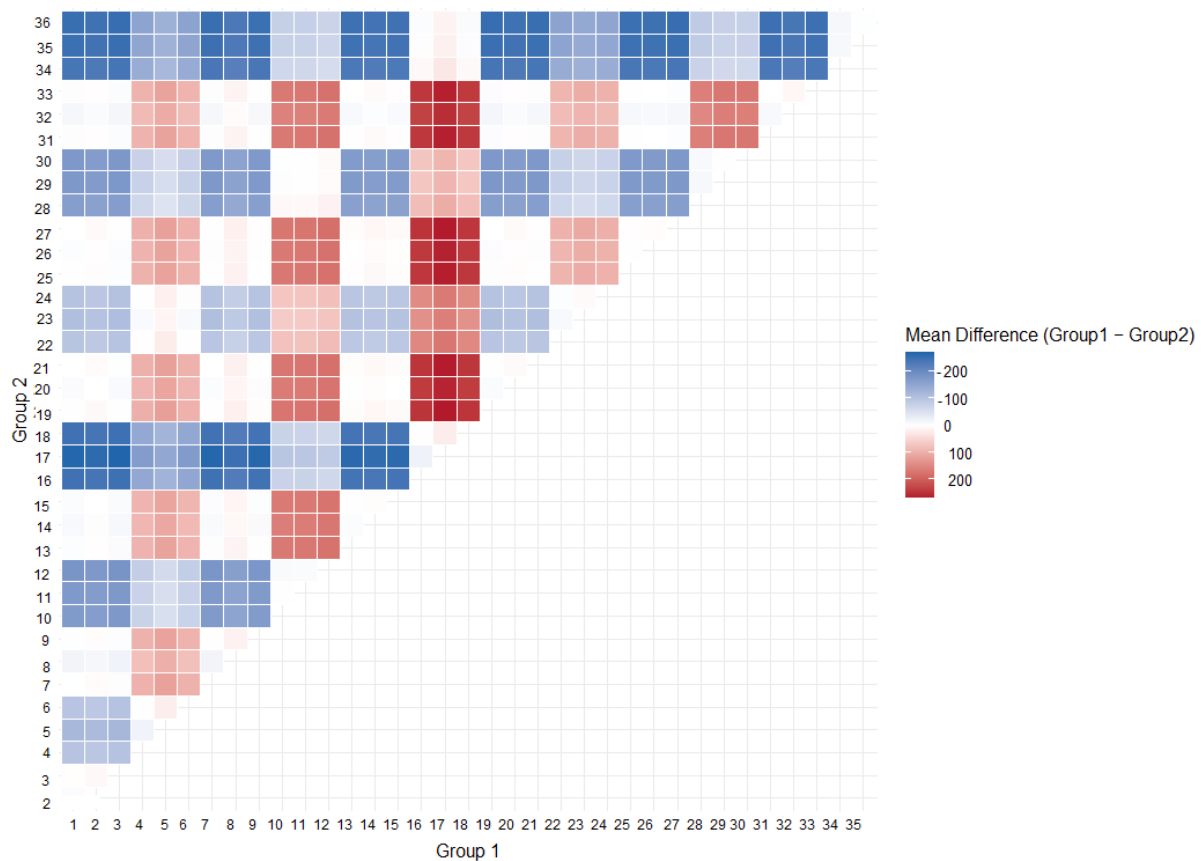
Section II.4 - Descriptive scenario results

Supplementary Table II.C: Parameter setting and average results for the 36 simulated scenarios

Scenario ID	Plate size	Clientele structure	Sustainability awareness	Communication strategy	Average PW/guest/day and standard deviation (g)
1	small	high business	high	no communication	11.46 ± 5.67
2	small	high business	high	provocative message	17.41 ± 6.37
3	small	high business	high	positive message	9.73 ± 5.76
4	small	high business	low	no communication	109.95 ± 18.96
5	small	high business	low	provocative message	130.01 ± 18.46
6	small	high business	low	positive message	108.53 ± 19.75
7	small	balanced	high	no communication	12.26 ± 7.39
8	small	balanced	high	provocative message	29.7 ± 8.44
9	small	balanced	high	positive message	13.43 ± 7.25
10	small	balanced	low	no communication	182.8 ± 25.64
11	small	balanced	low	provocative message	184.01 ± 25.41
12	small	balanced	low	positive message	191 ± 23.01
13	small	low business	high	no communication	15.44 ± 8.39
14	small	low business	high	provocative message	20.73 ± 8.71
15	small	low business	high	positive message	16.97 ± 7.43
16	small	low business	low	no communication	256.89 ± 29.03
17	small	low business	low	provocative message	277.41 ± 28.41
18	small	low business	low	positive message	255.63 ± 27.85
19	large	high business	high	no communication	10.61 ± 5.92
20	large	high business	high	provocative message	17.56 ± 6.3
21	large	high business	high	positive message	11.91 ± 6.29
22	large	high business	low	no communication	107.49 ± 17.27
23	large	high business	low	provocative message	117.82 ± 19.1
24	large	high business	low	positive message	111.08 ± 17.49
25	large	balanced	high	no communication	13.48 ± 8.05
26	large	balanced	high	provocative message	15.2 ± 7.25
27	large	balanced	high	positive message	11.02 ± 5.58
28	large	balanced	low	no communication	174.89 ± 25.85
29	large	balanced	low	provocative message	185.73 ± 24.46
30	large	balanced	low	positive message	184.93 ± 29.2
31	large	low business	high	no communication	14.77 ± 8.74
32	large	low business	high	provocative message	24.61 ± 11.98
33	large	low business	high	positive message	14.85 ± 7.59
34	large	low business	low	no communication	248.8 ± 29.03
35	large	low business	low	provocative message	260.25 ± 29.98
36	large	low business	low	positive message	262.36 ± 29.69

Section II.5 - Scenario differences using Tukey's Honest Significant Difference test

Supplementary Figure II.D illustrates the mean difference in PW between scenarios: red cells indicate higher PW in Group 1 scenarios, and blue cells indicate lower. Clear clusters appear, revealing combinations that systematically differ, particularly those with low awareness and low share of business guests.

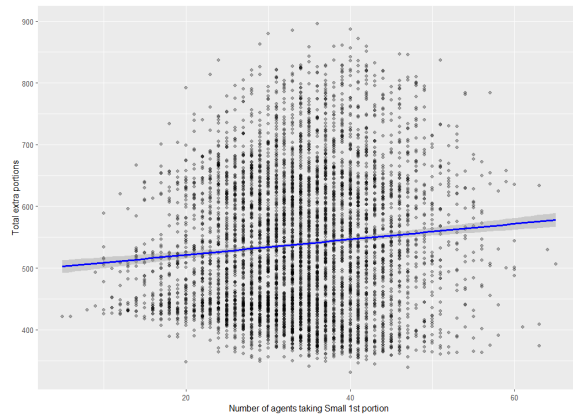


Supplementary Figure II.D: Heatmap of pairwise differences in mean PW across the 36 simulated scenarios. Each cell represents the mean difference between two scenarios (Group 1 – Group 2), with red indicating higher and blue indicating lower leftovers for Group 1.

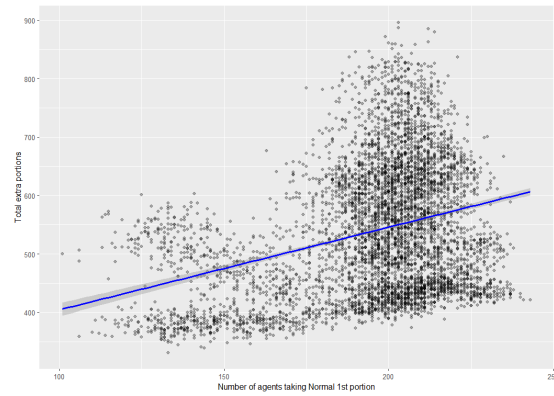
Section II.6 - Correlation between first portions and extra servings

To explore the link between initial portion size and refilling behaviour, we examine correlations between the number of agents choosing small, normal, or large first portions and the total extra servings per simulation. Supplementary Figure II.E shows that taking a small first portion is essentially uncorrelated with the extra servings ($r = 0.096$), suggesting that guests starting small do not systematically compensate later. Taking a normal portion is moderately positively correlated with extra portions ($r = 0.31$) (Supplementary Figure II.F). Large portions are

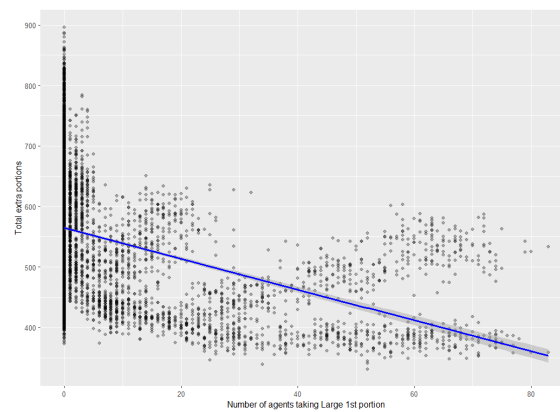
negatively correlated ($r=-0.42$), suggesting that larger initial servings reduce the likelihood of refills (Supplementary Figure II.G). These correlations justify including the mean first portion size as a predictor in Model 2 (see Section 3.2.2).



Supplementary Figure II.E: Correlation between the number of guests taking a small first portion and the total number of extra portions taken across simulations



Supplementary Figure II.F: Correlation between the number of guests taking a normal first portion and the total number of extra portions taken across simulations



Supplementary Figure II.G: Correlation between the number of guests taking a large first portion and the total number of extra portions taken across simulations

Section II.7 - Models' multicollinearity

Generalized Variance Inflation Factors (GVIF) were calculated to account for multi-level categorical predictors and interaction terms. The adjusted values, $GVIF^{1/(2 \cdot Df)}$, are reported, with all predictors showing acceptable collinearity ($GVIF^{1/(2 \cdot Df)} < 2$).

Supplementary Table II.D: Generalized Variance Inflation Factors for the three models

	GVIF	Df	GVIF ^{1/(2·Df)}
Portion model			
Small_plate	27.030	7	1.266
Sustainability	26.985	7	1.265
Clientele_structure	8.004	11	1.099
Message	8.004	11	1.099
Refill model			
Small_plate	32.780	7	1.283
Sustainability	35.631	7	1.291
Clientele_structure	11.428	11	1.117
Message	12.425	11	1.121
Mean_portion_size_s	1.606	1	1.267
Mediated leftovers model			
Mean_portion_size_s	10.454	3	1.479
Total_extra_s	10.454	3	1.479
Small_plate	82.747	7	1.371
Sustainability	129.051	7	1.415
Clientele_structure	35.713	11	1.176
Message	53.529	11	1.198

Section II.8 - Full specifications of Portion model, Refill model, Mediated Leftovers model, Total-effect Leftovers model

Supplementary Table II.E: Full specification for the Portion model, without interactions (Column 1) and with interactions (Column 2)

	Specification without interactions	Specification with interactions
Variable	Estimate (SE)	Estimate (SE)
Intercept	0.397 (0.047)***	0.789 (0.047)***
Large plate	0.012 (0.045)	0.377 (0.045)***
High Sustainability Awareness	-0.070 (0.045)	-0.178 (0.045)***
Clientele Structure Balanced	-0.065 (0.054)	-0.407 (0.054)***
Clientele Structure High Business	-0.170 (0.056)**	-0.843 (0.056)***
Positive Message	0.092 (0.056)	-0.761 (0.056)***
Provocative Message	-0.961 (0.057)***	-1.832 (0.057)***
Large plate x High Sustainability Awareness	-	0.122 (0.043)**
Large plate x Clientele Structure Balanced	-	-0.358 (0.054)***
Large plate x Clientele Structure High Business	-	-0.919 (0.053)***
Clientele Structure Balanced x Positive Message	-	0.808 (0.066)***
Clientele Structure High Business x Positive Message	-	1.649 (0.069)***
Clientele Structure Balanced x Provocative Message	-	0.754 (0.069)***
Clientele Structure High Business x Provocative Message	-	1.747 (0.067)***
High Sustainability Awareness x Positive Message	-	0.066 (0.054)
High Sustainability Awareness x Provocative Message	-	0.075 (0.055)
Adjusted R²	0.23	0.38

Significance codes: . $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Supplementary Table II.F: Full specification for the Refill model, without interactions (Column 1) and with interactions (Column 2)

	Specification without interactions	Specification with interactions
Variable	Estimate (SE)	Estimate (SE)
Intercept	0.542 (0.019)***	0.613 (0.019)***
Large plate	-0.718 (0.024)***	-0.920 (0.024)***
High Sustainability Awareness	-0.801 (0.018)***	-1.085 (0.018)***
Clientele Structure Balanced	-0.467 (0.024)***	-0.298 (0.024)***
Clientele Structure High Business	-0.812 (0.023)***	-0.814 (0.023)***
Positive Message	0.517 (0.025)***	0.683 (0.025)***
Provocative Message	1.415 (0.032)***	1.320 (0.032)***
Mean Portion Size	-0.039 (0.008)***	0.014 (0.008).
Large plate x High Sustainability Awareness	-	0.038 (0.025)
Large plate x Clientele Structure Balanced	-	0.038 (0.033)
Large plate × Clientele Structure High Business	-	0.510 (0.030)***
Clientele Structure Balanced × Positive Message	-	-0.327 (0.032)***
Clientele Structure High Business × Positive Message	-	-0.476 (0.032)***
Clientele Structure Balanced × Provocative Message	-	-0.225 (0.041)***
Clientele Structure High Business × Provocative Message	-	-0.257 (0.038)***
High Sustainability Awareness x Positive Message	-	0.192 (0.024)***
High Sustainability Awareness x Provocative Message	-	0.612 (0.031)***
Adjusted R²	0.76	0.79

Significance codes: . $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Supplementary Table II.G: Full specification for the Mediated Leftovers model, without interactions (Column 1) and with interactions (Column 2)

	Specification without interactions	Specification with interactions
Variable	Estimate (SE)	Estimate (SE)
Intercept	1.140 (0.022)***	1.067 (0.022)***
Mean Portion Size	0.035 (0.006)***	0.065 (0.006)***
Mean Extra Servings	0.171 (0.012)***	0.230 (0.012)***
Large plate	0.091 (0.024)***	0.164 (0.024)***
High Sustainability Awareness	-1.617 (0.020)***	-1.456 (0.020)***
Clientele Structure Balanced	-0.322 (0.020)***	-0.318 (0.020)***
Clientele Structure High Business	-0.633 (0.025)***	-0.610 (0.025)***
Positive Message	-0.063 (0.028)*	-0.137 (0.028)***
Provocative Message	-0.111 (0.031)***	0.037 (0.031)
Mean Portion Size × Mean Extra Servings	-	0.105 (0.007)***
Large Plate × High Sustainability Awareness	-	0.044 (0.018)*
Large Plate × Clientele Structure Balanced	-	-0.010 (0.021)
Large Plate × Clientele Structure High Business	-	-0.094 (0.027)***
Clientele Structure Balanced × Positive Message	-	0.112 (0.026)***
Clientele Structure High Business × Positive Message	-	0.128 (0.032)***
Clientele Structure Balanced × Provocative Message	-	-0.086 (0.026)***
Clientele Structure High Business × Provocative Message	-	-0.055 (0.033).
High Sustainability Awareness × Positive Message	-	-0.072 (0.021)***
High Sustainability Awareness × Provocative Message	-	-0.264 (0.024)***
Adjusted R²	0.88	0.89

Significance codes: . $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Supplementary Table II.H: Full specification for the Total-effect Leftovers model

Variable	Estimate (SE)
Intercept	1.226 (0.022)***
Large Plate	-0.047 (0.026).
High Sustainability Awareness	-1.739 (0.020)***
Clientele Structure Balanced	-0.384 (0.020)***
Clientele Structure High Business	-0.769 (0.025)***
Positive Message	0.047 (0.030)
Provocative Message	0.161 (0.033)***
Large Plate × High Sustainability Awareness	0.034 (0.018).
Large Plate × Clientele Structure Balanced	-0.018 (0.021)
Large Plate × Clientele Structure High Business	0.012 (0.027)
Clientele Structure Balanced × Positive Message	0.008 (0.025)
Clientele Structure High Business × Positive Message	-0.031 (0.032)
Clientele Structure Balanced × Provocative Message	-0.041 (0.026)
Clientele Structure High Business × Provocative Message	-0.010 (0.033)
High Sustainability Awareness × Positive Message	-0.056 (0.020)**
High Sustainability Awareness × Provocative Message	-0.047 (0.024).
Large Plate × Positive Message	0.034 (0.022)
Large Plate × Provocative Message	-0.033 (0.026)
Adjusted R²	0.88

Significance codes: . $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Section II.9 - References

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Supplementary Materials III

Chapter 3

Do Social Norms Shape Food Waste Behaviour in Primary School Canteens? Experimental Evidence from a Cluster Randomized Controlled Trial

Section III.1 – Sampling results

Supplementary Table III.A: Correspondence of Areas, AUSLs, and number of schools sampled for each Area based on the number of schools per AUSL

Area	AUSL	N° total schools	Weight	N° sampled schools
A1	MODENA	140	31.96%	4
	PARMA	94	21.46%	1
	PIACENZA	76	17.35%	2
	REGGIO EMILIA	128	29.22%	3
	Total	438	100.00%	10
A2	BOLOGNA	156	59.32%	7
	FERRARA	76	28.90%	2
	IMOLA	31	11.79%	1
	Total	263	100.00%	10
A3	FORLI' - CESENA	102	38.78%	5
	RAVENNA	74	28.14%	3
	RIMINI	87	33.08%	2
	Total	263	100.00%	10



Supplementary Figure III.A: Map of the 22 schools included in the sample. Red = Control, Yellow = Treatment

Supplementary Table III.B: Final sample of schools divided by VA and AUSL

	Area 1				Area 2			Area 3	TOTAL
AUSLs	Piacenza	Parma	Reggio Emilia	Modena	Bologna	Ferrara	Imola	Romagna	
N° sampled schools	2	1	3	4	0	2	1	9	22
N° treatment schools	0T	0T	2T	3T	0	0	1	5T	11T

Section III.2 - Intervention timeline

Supplementary Table III.C: Measurement and intervention timeline. Yellow cells = T0 measurement, Red cells = co-design activity suggested week, Blue cells = T1 measurements, P = poster displayed. Menu seasonality: A/W= Autumn/Winter, S/S= Spring/Summer

						WEEKS													
Area	AUSL	School ID	Experimental Group	Menu seasonality T0	Menu seasonality T1	24/02/25	03/03/25	10/03/25	17/03/25	24/03/25	31/03/25	07/04/25	14/04/25	21/04/25	28/04/25	05/05/25	12/05/25	19/05/25	26/05/25
A1	Piacenza	School #1	Control	S/S	S/S							T0	CLOSURE FOR EASTER AND NATIONAL HOLIDAYS			T1			
		School #2	Control	S/S	S/S							T0				T1			
	Parma	School #3	Control	Annual	Annual			T0				T1							
		School #4	Treatment	S/S	S/S			T0			P	P, T1							
	Reggio Emilia	School #5	Treatment	S/S	S/S			T0									P	P, T1	
		School #6	Control	S/S	S/S				T0								T1		
	Modena	School #7	Treatment	A/W	S/S	Pilot testing		T0										P	P, T1
		School #8	Treatment	A/W	A/W		T0			P	P, T1								
		School #9	Treatment	A/W	A/W		T0			P	P, T1								
		School #10	Control	A/W	A/W		T0				T1								
A2	Ferrara	School #11	Control	A/W	S/S							T0	CLOSURE FOR EASTER AND NATIONAL HOLIDAYS					T1	
		School #12	Control	S/S	S/S											T0			T1
	Imola	School #13	Treatment	Annual	Annual						T0							P	P, T1
A3	Romagna	School #14	Treatment	Annual	Annual					T0								P	P, T1

		School #15	Treatment	A/W	S/S							T0			P	P, T1		
		School #16	Treatment	Annual	Annual			T0								P	P, T1	
		School #17	Treatment	A/W	S/S						T0					P	P, T1	
		School #18	Treatment	Annual	Annual			T0								P	P, T1	
		School #19	Control	A/W	S/S				T0								T1	
		School #20	Control	Annual	Annual				T0								T1	
		School #21	Control	Annual	Annual					T0					T1			
		School #22	Control	Annual	Annual					T0							T1	

Note: Annual menus are also subject to food seasonality, with variations introduced in March/April

Section III.3 - Correction of inconsistent measurements

A data-quality assessment was conducted to identify inconsistencies in the recorded PF, SW, and PW weights. For a small share of observations, PW% exceeded 100% or resulted in negative values, conditions that are impossible given the definitions of PF, SW, and PW. These errors were distributed irregularly across schools and days.

Given the limited presence and the non-systematic nature of these errors, we implemented a correction procedure to maintain the structure of the dataset.

Corrections were performed separately for control and intervention classes. For control classes (u), when an implausible value was identified for a given class/dish/day at T0 or T1, we replaced the observation with the PW% of the same class for the same dish at the alternate measurement point t' (i.e., T1 substituted implausible T0 values and vice versa) following Eq. III.A.

(III.A)

$$PW\%_c^{u,d,f,t,corr} = PW\%_c^{u,d,f,t'}$$

For treated classes, because treatment may affect PW between T0 and T1, the within-class substitution used for control classes was not appropriate. Therefore, for each incorrect value, we estimated the mean PW% using Eq. III.B. PW% was calculated for the same dish $c \in \{FD, SeD, SiD\}$ as the average PW% in other treated classes (u) belonging to the same AUSL (A) (or the same Area when sufficient AUSL-level data were not available), for the same food category (f) and at the same measurement time (t).

(III.B)

$$PW\%_c^{u,d,f,t,corr} = \frac{1}{X_{A,c}^{f,t}(u)} \sum_{u' \in X_{A,c}^{f,t}(u)} PW\%_c^{u',d,f,t}$$

Where $X_{A,c}^{f,t}(u)$ represents the set of treated classes other than class u in the same AUSL (or Area), served with the same dish and food category, at the same measurement time. This strategy preserves the treatment status (T0 or T1), territorial comparability, and dish correspondence.

All corrected observations were documented in the dataset. Sensitivity checks excluding these values yielded qualitatively similar results, confirming that the corrections did not affect the results.

Section III.4 - Food categorization

Supplementary Table III. D: Food categories

Firs Dish		Second Dish		Side Dish	
Soups	1,01	White meat (fresh)	2,01	Carrots	3,01
Pasta with meat	1,02	Meat (processed)	2,02	Cauliflower	3,02
Pasta with pulses	1,03	Fresh meat (beef, fresh)	2,03	Cabbage	3,03
Pasta with fish	1,04	Fresh meat (pork, fresh)	2,04	Green beens	3,04
Pasta with vegetables	1,05	Red meat (others, fresh)	2,05	Fennels	3,05
Fresh pasta	1,06	Cheese (fresh)	2,06	Mixed salad and raw vegetables	3,06
Pasta with oil	1,07	Cheese (matured)	2,07	Potatoes	3,07
Pizza	1,08	Pulses (fresh)	2,08	Peas	3,08
Rice	1,09	Pulses (processed)	2,09	Spinach	3,09
Others	1,1	Fish (canned)	2,1	Zucchini	3,1
No FD	1,11	Fish (fresh)	2,11	Mixed cooked vegetables	3,11
		Fish (processed)	2,12	No SiD	3,12
		Eggs	2,13	Broccoli	3,13
		Cakes (pies, salty cakes)	2,14		
		Others	2,15		
		No SeD	2,16		

Section III.5 - Descriptive results

Supplementary Table III. E: Descriptive statistics for the two experimental groups at the Area level

Variable	Area 1		Area 3	
	Control group	Treatment group	Control group	Treatment group
Number of AUSL	4	2	1	1
Number of schools	5	5	4	5
Number of classes	8	11	4	9
Min. students per class	15	13	21	11
Max. students per class	23	23	24	22
Mean students per class	19.8	20	22.3	17.7
Total students	158	219	89	159
Number of observations	75	109	38	87
Total meals weighted	1337	1938	787	1376

Supplementary Table III.F: Differences at T0, Welch two-sample t-test, full sample

Variable	Control (mean)	Treatment (mean)	Diff. (T – C)	p-value (t-test)
Pupils per class	17.6	17.5	-0.1	.912
First course (avg. PW%)	23.76	21.75	-2.01	.615
Second course (avg. PW%)	28.96	27.13	-1.83	.718
Side dish (avg. PW%)	46.56	39.88	-6.68	.307

Notes: Means are based on class-level averages. Diff. = difference in means between treatment and control

Supplementary Table III.G: Cluster-robust linear regressions to test the baseline comparability of treatment and control groups, full sample

Outcome	Coefficient (Treatment vs Control %)	Std. Error (clustered)	t	p-value
First dish (%)	-2.00	4.35	-0.46	.648
Second dish (%)	-1.84	5.85	-0.31	.756
Side dish (%)	-6.68	6.61	-1.01	.319

Supplementary Table III.H: Differences at T0, Welch two-sample t-test, Area level

Variable	Control (mean)	Treatment (mean)	Diff. (T – C)	p-value
Area 1				
Pupils per class	17.63	17.88	0.25	.876
First course (avg. PW%)	24.96	15.52	-9.44	.068
Second course (avg. PW%)	29.73	24.50	-5.23	.483
Side dish (avg. PW%)	47.76	37.05	-10.41	.216
Area 3				
Pupils per class	20.5	15.8	-4.7	.02
First dish (avg. PW%)	26.7	30.29	3.59	.664
Second dish (avg. PW%)	30.35	25.74	-4.61	.618
Side dish (avg. PW%)	44.34	41.07	-3.27	.778

Notes: Means are based on class-level averages. Diff. = difference in means between treatment and control.

Supplementary Table III.I: Cluster-robust linear regressions to test the baseline comparability of treatment and control groups, Area level

Outcome	Coefficient (Treatment vs Control %)	Std. Error (clustered)	t	p-value
Area 1				
First dish (%)	-8.4	4.7	-1.79	.090
Second dish (%)	-5.2	8.8	-0.59	.560
Side dish (%)	-10.7	8.6	-1.25	.228
Area 3				
First dish (%)	3.6	7.6	0.472	.646
Second dish (%)	-4.6	8.3	-0.56	.589
Side dish (%)	-3.3	11.2	-0.29	.775

Supplementary Table III.J: Matching of food categories at T0 and T1, class level

First Dish	Matches (T0 = T1)	Non-matches	Match (%)	Non-match (%)
Pasta with fish	6	1	85.7	14.3
Pizza	10	3	76.9	23.1
Rice	31	11	73.8	26.2
Soups	29	18	61.7	38.3
Pasta with vegetables	45	29	60.8	39.2
Pasta with oil	8	9	47.1	52.9
Pasta with meat	5	7	41.7	58.3
Pasta with pulses	0	2	0.0	100.0
Fresh pasta	0	6	0.0	100.0
Others	0	14	0.0	100.0
No FD	0	1	0.0	100.0
Second dish	Matches (T0 = T1)	Non-matches	Match (%)	Non-match (%)
Fish	38	5	88.4	11.6
Meat	50	11	82.0	18.0
Cheese (fresh)	9	9	50.0	50.0
Eggs	10	13	43.5	56.5
Cakes (pies, salty cakes)	9	11	45.0	55.0
Pulses (processed)	7	6	53.8	46.2
Other second dish	4	3	57.1	42.9
No SeD	3	6	33.3	66.7
Side Dish	Matches (T0 = T1)	Non-matches	Match (%)	Non-match (%)
Mixed salad and raw vegetables	70	28	71.4	28.6
Carrots	19	12	61.3	38.7
Potatoes	15	12	55.6	44.4
Green beans	7	10	41.2	58.8
Fennel	4	6	40.0	60.0
Spinach	1	1	50.0	50.0
Mixed cooked vegetables	6	14	30.0	70.0
Cabbage	1	6	14.3	85.7
Broccoli	2	12	14.3	85.7
Cauliflower	0	10	0.0	100.0
Peas	0	4	0.0	100.0
Zucchini	0	10	0.0	100.0

Note: Different meat categories were aggregated, as well as fish categories

Supplementary Table III.K: Summary statistics of PW% (total sample), divided by group, dish, and measurement period

Group	Time	Mean (SD)	Median [IQR]
First dish			
Control	T0	23.8 (12.0)	21.2 [15.5]
Control	T1	24.4 (14.4)	22.7 [17.9]
Treatment	T0	21.8 (11.0)	20.9 [18.3]
Treatment	T1	25.9 (15.3)	27.6 [26.2]
Second dish			
Control	T0	29.0 (17.5)	30.5 [20.0]
Control	T1	27.8 (12.6)	29.1 [13.3]
Treatment	T0	27.1 (8.6)	26.0 [9.7]
Treatment	T1	28.5 (13.6)	30.0 [20.2]
Side Dish			
Control	T0	46.6 (21.7)	43.0 [26.4]
Control	T1	41.6 (16.5)	41.9 [16.6]
Treatment	T0	39.9 (12.5)	39.4 [16.9]
Treatment	T1	36.7 (10.7)	37.9 [16.4]

Supplementary Table III.L: Robustness check, average treatment effect for the full sample after removing VA2 schools

	PW% FD (SE)	PW% SeD (SE)	PW% SiD (SE)
Full sample (A2 excluded)	4.184 (3.880)	8.486 (7.707)	9.011 (7.809)
Observations	299	299	296

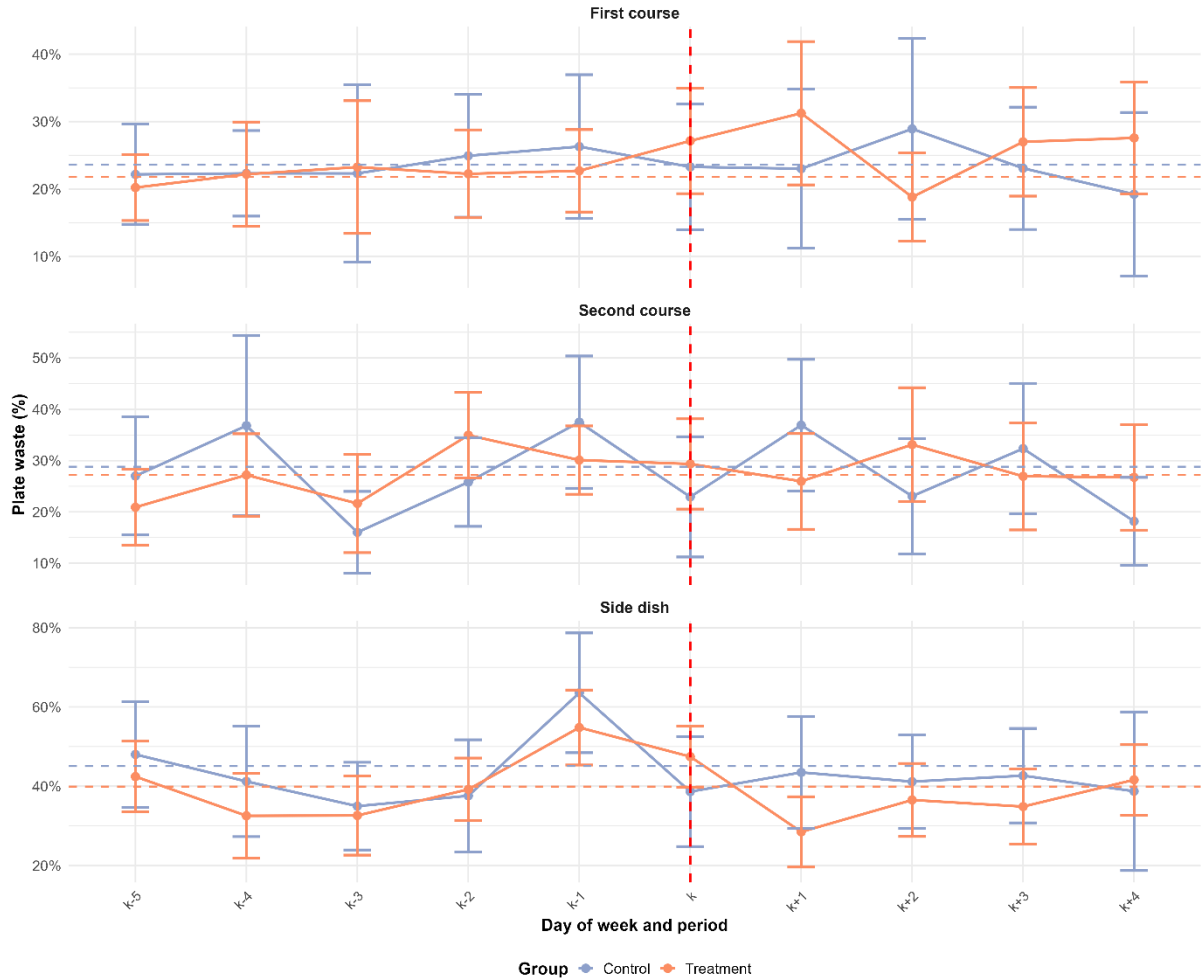
Significance codes: . $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$

Note: Values in percentage points (pp), standard errors in brackets

Supplementary Table III.M: Robustness check, average treatment effect for the full sample after removing 4 classes with incorrect posters

	PW% FD (SE)	PW% SeD (SE)	PW% SiD (SE)
Full sample	7.408 (4.642)	8.983 (6.303)	1.462 (7.687)
Observations	300	300	297

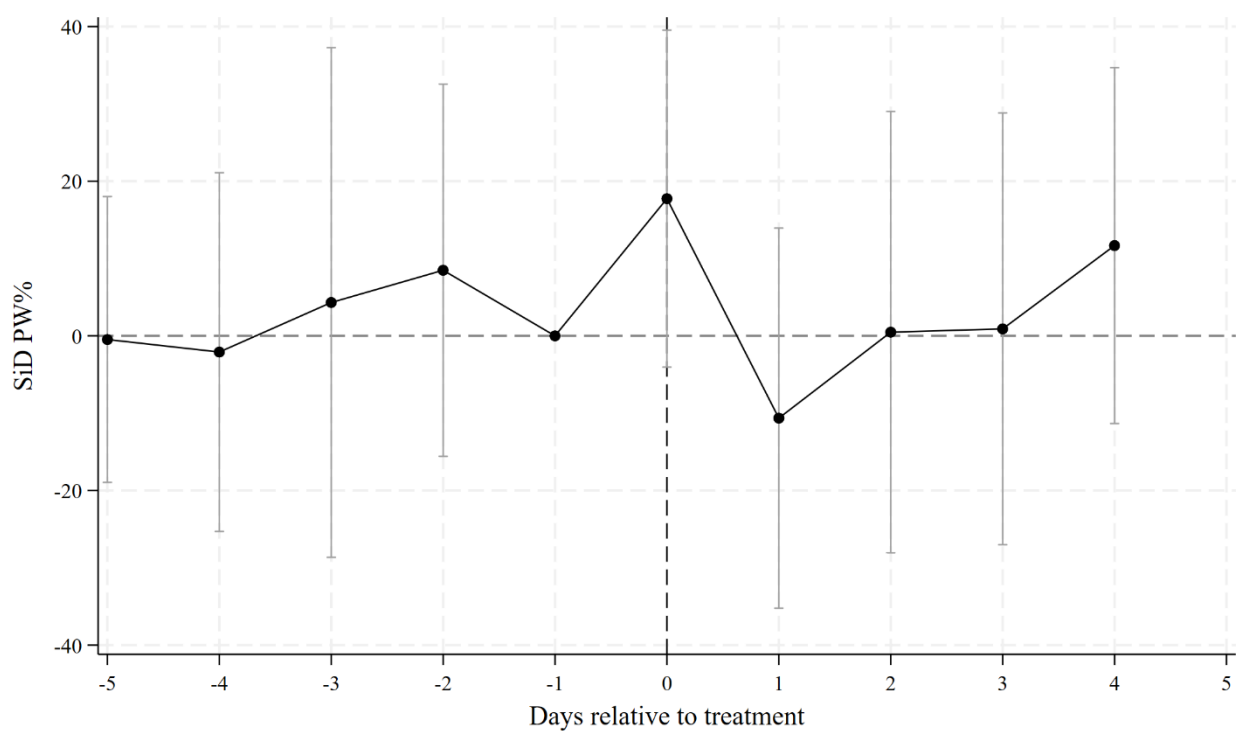
Significance codes: . $p < 1$; * $p < .05$; ** $p < .01$; *** $p < .001$



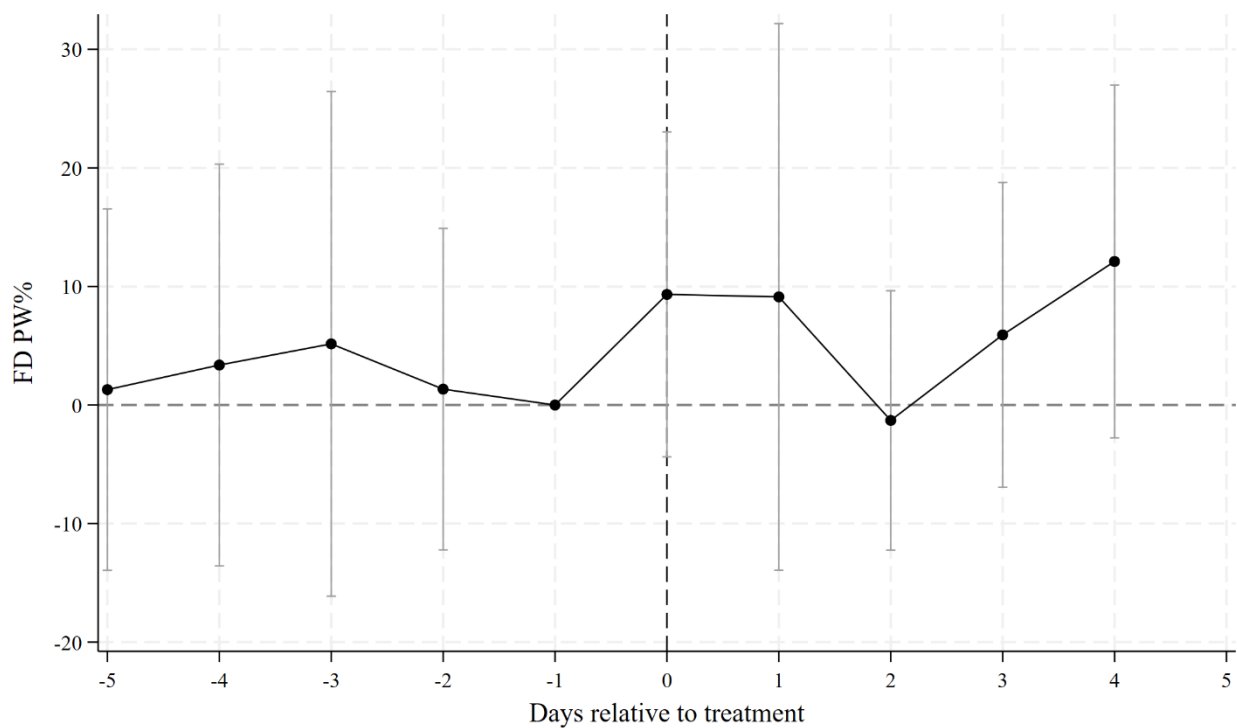
Supplementary Figure III.B: Means and 95% CIs PW% dynamics over time by course, full sample. Notes: the horizontal lines indicate the pre-treatment average PW% for control (blue) and treatment (orange) groups, the vertical red line indicates the first day of post-treatment measu

Supplementary Figure III.B plots class-day average PW% for FD, SeD, and SiD over the 10 days of observation for the full sample. Time is expressed relative to the start of the post-intervention period (day $k = 0$), with negative values indicating pre-intervention days and positive values indicating post-intervention days. The figure provides a descriptive overview of daily PW% patterns before and after the intervention, allowing visual inspection of pre-treatment trajectories and post-treatment developments across meal courses. The descriptive patterns shown in this figure complement the estimated dynamic DiD analyses presented in the main text.

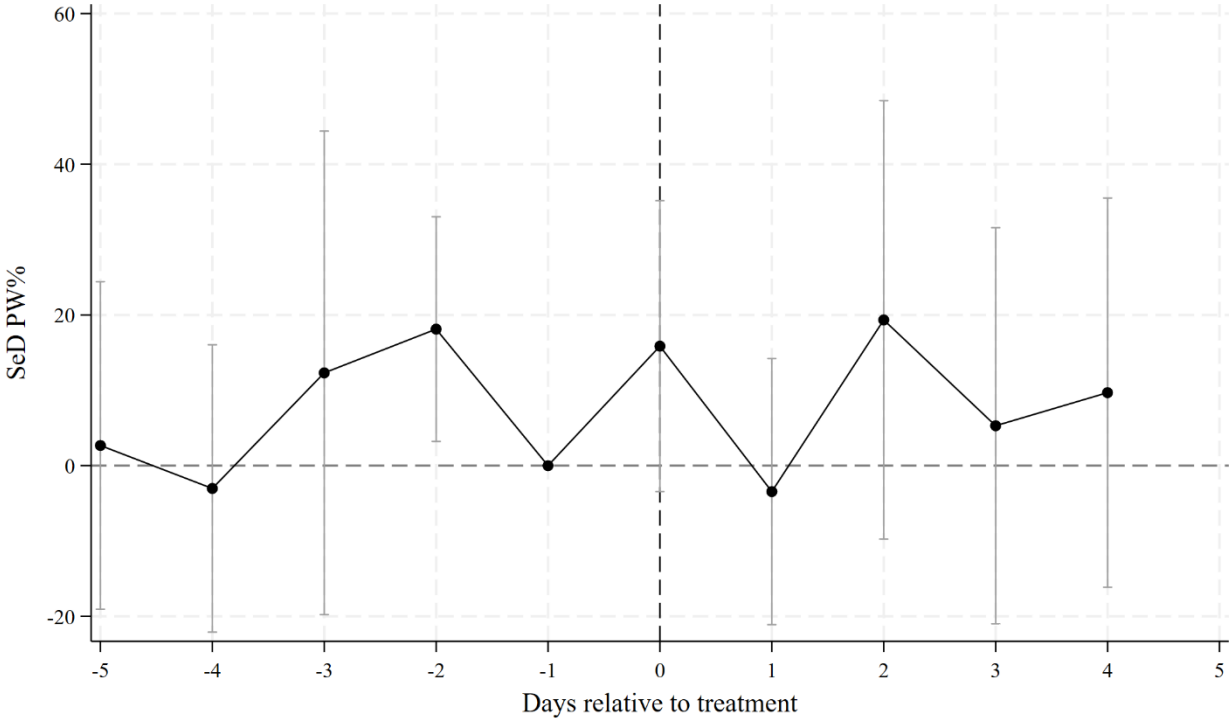
Section III.6 - Event-study robustness checks



Supplementary Figure III.D: Robustness check, dynamic treatment effects on SiD PW%: event-study estimates on the full sample, removing 4 classes with incorrect posters

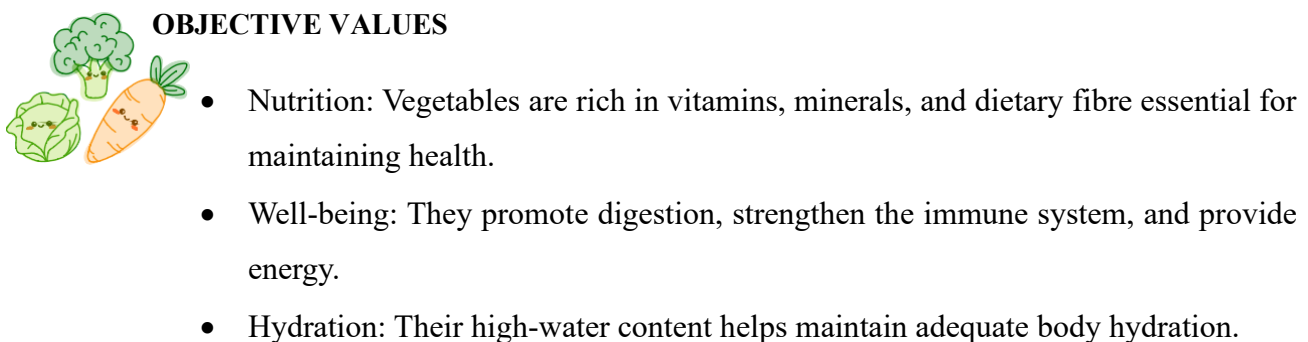
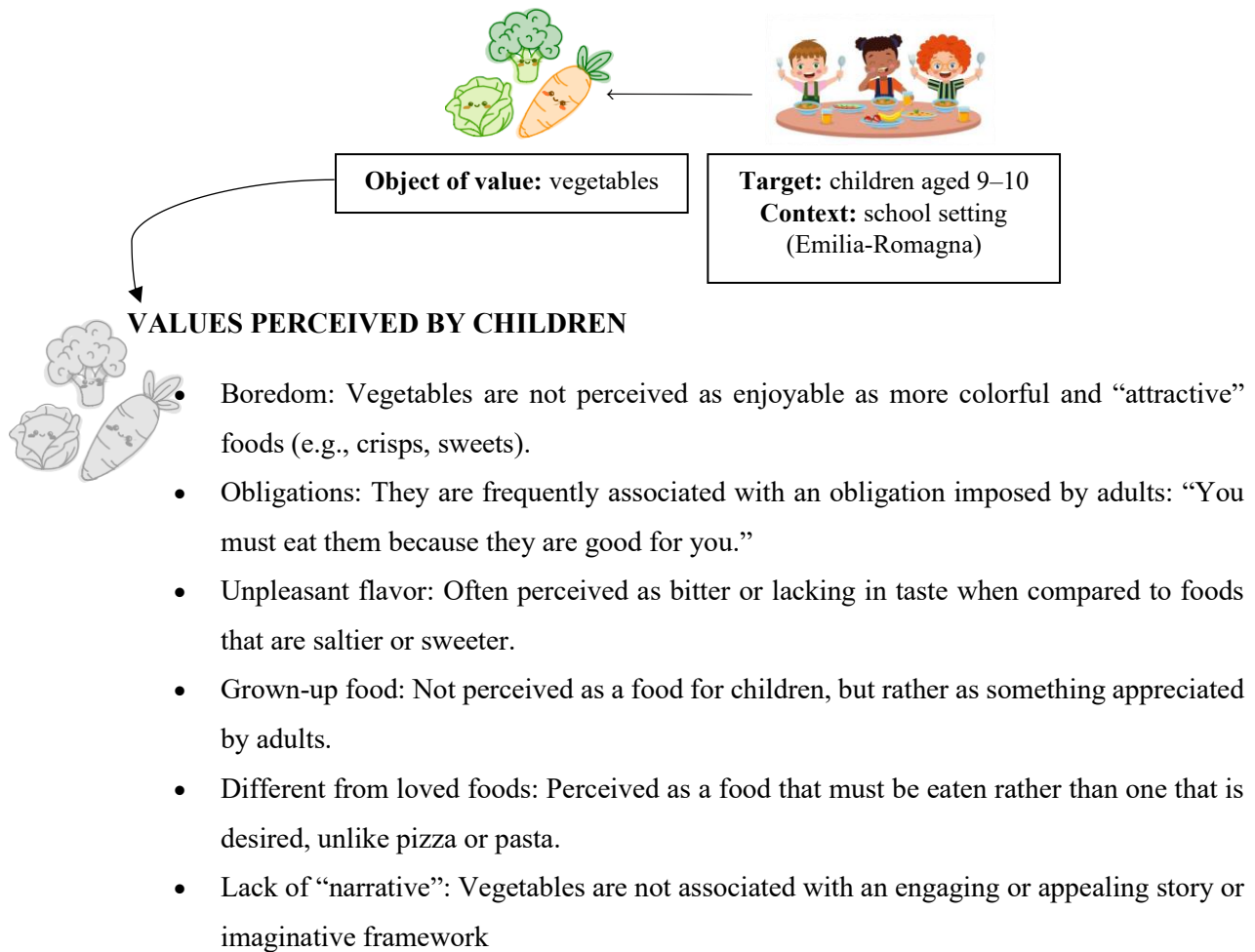


Supplementary Figure III.C: Robustness check, dynamic treatment effects on FD PW%: event-study estimates on the full sample, removing 4 classes with incorrect posters



Supplementary Figure III.E: Robustness check, dynamic treatment effects on SeD PW%: event-study estimates on the full sample, removing 4 classes with incorrect posters

Section III.7 - Social norm message semiotic analysis



Supplementary Table III.N: Floch's valorization square (Floch, 2001)

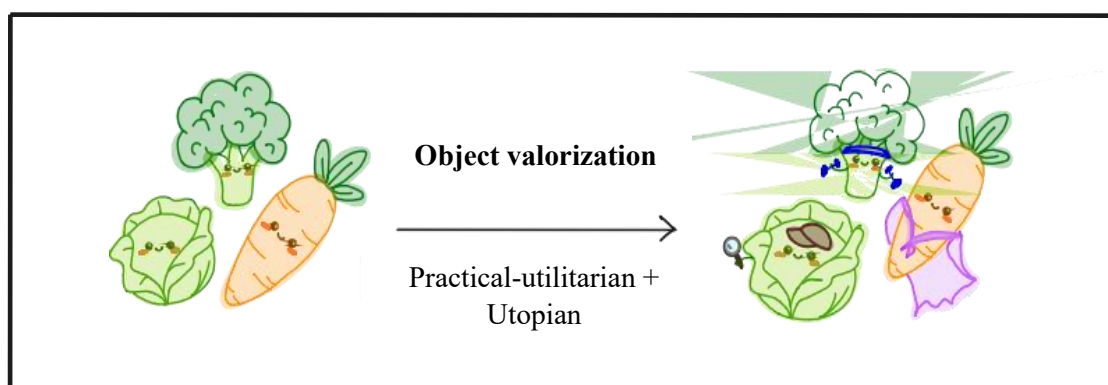
	Adherence to the system	Transgression of the system
Function	Practical-utilitarian value → "Vegetables are good for health, nourishing, and essential for the body."	Critical value → "Eating vegetables represents a stance against the junk food industry and the overconsumption of meat."
Existence	Utopian value → "Vegetables signify sustainability, nature, harmony with the environment, and collective well-being."	Playful value → "Vegetables embody creativity in the kitchen, color, sensory experience, and play."

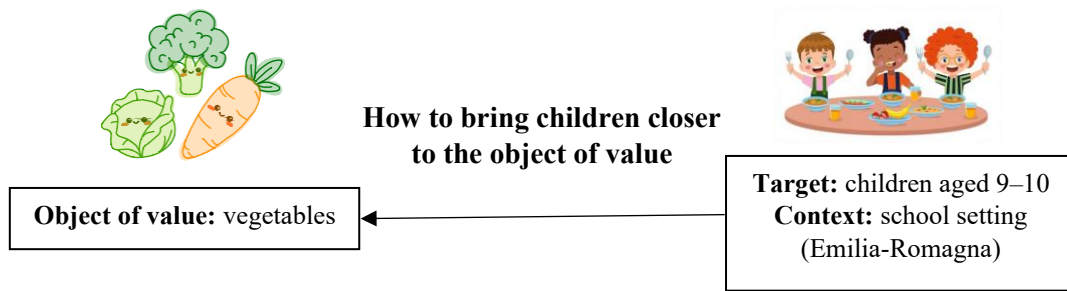
Supplementary Table III.O: Floch's valorization square - Adaptation for children

	Adherence to the system	Transgression of the system
Function	Practical-utilitarian value → "Vegetables make you strong and fast; they give you super energy to play and do sports."	Critical value → "Eating vegetables is for true rebels - if you want to be different from those who only eat chips..."
Existence	Utopian value → "Vegetables are magical; they have superpowers like in fairy tales and video games."	Playful value → "Vegetables are fun: they have strange colors, funny shapes, and you can use them to play in the kitchen or do experiments."

Critical value to be avoided as it conveys a framework of negative separation.

Playful value to be avoided as it focuses on taste and manual skills, which are not included in the intervention strategy.





Manipulation techniques (Greimas & Courtes, 1982):

1. Manipulation through seduction (Making one desire)

Strategy: Vegetables are presented as a positive element, associated with something the child aspires to, as strength, energy, adventure. (*Example: “Do you want to be as fast as an athlete or as strong as an explorer?”*)

→ Children respond well to positive and aspirational models.

Modal verbs:

- **To want** → “Do you want more energy?”
- **To be able to** → “You can become stronger with vegetables!”

This approach highlights positive values and makes the child feel free to make his or her own choice.

2. Manipulation through temptation (Making one believe)

Strategy: Create a challenge or game around vegetables, turning them into a fun and adventurous experience. (*Example: “Are you brave enough to uncover the athletes’ secret?”*)

→ Children enjoy challenges and the feeling of discovery.

Modal verbs:

- **To be able to** → “You can try and discover a superpower!”
- **To dare** → “Dare to taste and see what happens!”

This approach fosters a sense of play and discovery, positioning the child as an active subject (actant) in the narrative process.

3. Manipulation through provocation (Making one act)

Strategy: Encourage the child not to back down by suggesting that others have already accepted the challenge. (*Example: “Your friends already do it! Eating vegetables is the secret to having more energy and more fun. How about you?”*)

→ Children are motivated by the desire to belong to the group and not to feel left out.

Modal verbs:

- **To have to** → “You have to try it if you want to be part of the team!”
- **To know** → “Did you know that athletes always eat vegetables?”

To be used with caution, in order to avoid creating a sense of inferiority in children.

4. Manipulation through intimidation or sanction (Inducing fear)

Strategy: Suggest a potential disadvantage or consequence of not eating vegetables, without adopting an overtly threatening tone. (*Example: “If you don’t eat vegetables, you might get tired...”*)

→ This form of manipulation carries a high risk of refusal, though it can be employed playfully and with caution.

Modal operations:

- **To risk** → “You risk running out of energy!”
- **To have to** → “You have to eat them to keep your strength!”

This strategy should be avoided, as it can be perceived as a form of coercion and conveys a negative or punitive framework.

**POSSIBLE MESSAGE**

*“Explorers and athletes have a secret: vegetables!
At school, children eat vegetables to have more energy and
enjoy their day. Eat them too and discover their
superpowers!”*

SEMIOTIC ANALYSIS**Greimasian narrative structure (Actantial Model) (Greimas, 1983)**

- **Subject:** The child, who must perform the action of eating vegetables.
- **Object of value:** Vegetables, which provide energy and “powers”.

- Sender (Destinator): The desire to be like explorers and athletes, reinforced by the social norm that many children already eat vegetables.
- Helper: The message itself, which motivates and makes the action desirable.
- Opponent: The prejudice against vegetables, perceived as bland or boring.
- Receiver (Destinataire): The child, who gains energy and enjoyment from eating them.

Manipulative acts

- Seduction → “The secret” generates a sense of mystery and attraction. The child discovers what makes explorers and athletes special.
- Temptation → Encourages the child to try, to see what happens or to test the promised outcome.
- Provocation (mild form) → “You should eat it too” suggests that others already do so; abstaining might mean missing out on benefits. - Modal verbs used: *To have* (possession of a desired object) and *To be able to* (which appeals to curiosity and empowerment).

Valorization of the object of value according to Floch’s semiotic square

- Practical-utilitarian: The message links vegetables to a tangible, concrete benefit.
- Utopian: It charges the act with heroic and adventurous value.

Social norm and reference group

- Desirable reference model: Explorers and athletes, admired by children and embodying positive values, become role models for healthy eating behaviour.
- Peer reference: “At school, many children eat vegetables too”, normalizes the behaviour and reinforces a sense of belonging.
- Implicit social norm: If many children do it, it is right and positive for you to do it as well.

Persuasive construction

A strong and decisive call to action is achieved through the repeated use of the verb to eat, echoing the shared action. The use of the imperative and the direct address (you) gives firmness and direction, yet is softened by the promise of reward, the “superpowers”. In short, the message communicates: If you want superpowers, then you have to eat vegetables.

References

- Floch, J.-M. (2001). *Semiotics, marketing and communication: Beneath the signs, the strategies*. Palgrave Macmillan.
- Greimas, A. J., & Courtés, J. (1982). *Semiotics and Language: An Analytical Dictionary* (L. Crist et al., Trans.). Bloomington: Indiana University Press.
- Greimas, A. J. (1983). *Structural Semantics: An Attempt at a Method* (D. McDowell & R. Schleifer, Trans.). Lincoln: University of Nebraska Press.

Section III.8 - Teacher's guidelines for the in-class activity (translated from Italian)

The activity that teachers will conduct with their classes consists of two phases:

1. Introduction and interactive activity on healthy eating (approximately 40-60 minutes)
2. Poster creation (approximately 60 minutes)

The aim is to raise awareness among children about the importance of eating vegetables and to actively involve them in creating a poster that will be displayed in the school canteen.

Materials needed:

- Blank poster (provided by the research team)
- Materials for the game “Let's complete the healthy plate” (printout of the plate + stickers)
- Pencils, markers, crayons, scissors, glue
- Food magazines from which to cut out pictures (optional)
- Smaller sheets of paper to work on, which will then be glued to the poster (optional)

Please note that the activity can only be carried out after the first week of waste collection in the canteen. During the first week of collection, you will be given two posters to use (you can use both or just one) and you will be given the start date of the second week of collection, so that you can plan the poster activity at least two weeks in advance.

Estimated time	Instructions
40-60 minutes	1. INTRODUCTION AND INTERACTIVE ACTIVITY ON HEALTHY EATING This first part aims to introduce the topic of healthy eating and create an engaging moment for the children. If your class has already had training days on this topic, it is up to you whether or not to carry out this first part. The teacher can begin by showing Harvard's “Healthy Eating Plate” on a large projected or printed image. • Using an image of the Healthy Eating Plate, explain in simple terms what the main food groups are and how to compose a balanced meal. Reference to Annex 1.

	- Ask the children if they can give some examples of foods for each category, if they eat them regularly and why vegetables take up so much space on the plate. Short, interactive activity (15 minutes) Game: “Let's complete the Healthy Eating Plate” - See Annex 2 Materials needed (provided to teachers) - Printout of the empty Healthy Eating Plate (only the outline with the coloured sections). Alternatively, you can use the plate template by projecting it onto the virtual whiteboard or drawing it on the blackboard. - Cut-out food pictures (one for each child). See Annex 4 How to play: - The teacher distributes the food pictures to the children, one per child. - The teacher says the name of a dish aloud (e.g. “Pasta with tomato sauce”), choosing it from the list of foods provided. - The child with the corresponding card stands up, shows the card, says aloud what the main ingredients are (e.g. pasta, tomato, oil) and indicates where they should be placed on the healthy eating plate. - The teacher writes the ingredient in the corresponding section of the healthy eating plate. - Continue until the plate is complete, briefly discussing the choices. Variation: At the end of the game, the teacher can ask the children to look at the complete plate and think about which foods they eat most often and which ones they could add more of to their diet.
60 minutes	2. POSTER CREATION After introducing the topic, move on to the practical phase in which the children will create the poster. Present the activity: Explain to the children that their task is to create a poster to hang in the canteen. Provide the materials and the message to be included: Hand out a white poster and the message to be included. "Explorers and athletes have a secret: vegetables! Even at school, many children eat vegetables to have lots of energy and have more fun. Eat them too and discover their superpowers!" <u>It is essential that this message is included on the poster.</u> Encourage creativity: - Ask the children to illustrate what the message means to them with drawings and slogans. - Give them room for imagination: they can depict everyday situations (e.g. children eating vegetables on their plate at lunch, etc.). - If you wish, you can show the children the poster examples in Annex 3 Practical tips:

	• The teacher can divide the class into small groups, each responsible for a part of the poster (drawings, writing, decorations). • At the end, each group can present their contribution to the rest of the class before assembling the final poster. Key message to convey: The poster will be displayed in the canteen to help everyone make healthier food choices!
	Conclusion Once the poster is complete, the teacher can collect comments from the children about the activity: • What was the most fun part? • Did they discover anything new about their eating habits? • Do they think the poster will help their classmates eat more fruit and vegetables?
	Final note: Keep all posters, as they will need to be displayed in the canteen near the table(s) where the class has lunch for two weeks. If possible, please send us a photo of the posters to caterina.rettore2@unibo.it, specifying the name of the school and section. <u>Thank you for your help!</u>

Section III.8.1 - ANNEX 1: The healthy eating plate: what it is and how it is composed

The Healthy Eating Plate, developed by the Department of Nutrition at Harvard University, is a simple visual guide that helps you compose balanced and healthy meals. Through this simple presentation, we want to accompany children on their journey to discover healthy eating, explaining to them how to distribute food correctly on their plate.

How to compose a healthy meal

Half of the plate: fruit and vegetables

- The largest part of the plate (50%) should consist of vegetables and fruit.
- It is important to vary the colours: eating at least one green food (e.g. spinach), one yellow/orange food (e.g. carrots) and one red food (e.g. tomatoes) every day helps you to get essential vitamins and minerals.

Vegetables can be raw or cooked, preferably in season.

A quarter of the plate: whole grains

- Another 25% of the plate should contain whole grains such as brown rice, wholemeal pasta, spelt, barley and oats.
- Whole grains are preferable to refined grains (such as white bread or polished rice) because they help maintain energy levels for longer and have a lower glycaemic index.

A quarter of the plate: healthy proteins

- The last 25% should consist of proteins, alternating between meat, fish, eggs and legumes.
- It is best to limit red meat consumption and avoid processed products such as sausages and frankfurters.

Drink water

- It is important to drink water during meals and throughout the day, avoiding sugary drinks and industrial fruit juices.

Use healthy condiments

- Extra virgin olive oil is the best choice for dressing dishes.

- Less healthy fats, such as those found in palm oil and margarine, should be avoided.

The importance of exercise

- A healthy diet should always be accompanied by physical activity! The WHO recommends at least 30 minutes of exercise per day, such as a brisk walk or outdoor games.

Additional resources:

- AIRC - Un piatto colmo di cibo sano: <https://www.airc.it/cancro/prevenzione-tumore/alimentazione/un-piatto-di-cibo-sano> (Italian)
- The Nutrition Source, Harvard: <https://nutritionsource.hsph.harvard.edu/healthy-eating-plate/translations/italian/>



Section III.8.2 - ANNEX 2: Material for the game “Let's complete the Healthy Eating Plate”

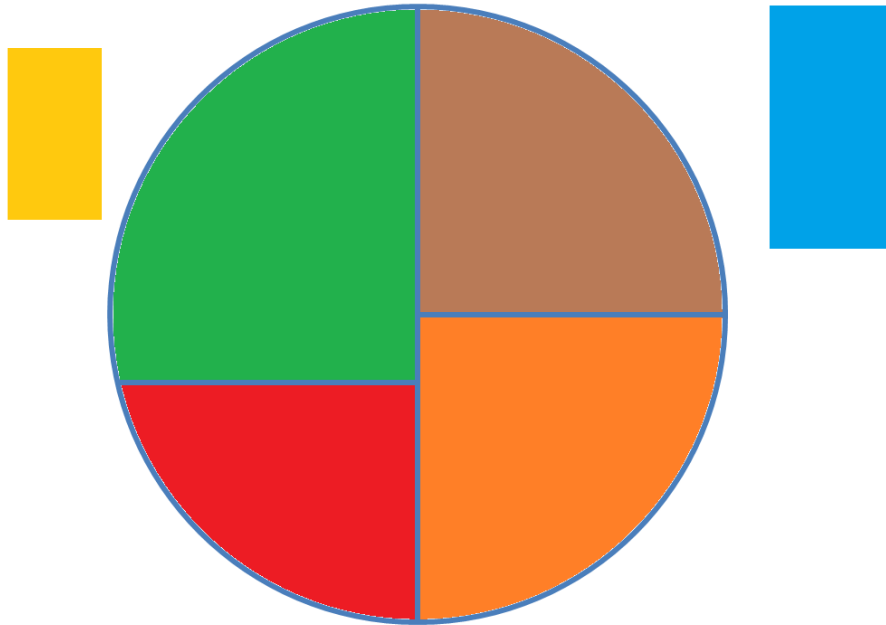
Food list for teachers (with ingredients and corresponding categories in the healthy eating plate)

Recipe	Ingredients (with healthy eating plate category)
Pasta with tomato sauce	Pasta (Grains), Tomato (Vegetable), Olive oil (Condiments)
Risotto with zucchini and parmesan	Rice (Grains), Zucchini (Vegetable), Parmesan cheese (Protein), Olive oil (Condiments)
Vegetable minestrone soup	Mixed vegetables and legumes (carrots, beans, zucchini) (Vegetables and Legumes), Olive oil (Condiments)
Margherita pizza	Flour (Grains), Tomato (Vegetable), Mozzarella (Protein), Olive oil (Condiments)
Vegetable purée with small pasta	Pasta (Grains), Vegetables (carrots, zucchini) (Vegetable), Olive oil (Condiments)
Baked chicken with potatoes	Chicken (Protein), Potatoes (Grains - as carbohydrates), Olive oil (Condiments), Rosemary (Condiments)
Spinach omelette	Eggs (Protein), Spinach (Vegetable), Parmesan cheese (Protein), Olive oil (Condiments)
Lasagna with meat sauce	Pasta sheets (Grains), Ground meat (Protein), Tomato (Vegetable), Béchamel (Condiments)
Vegetable risotto	Rice (Grains), Mixed vegetables (zucchini, peppers, eggplant, tomatoes) (Vegetable), Olive oil (Condiments)
Pasta with meat sauce	Pasta (Grains), Tomato (Vegetable), Onion (Vegetable), Ground meat (Protein)
Steamed fish with vegetables	Cod (Protein), Carrots and zucchini (Vegetable), Olive oil (Condiments)
Chickpea balls	Chickpeas (Protein/Legumes), Breadcrumbs (Grains), Eggs (Protein), Olive oil (Condiments)
Yogurt with fruit and cereal	Yogurt (Protein), Fruit (strawberries, blueberries) (Fruit), Cereal (Grains)
Pasta with pesto	Pasta (Grains), Basil (Vegetable), Olive oil (Condiments), Parmesan cheese (Protein)
Toast with ham and salad	Bread (Grains), Ham (Protein), Lettuce (Vegetable)

Recipe	Ingredients (with healthy eating plate category)
Couscous with vegetables	Couscous (Grains), Peppers and zucchini (Vegetable), Olive oil (Condiments)
Meatballs in tomato sauce	Meat (Protein), Egg (Protein), Tomato (Vegetable)
Whole wheat flatbread with cheese and vegetables	Flour (Grains), Cheese (Protein), Rocket (Vegetable), Tomatoes (Vegetable)
Pumpkin soup	Pumpkin (Vegetable), Potatoes (Grains - as carbohydrates), Olive oil (Condiments)
Fruit salad	Apple, banana, orange, kiwi (Fruit)
Gnocchi with tomato sauce	Potatoes (Grains - as carbohydrates), Flour (Grains), Tomato (Vegetable), Olive oil (Condiments)
Veal stew with potatoes	Veal (Protein), Olive oil (Condiments), Potatoes (Grains - as carbohydrates)
Bruschetta with tomato	Whole wheat bread (Grains), Tomato (Vegetable), Olive oil (Condiments)
Baked salmon with vegetables	Salmon (Protein), Mixed vegetables (e.g. zucchini, tomato, peppers) (Vegetable), Olive oil (Condiments)
Chickpea hummus	Chickpeas (Protein/Legumes), Olive oil (Condiments)
Grated carrots	Carrots (Vegetable)
Ravioli with ricotta and spinach in tomato sauce	Pasta (Grains), Ricotta cheese (Protein), Spinach (Vegetable), Olive oil (Condiments), Tomato (Vegetable)
Green salad with corn	Lettuce (Vegetable), Corn (Grains)
Fruit smoothie	Milk (Protein), Fruit of choice
Grilled vegetables	Eggplant, peppers, zucchini (Vegetable), Olive oil (Condiments)
Rice with peas	Rice (Grains), Peas (Protein/Legumes), Parmesan cheese (Protein), Olive oil (Condiments)
Boiled egg with whole wheat bread	Eggs (Protein), Whole wheat bread (Grains), Olive oil (Condiments)
Whole wheat focaccia with olives and cherry tomatoes	Flour (Grains), Olives (Fruit), Cherry tomatoes (Vegetable), Olive oil (Condiments)
Raw vegetable crudité	Carrots and celery (Vegetable)

Recipe	Ingredients (with healthy eating plate category)
Mashed potatoes	Potatoes (Grains - as carbohydrates), Milk (Protein)

Blank Healthy Eating Plate to draw or project on the blackboard



Section III.8.3 - ANNEX 3: Poster examples



Section III.8.4 - ANNEX 4: Dishes figures for the game “Let’s complete the Healthy Eating Plate”













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