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The Power of System Archetypes: the Case of Shifting towards More Plant-Based Diets

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Abstract

A shift to more plant-based diets is crucial for human and planetary health, yet research often overlooks the complexities of the food environment. This study applied system archetypes – common behaviour patterns that aid in diagnosing system structures underlying observable events – to analyse feedback loops and delays in European food environments. A complex review of 47 articles identified six archetypes: Fixes that fail, Shifting the burden, Escalation, Success to the successful, Tragedy of the commons, and Supply and demand. Expert panel discussions revealed the socio-political context sustaining these archetypes. The findings identify both systemic barriers and solution pathways to accelerate the protein transition.

Keywords

consumption – complex system – food environment – protein transition – system archetypes

1 Introduction

Societies, prompted by human and planetary health targets, increasingly recognize the benefits of shifting from primarily animal-based protein sources towards more plant-based diets (Aiking and de Boer, 2020; Aleksandrowicz et al., 2016; McMichael et al., 2007; Pimentel and Pimentel, 2003; Sabaté et al., 2015; Tilman and Clark, 2014). Consumers decide about acquiring, preparing, and consuming food within the food

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environment, defined here as the "physical, economic, political and socio-cultural context in which consumers engage with the food system" (HLPE, 2017: p. 28). The food environment exhibits the characteristics of a complex system, including feedback loops, temporal delays, and multiple interacting levels of structure (Gotts et al., 2019). The shift towards healthier and more sustainable protein consumption has yet to gain momentum (Graça et al., 2019; Nguyen et al., 2022; Peeters et al., 2024).

A wealth of research reports how the food environment affects the consumption of animal- and plant-based protein (Bianchi et al., 2018; Graça et al., 2019; Stoll-Kleemann and Schmidt, 2016; Zaleskiewicz et al., 2024). Causal loop diagrams (CLDs) have been devised to conceptualize the food environment as a system (Friel et al., 2017; Gerritsen et al., 2019; Mui et al., 2019; Sawyer et al., 2021; Waterlander et al., 2020; Wopereis et al., 2024), including the protein transition (Blokhuis et al., 2024). Previous studies using CLDs have visualized systemic structures of the food environment but have not captured unintended behavioural patterns caused by temporal delays. Moreover, core mechanisms may be hidden among what Richmond (1994) refers to as a laundry list of variables. This study aims to fill that gap by applying system archetypes (SAs).

SAs are generic system structures found across all types of systems (e.g. ecosystems, organizations, animals) that show patterns of system behaviour over time, developed through decades of research about system dynamics (Wolstenholme 2003). SAs are valuable in diagnosing a complex system, as they account for system feedback and long-term effects (Meadows, 2008; Sterman, 2002) and provide insight into the origin of unintended reactions (Braun, 2002; Coyle, 2000; Wolstenholme, 2003). Between eight and ten distinct SAs have been identified (Braun, 2002; Kim, 2000; Wolstenholme, 2003).

Research on the wider food system shows that the identification of SAs promises to improve our understanding of food-related complex systems (Bano et al., 2022; Banson et al., 2016; Benninger et al., 2021; Edwards et al., 2023; Posthumus et al., 2018; Queenan et al., 2022; Sharif and Irani, 2016). SAs act as boundary objects – visual representations of a system – and facilitate common understanding among stakeholders (Black and Andersen, 2012). An advantage of SAs is that they represent fundamental system dynamics, which are easier to communicate to policymakers than large CLDs. Furthermore, identification of SAs provides a foundational structure upon which quantitative models can be further developed (Banson et al., 2016; Coyle, 2000). Thus, they are useful for examining whether proposed policies could produce the desired system behaviour (Braun, 2002).

System components, their relationships within the food environment, and their interconnectedness with current protein consumption practices can be obtained from both qualitative and quantitative literature sources. As these data sources can be diverse and their synthesis should represent the system dynamics, a complex review rather than a systematic review is most appropriate (Mahtani et al., 2018).

The main objective of this study is to apply SAs as a tool for gaining insight into feedback loops and temporal delays regarding protein consumption in the context of European food environments, using empirical evidence obtained from a complex systematic literature review. By offering a holistic view of system behaviour, SAs support researchers, particularly modellers, in deepening their understanding of connections and dependencies between system components. Policymakers and other relevant stakeholders (e.g. retail, industry) can use the SAs to assess whether proposed policies or regulations are likely to modify the food environment in a way that encourages a shift towards more plant-based diets.

2 Methods

The present study identified SAs from empirical evidence retrieved from literature and validated them using an expert panel. Their completeness was checked using an overview of currently implemented policies. As this study adopts systems thinking, relevant literature had to describe the mutual influence of the food environment on consumption of meat or meat alternatives. Given the multidisciplinary nature of research about the food environment, four additional conditions needed to be met (Mahtani et al., 2018): first, inclusion of multiple study designs (e.g. quantitative or qualitative) because rich narratives complement the systematic analysis of measurable outcomes; second, representation of the perspectives and interest of all stakeholders involved in the protein transition; third, provision of insight into contextual dependencies of variable relationships and/or interventions; fourth, inclusion of researchers from various relevant fields. A complex systematic review was most suited for our study design, as it includes literature and means of synthesis that a conventional systematic review does not consider.

2.1 *Summary of the Review*

A protocol for this complex systematic review was published on Open Science Framework (Blokhuis et al., 2022) (https://osf.io/fsep6/). This protocol prescribed the inclusion of studies describing the dynamics between the food environment and meat/meat alternatives consumption practices. Included in the dataset were articles about actual food consumption and behaviour that could precede actual consumption, including intention, willingness, purchase, selection, and preparation. Only direct relationships (e.g. A leads to B) were included. The geographic scale was limited to Europe. Eight electronic databases were searched in autumn 2022 with a pre-specified keyword search. Initial literature screening was performed in the machine learning framework in ASReview (van de Schoot et al., 2021). Two authors independently assessed the eligibility of studies at title and abstract level and evaluated methodological quality.

Using realist evaluation to make assumptions closely resembles the definition of systems thinking proposed by Richmond (1994: p. 139) "making reliable inference about behaviour by developing an increasingly deep understanding of underlying structure". Consequently, publication standards of a realist evaluation (RAMESES) guided our reporting (Wong et al., 2017). Our data labels aimed to capture the dynamic and multilevel characteristics of the food environment. Two authors separately extracted data from half of the eligible studies. Relationships between variables were stored in a spreadsheet. For quantitative studies, statistically significant relationships were obtained from text, tables, and figures. For qualitative studies, purposive text analysis (Kenzie, 2021; Turner et al., 2013) was used. For details of the review, see Supplementary Files 1.

2.2 *Data Synthesis*

Data synthesis consisted of four consecutive steps. First, an exploratory analysis of the data labels was conducted. A summary of the data labels was reported in either text or histograms.

Second, we accounted for the multidisciplinary literature set. Variable categorization was guided by the DONE framework, Determinants Of Nutrition and Eating, developed to contain the factors that drive human eating and nutrition (Stok et al., 2017), following the approach proposed by Blokhuis et al. (2024) and Sawyer et al. (2021). In addition, guidelines were followed to formulate system variables (Kim, 1992; Meadows, 2008). Three authors checked the consistency of categorization and definition of the final variables.

Third, polarities of variable relationships were checked systematically by plotting a connection diagram (Supplementary File 4) using the VisNetwork package (https://visjs.org) in R Studio (version 2023.06.1). Each extracted relationship was characterized by a polarity. This polarity could be either positive, meaning that variable A increases variable B, or negative, meaning that variable A decreases variable B. Polarities were checked by two authors.

Fourth, SAs were identified from the final dataset. Topics and variable relationships were linked to the generic structure of established SAs. For all SAs, both a problem and a solution structure were distinguished and temporal delays were marked (Wolstenholme, 2003). If the dataset could not fully describe the SA, any variable relationships not present in the dataset were added using logic and expert consultation and marked in the archetype's structure. All identified SAs were subjected to review by the full author team and eight experts, as described below.

Finally, interventions and policies educed by either the dataset and/or the consulted experts were cross-referenced with existing policies and policy recommendations. We used the list of global and EU-level policies as reported by Hundscheid et al. (2024), who differentiated each policy based on six policy intervention points – a framework for assessing policy mixes in sustainability transformations by Kanger et al. (2020). Each intervention point represents a system level at which policies can intervene, with the lower-ranked intervention points aiming for shallower systemic levels and each subsequent intervention point aiming at a deeper systemic level than the previous one, gradually becoming more intrusive and holistic. The intervention points are labelled: (I) Stimulate diverse niches; (II) Accelerate niche development; (III) Destabilize the existing regime; (IV) Address the broader consequences of regime destabilization; (V) Coordinate interactions across multiple regimes; and (VI) Influence landscape-level pressures. For more details, see Hundscheid et al. (2024). For the final dataset and R scripts, see Open Science Framework (https://osf.io/fsep6/).

2.3 *Expert Validation Process*

For the present study, the SAs validation was conducted with two aims: to identify variable relationships that could not be obtained from the literature search and to test the applicability of the SAs as visual boundary

objects for fostering common understanding among experts. A convenience sample of experts from academia and an NGO were invited by email to validate the identified SAs. Nine experts were approached and eight agreed to a one-hour interview (having provided written consent by email). They had various backgrounds within the scope of the food environment and/or wider food system (Table 1). The main author encouraged each expert to comment on one or two SAs. The number of SAs discussed depended on the expert's research area. Several experts suggested additional literature to be included in the narrative accompanying the SAs. All interviews took place in August 2024 and were conducted by the main author. One interview took place online; the others were conducted physically.

3 Results

3.1 *Assessment of Studies*

For this complex systematic review, 47 studies were included. Figure 1 shows the quantitative assessment of studies: types of studies in this review and the domains, scale levels, and time elements covered. Most studies (n = 32) focused on animal-based proteins (e.g. meat, beef, processed meat), 10 studies reported on a mix of animal- and plant-based proteins, 4 studies used meat alternatives (e.g. insects, lab-grown meat), and 1 study focused solely on plant-based food. Here, we define meat alternatives as any product with "an appearance, texture, and taste similar to that of meat" (Ketelings et al., 2023: p. 7), also referred to as meat substitutes, and any product that, in the European context, is considered an alternative to meat (e.g. tofu, tempeh) (Michel et al., 2021).

Evaluation of methodological quality showed that 2 out of 8 secondary data analyses and simulation studies lacked details about study design; for all 8 of these studies, data analysis and reporting were clear and complete. For 39 experimental, cross-sectional, and qualitative studies, 14 were unclear in their sample description, 19 reported incompletely about their data collection, 5 provided no information about data collection. For 11 studies, data analysis descriptions were unclear; and for 2, incomplete. All of these studies provided a full account of their discussion and conclusion. Details of quality appraisal are provided in Supplementary Files 2.

A total of 614 variables were extracted, of which 153 (25%) originated from qualitative (i.e. descriptive) studies and 461 (75%) from quantitative (i.e. using statistics or computer simulation) studies. Extracted variables described 361 variable relationships, of which 84 (23%) were qualitative and 277 (77%) quantitative. Labels used in data extraction can be found in Supplementary File 3. Figure 2 shows the exploratory analysis of the final set of variables and variable relationships after categorization in the DONE framework. All data and R scripts to generate the figures are available through Open Science Framework (https://osf.io/fsep6/).

TABLE 1 Overview of participants

Participant ID	Occupation	Organization	Area of expertise	System archetype(s) discussed
1	Researcher	University	Consumption sociology	Fixes that fail
2	Researcher	University	Food environment policy	Shifting the burden, Supply and demand
3	Researcher	University	Prevention and public health nutrition	Shifting the burden, Supply and demand
4	Researcher	University	Food and agricultural policy	Tragedy of the commons, Supply and demand
5	Researcher	University	Industrial design engineering	Success to the successful
6	Researcher	University	Political science and government	Tragedy of the commons, Supply and demand
7	Researcher	Research institute	Health sociology	Fixes that fail, Shifting the burden, Escalation
8	Senior advisor	NGO	Human nutrition and health	Escalation, Tragedy of the commons

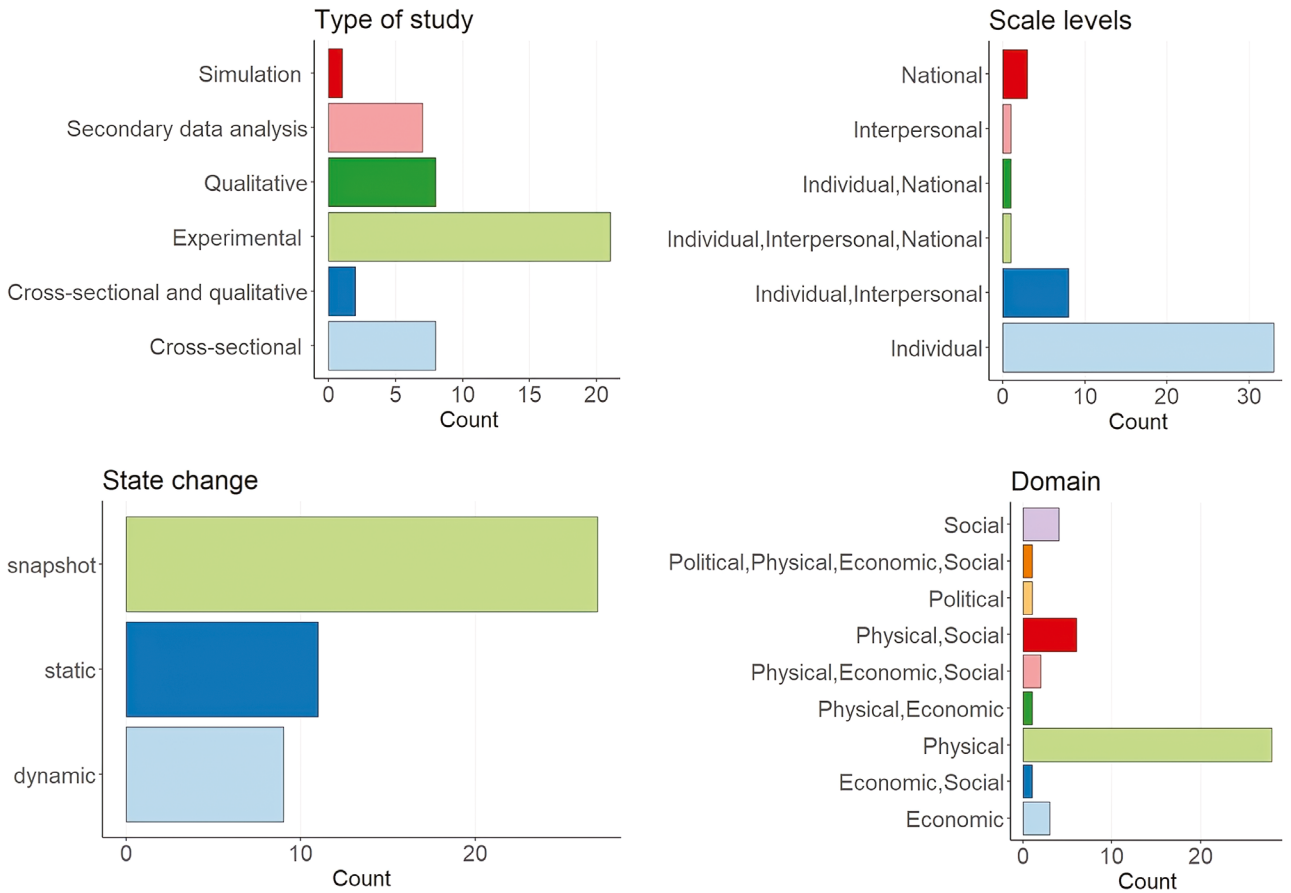

FIGURE 1 Count of types of studies (upper left), scale levels (upper right), state change of variables (bottom left) and domains (bottom right) in this study.

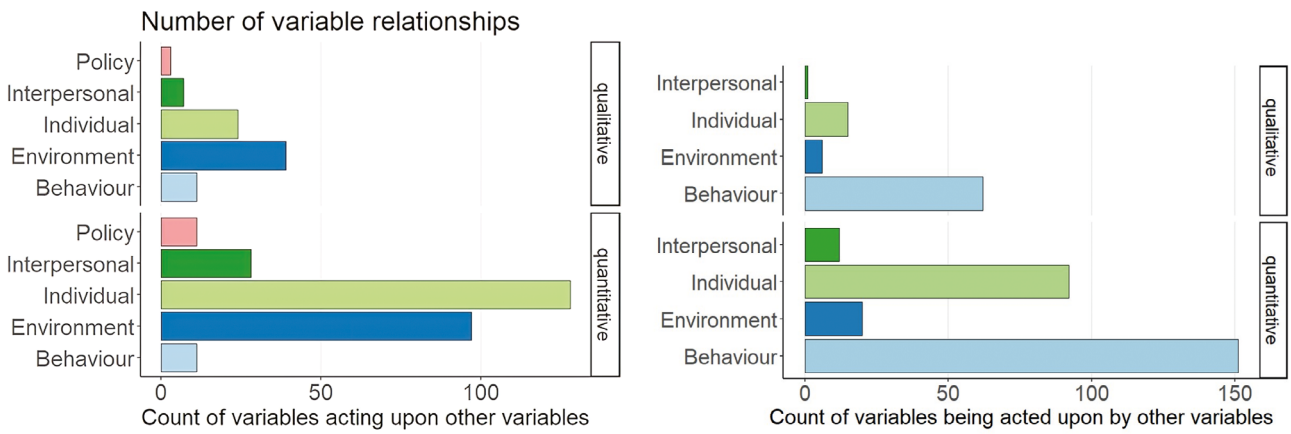

FIGURE 2 Count of variable relationships per DONE category, sorted for qualitative and quantitative studies, and grouped by variables acting upon other variables (left) and variables acted upon by other variables (right).

3.2 *Identifying System Archetypes*

Six SAs were identified in this study: Fixes that fail, Shifting the burden, Escalation, Success to the successful, Tragedy of the commons, and Supply and demand. In contrast to Wolstenholme (2003) core set, the SAs Limits to success, Growth and underinvestment, Accidental adversaries, and Drifting goals were not discovered in this study. For each identified archetype, the formal problem/solution structure from literature is included in Supplementary Files 5. The problem/solution structure based on the data set is shown in Figure 3. Descriptions are provided using the final

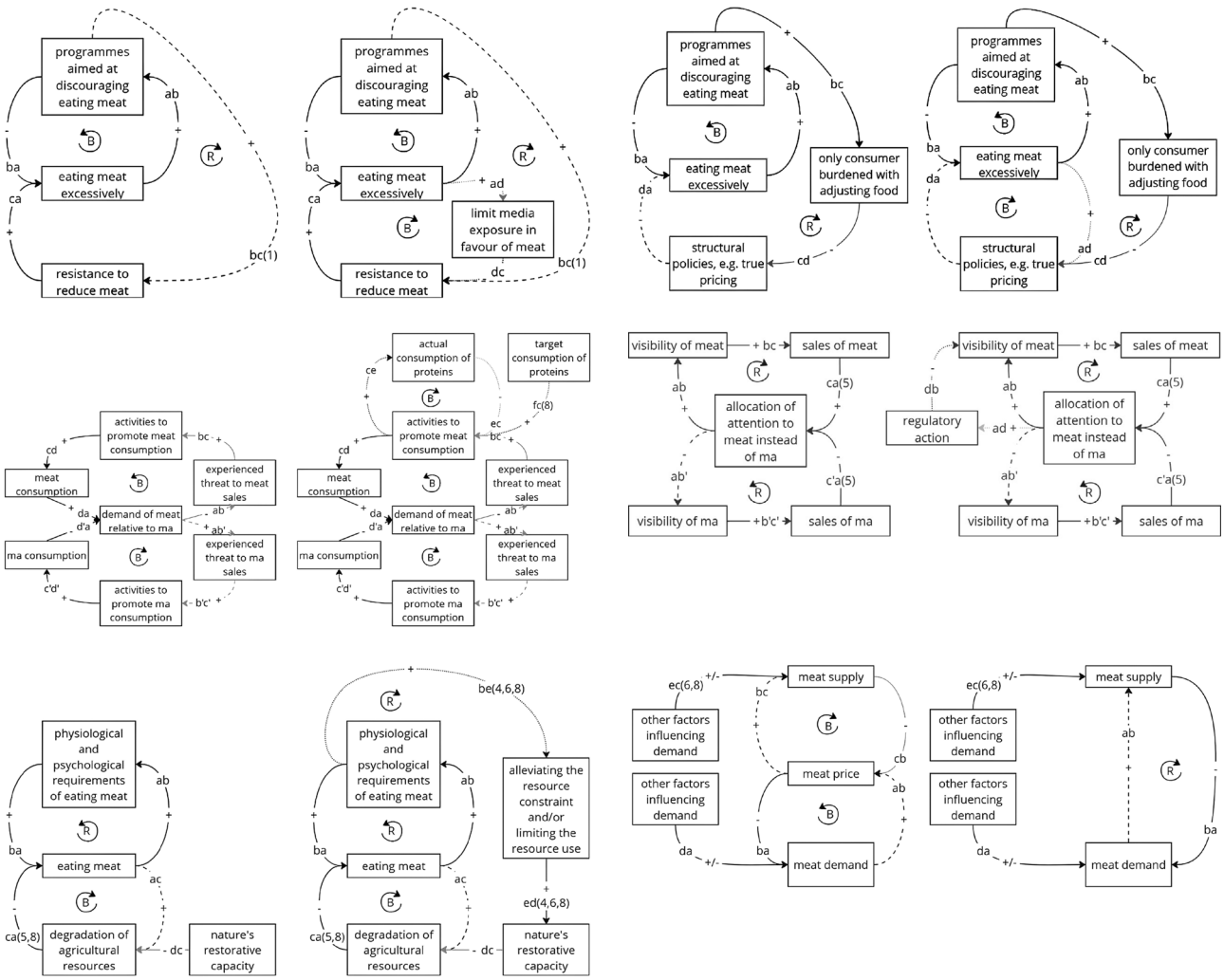

FIGURE 3 Summary and depiction of identified system archetypes (SAs). (Top left) The Fixes that fail archetype describes how unintended consequences (e.g. resistance to reducing meat) of solutions (e.g. programmes aimed at discouraging meat) worsen the original problem. A potential solution is to introduce one or more fundamental solutions that add a balancing loop to the archetype. (Top right) The Shifting the burden archetype describes how a symptomatic solution (e.g. programmes aimed at discouraging meat) diverts attention away from a fundamental solution (e.g. structural policies to reduce meat consumption). The addition of a balancing loop in this archetype represents governments implementing structural policies. (Middle left) The Escalation archetype describes how a fight for superiority (e.g. meat vs meat alternatives (ma)) spirals out of control. Monitoring (e.g. actual consumption of proteins) and setting a target (e.g. recommended minimum and maximum intake) are two policy instruments that can de-escalate the situation. (Middle right) The Success to the successful archetype describes how one party (e.g. meat) is allocated all the resources and therefore remains superior. A regulatory action is required to shift the balance more in favour of the inferior party (e.g. meat alternative (ma)). (Bottom left) The Tragedy of the commons archetype occurs when multiple individuals exhaust a common, depletable resource (e.g. agricultural resources). Hence, individual gain from the resource declines over time. There are two solutions for a Tragedy of the commons: alleviating the resource constraint (e.g. nature's restorative capacity) and limiting the resource use (e.g. meat eating). (Bottom right) The Supply and demand archetype occurs in a free market economy: supply (e.g. of meat) and demand (e.g. for meat) interact freely through price (e.g. price of meat) (left). Ways to interfere in this dynamic include measures acting upon supply, demand, and/or price. The literature suggests a direct reinforcing loop between supply and demand (right). Plus (+) indicates an effect in the same direction (positive); minus (−) indicates an effect in the opposite direction (negative). Solid lines represent a direct effect; dashed lines represent a delay. The dotted line represents the solution link. The letter codes on the links of each archetype correspond with the variable relationships per literature source (Supplementary File 5). Numbers in parentheses represent links validated by experts and supported by additional literature in the main text. Grey arrows could not be supported by the data.

variables; specific, underlying variables are stored in the spreadsheet, which can be found in Supplementary File 6.

3.3 *Fixes That Fail: Resistance to Reducing Meat Consumption*

The Fixes that fail archetype (Figure 3, top left) occurs when an implemented solution leads to an unintended consequence that worsens the original problem (Braun, 2002; Kim, 2000). If meat consumption is considered problematic, programmes aiming to discourage this behaviour can be implemented. However, the programmes can lead to resistance against reducing meat if they trigger perceptions or feelings of identity. Resistance here is understood in the context of social change and originates from a regime that insists on meat as a dietary preference (participant 1). The degree of resistance depends on the socio-political context. Populations that emphasize meat consumption as normative are more likely to oppose such programmes than those already embracing a more plant-based lifestyle (participant 7). A solution can be found by introducing a balancing loop, after which the unintended consequence is reduced or eliminated (Wolstenholme, 2003). One solution derived from the dataset is to limit the media exposure to information and opinions in favour of meat and its production methods.

Resistance against programmes that encourage meat reduction can be linked to political ideologies. To prevent resistance, the discourses on reduced meat consumption should align with carnism, neoliberalism, and populism, as these ideologies play a role in resistance to meat reduction. Additionally, social change that challenges meat consumption as the norm and promotes more plant-based diets may exacerbate resistance, particularly among those who feel pressured to conform to a minority preferring meat alternatives (participant 1).

3.4 *Shifting the Burden: Focus on the Individual Consumer*

The Shifting the burden archetype (Figure 3, top right) occurs when an implemented solution aims to alleviate a perceived problem but, through a side-effect, may prove to fix this problem only temporarily, and often worsens the situation in the long term (Braun, 2002; Kim, 2000). Efforts to reduce meat consumption often target individual behaviour, as do many interventions promoting more sustainable behaviour (Chater and Loewenstein, 2023), but this shifts responsibility from broader societal change and has limited impact, influencing mainly those already aware (participant 3). Given its public and environmental consequences, overconsumption should be seen as a societal issue (participant 2). A Shifting-the-burden problem can be solved by introducing a direct link between the problem and the fundamental solution (Wolstenholme, 2003). More fundamental solutions include structural changes in choice architecture such as the adjustment of meat availability, visibility, and accessibility. Structural universal policy strategies are more effective than interventions targeted at individuals (e.g. informing people) (participant 4). Structural policies should preferably be implemented through official regulations, as requesting retailers to voluntarily adjust their product range has proved to be ineffective (participant 3). Public food procurement is generally considered to be an effective structural policy instrument, because it offers the possibility to determine what food will be purchased (e.g. more plant-based, healthy foods), from whom, and from which type of production (Djojosoeparto et al., 2024). A more fundamental solution could be adjusting price (participants 2 and 3) (see Supply and demand), in particular true pricing (participants 3 and 4).

3.5 *Escalation: Eating Meat vs Meat Alternatives*

The Escalation archetype (Figure 3, middle left) occurs when two competing parties become locked in a fight for superiority (Braun, 2002; Kim, 2000). As meat, dairy, and eggs can be provided by the same producer and are therefore not necessarily competing for profit, in this example it is assumed that the meat alternatives are plant-based (e.g. legumes, tofu) and produced by others. The demand for meat and meat alternatives is here presented as a ratio. Any changes in the demand for either protein source can disrupt the balance. For example, meat sellers can experience a growing demand for meat alternatives as a threat to meat sales. The experienced threat can trigger activities to promote meat, including (social) media exposure, marketing campaigns, and government-initiated educational programmes.

Escalation can be prevented by introducing a balancing loop that monitors the product or service that grants one of the competing parties superiority and a target that limits the total gain of both parties (Wolstenholme, 2003). A regulation to balance the promotion of meat alternatives relative to meat promotion could potentially de-escalate the competition between meat alternatives and meat. Promotional activities could be guided by monitoring population-level protein consumption; this activity is already in place in Europe through national food consumption surveys. A target fitting the archetype's structure could be a limit to consumption of

proteins per individual, though such a stringent measure is unlikely to be implemented. Nonetheless, health and nutrition authorities in European countries already recommend a minimum daily protein intake, but no advice has been issued on a maximum intake. Currently, the recommendation for a minimum protein intake is based on health aspects; several countries have, however, started including sustainability aspects in dietary advice, and this could impact the recommended type and amount of protein (see, for instance, Nordic Council of Ministers, 2023). Rather than setting a maximum protein intake, a maximum target can be set for any of marketing's 4Ps (product, price, placement, promotion) or for minimizing climate impact and/or environmental footprint (participant 5).

3.6 *Success to the Successful: Attention on Meat vs Alternative Products*

The Success to the successful (Figure 3, middle right) archetype occurs if two parties are competing for success and the winning party is continuously allocated all resources and therefore remains the winner (Braun, 2002; Kim, 2000). As meat is more availably, visible, and accessible in supermarkets, it outcompetes sales of meat alternatives. In a profit-driven market, retail managers will allocate attention to the products that sell best, resulting in a disadvantaged position for meat alternatives. Retail managers' anticipated sales in combination with consumer abstinence contribute to a self-fulfilling prophecy that meat alternatives are not profitable (van Hoeven et al., 2024). If an imbalance in attention is detected and perceived as a problem, the introduction of a regulatory action balances the resource allocation (Wolstenholme, 2003). Implementation of regulatory action may be subject to a threshold, such as public pressure to allocate more attention to meat alternatives (participant 8). Efforts must be made to work towards more consumption of meat alternatives in a collective process of multiple actors (Fuentes and Fuentes, 2022). The dataset lacked regulatory actions, though two interventions were mentioned: increased proportion of vegetarian options in cafés (Garnett et al., 2019); increased visibility of meat alternative in a supermarket by offering these in the meat section and in a pair-wise presentation with a similar meat product (Vandenbroele et al., 2021).

3.7 *Tragedy of the Commons: Environmental Degradation as a Result of Eating Meat*

The Tragedy of the commons archetype (Figure 3, bottom left) occurs when multiple individuals exhaust a common depletable resource and individual gain from the resource declines over time (Braun, 2002; Kim, 2000). Meat is consumed for several physiological and psychological reasons, including the perceptions that meat is healthy, required for a "proper" meal, provides pleasure, and has a favourable odour, taste, and texture. Consumers that identify as meat eaters are least likely to be knowledgeable about, and care for, the adverse effects of their consumption pattern on the environment (participant 6). Moreover, the concept of sustainability is, for most people, more difficult to comprehend than immediate effects on their own wellbeing (participant 5).

Meat consumption causes environmental degradation through the highly intensive cattle industry. Good environmental quality, meaning that planetary boundaries are maintained (Rockström et al., 2009), is a resource that provides the potential to produce and consume meat in the future. Current meat production practices harm environmental quality and do not stimulate nature's restorative capacity. The Tragedy of the commons archetype stems from the assumption that each individual consumer optimizes his (economic) utility, as characterized in the neoliberal paradigm. Consequently, no one will account for others' use of the resource (participant 6). An essential nuance here is that technological innovation and intensification has, so far, delayed the point at which environmental degradation limits meat production (participants 5 and 8), a development first described by Boserup (1965).

There are two possible solutions for the Tragedy of the commons archetype: alleviating the resource constraint and limiting the resource use (Wolstenholme, 2003). Consuming organically or locally are options, although local (Stein and Santini, 2022) and organic (Ritchie, 2017) production are not necessarily more sustainable than foreign or conventional production; a switch to more plant-based production will be more beneficial in securing environmental quality (Poore and Nemecek, 2018). Other solutions include strengthening awareness of the link between consumption and adverse environmental impacts, choosing the most appropriate soil type for cattle farming and croplands (Beyer et al., 2022), or restricting production or consumption of meat within the resource's capacity, i.e. planetary boundaries (Gerten et al., 2020). A governmental structure that emphasizes community agreement in resource use would be beneficial for navigating the food system towards more plant-based production and consumption (participant 6).

An example is polycentricity as coined by Ostrom et al. (1961).

3.8 *Supply and Demand: Meat*

The Supply and demand archetype (Figure 3, bottom right) occurs in a free market economy: supply and demand interact freely through price (Braun 2002; Kim 2000). The dataset provided sufficient variable relationships to draw the Supply and demand archetype for meat but not for meat alternatives. The first is depicted in Figure 3.

Supply of meat directs demand through price; demand directs supply through price. However, several sources from the dataset reported a direct link between supply and demand, implying an additional, reinforcing loop in the archetype. Meat supply is plentiful and its production is heavily subsidized: in European agriculture, 82% of subsidies are allocated to income support for farmers (38%) and animal feed (44%), suggesting a significant support from the EU's Common Agricultural Policy for animal-based production (Kortleve et al., 2024). Of financial aid available over the life cycles of animal-based products, production receives 99.7%. Financial support for the novel alternatives sector amounts to 0.1% of the annual spending for animal-based farming (Vallone and Lambin, 2023). The high level of meat consumption is maintained both economically and politically (Schleicher and Töller, 2024) and resembles yet another Success-to-the-successful situation. The dataset provided a large number of explanations for why demand would rise or fall, most of which have been mentioned for previous archetypes. To include the corresponding literature transparently, we added a variable – factors influencing demand – to the archetype.

Any measures targeting supply, price, or demand can shift the Supply and demand archetype towards more meat alternatives. Subsidies, adjusting availability, and pricing, including true pricing, meat tax, and emissions tax (participants 3 and 4), were mentioned. Other financial measures include reducing VAT (if charged) on plant-based foods and subsidizing public organizations supporting the protein transition (Djojosoeparto et al., 2023). The provision of significant subsidies for meat production suggests that free market conditions are not being met, implying that the formal Supply and demand archetype is not a valid representation of supply–demand interactions in the context of the protein transition (participants 6 and 8). Nevertheless, competing interests and the complexity of Europe's agricultural sector complicate the implementation of an alternative subsidy system (Members of the Strategic Dialogue 2024).

3.9 *Cross-Referencing Solutions with Existing Policies*

Figure 4 presents the results of cross-referencing existing policies with the SA solutions identified in this study. Most policies intervene at the shallower systemic levels, reflected by interventions points I to IV. An EU Climate Law amendment obliges reporting about achieving climate neutrality in 2050 and links to the suggested monitoring in the Escalation archetype and ways to secure nature's restorative capacity in the Tragedy of the commons archetype. The other solutions proposed in this study have currently not been implemented; however, several solutions are suggested for implementation. For instance, at EU level, stimulation of market availability, visibility, and accessibility of alternative proteins and true meat pricing (including meat and emissions tax) have been suggested for implementation as part of the Farm to Fork Strategy (European Commission, 2020). Solutions focusing on reduced meat intake, a ban on advertisements for processed meats, and reduced emissions originate from the Global Sustainability Report – the future is now (UN, 2019). A shift from primarily subsidizing meat towards a more balanced financial support system and a governance structure emphasizing community agreement (e.g. polycentricity) are both recommended in the report, "A sustainable food system for EU" (SAPEA, 2020). As directions for future dietary patterns, reducing meat and increasing plant-based intake are advised in Chapter 5 of the Global Assessment Report Biodiversity & Ecosystem Services (IPBES, 2019). We could not match some solutions identified in this study to existing policies, but we still classified them into one of the intervention leverage points. Examples include monitoring of protein, which is performed though through dietary assessment (European Food Safety Authority, 2014), lifting perceived price barriers regarding meat alternatives, and regulating production based on planetary boundaries.

4 Discussion

This study is the first to apply system archetypes (SAs) as a tool to improve the systemic understanding of shifting dietary protein consumption patterns. Applying SAs to elucidate the intricate dynamics of the food environment has yielded six simple systemic structures, each of which represents a complex system. Overall, the SAs elucidate the system-level causes – arising from underlying mechanisms – of the unintended sustainment of excessive meat consumption. Essentially, six different

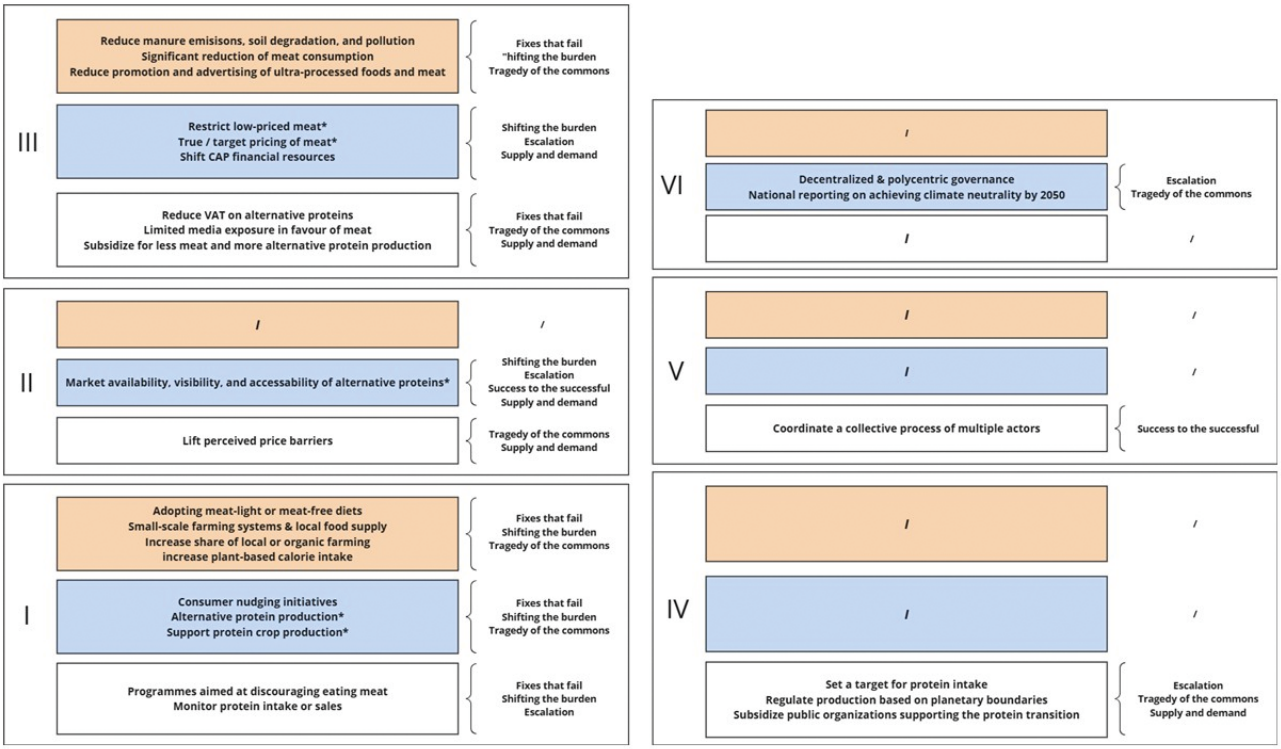

FIGURE 4 Overview of cross-referencing existing policies with solutions identified through the system archetypes from this study. Orange indicates global-level policies; blue indicates EU-level policies; blank indicates solutions that we could not match to existing policies. Policies marked with an asterisk (*) are currently at least suggested for implementation.

SAs typify the systemic causes of resistance to change towards more plant-based diets and at the same time provide potential solution pathways.

4.1 *Lessons Learnt from the SAs*

Both Fixes that fail and Shifting the burden illustrate the limited effect of educational programmes aimed at discouraging consumption of meat. Longer and more intrusive measures are required to sufficiently prompt the majority of consumers to follow a more plant-based diet. For both Escalation and Success to the successful, the proposed solutions can, over time, create a ratio between animal- and plant-based that aligns with public and planetary health. Both Tragedy of the commons and Supply and demand, which are strongly linked to agricultural production, extend beyond the scope of this study. These archetypes demonstrate that current consumption patterns have emerged from components of the food system that remain invisible to most consumers.

Temporal delays contained in each of the archetypes show where relationships between action and long-term impact are obscured in the food environment. It may be mistakenly concluded that an intervention or policy has failed, whereas in reality the system may not yet have had sufficient time to exhibit its effects. One example is attention on meat vs meat alternatives, as illustrated by the Success to the successful archetype. The archetype can help to visualize the consequences of food retail managers' activities. When temporal delays grow, it becomes increasingly difficult to anticipate unintended consequences. The loop between eating meat and environmental degradation in the Tragedy of the commons archetype provides an example. When a system is defined too narrowly, it becomes difficult to see how actions affect long-term outcomes (Wolstenholme, 2003).

Several, if not all, problem archetypes develop and are maintained in a socio-political context that appeals to individual freedom, such as neoliberalism (Pyysiäinen et al., 2017). As illustrated by the Shifting the burden archetype, an emphasis on individual responsibility diminishes governmental accountability for implementing more structural policies. In their latest report, the International Panel of Experts on Sustainable Food Systems calls for a move away from the narrow consumer focus and the adoption of a more holistic approach to transform the food system (IPES-FOOD, 2022). Middel et al. (2024) reported the focus on individual responsibility as an explanation for the persistence of unhealthy dietary behaviours in the Netherlands. Government

regulation could establish a level playing field for promoting healthy foods, but this conflicts with the prevailing neoliberal paradigm, which upholds the belief that food choice is a personal responsibility.

For Supply and demand and Tragedy of the commons, the scope of the archetype extends into the wider food system. This finding suggests that, for the purpose of understanding all dynamics of the food environment, the context of the wider food system is a prerequisite (HLPE, 2017). Systemic approaches that encompass both production and consumption are, moreover, underrepresented in studies on the protein transition, because most scientific research and public discourse are orientated towards consumption and innovation (Paloviita, 2021).

Solutions educed from literature and experts included in our study imply a regime shift (Hundscheid et al., 2024), taking into account the multiple levels, interconnections, and stakeholders contained in the system (Ruben, 2024), and in particular a departure from the neoliberal paradigm (participants 6 and 8). Moreover, cross-referencing existing policies with the solutions identified through each system archetype revealed that only one solution is currently being implemented, although several are proposed for future implementation. One reason for the low rate of policy implementation could be that national food system transformation pathways pay limited attention to accelerating the shift towards more plant-based diets (Candel et al., 2025).

4.2 *Strengths and Limitations*

This study has notable strengths. First, it integrates knowledge about the system-level transition towards more plant-based diets. It demonstrates the relative importance of system components in maintaining or changing current consumption practices regarding protein sources. Second, the use of SAs allowed for the retrieval of elementary feedback loops in which both the problem (i.e. excessive consumption of meat and related adverse effects on public and planetary health) and potential solutions can be identified. The SAs illustrate the cause of the problem and show the part of the system in which intervening would be most effective in solving it. Third, this study conceptualized a qualitative model of the food environment based on existing archetypes. A common alternative is to omit system components because of missing data, but this can result in an incomplete system overview (Sterman 2002). The approach taken in this study prevents a partial model and aids in identifying where knowledge and data gaps exist within the system (Sterman 2002). Fourth, combining empirical evidence from literature with expert consultation accounts for the interpretative nature of system definition (Meadows, 2008). In acting as boundary objects, the SAs enable a conversation about the underlying mechanisms that give rise to current protein consumption practices and identify, in collaboration with stakeholders, relevant courses of action. A final strength of this study is the transparency in the steps taken to apply SAs to the food environment, allowing for reproducibility.

This study has some limitations too. First, variable relationships were retrieved from empirical work performed in a reductionist paradigm, resulting in mainly unidirectional rather than reciprocal relationships. Unidirectional relationships complicate the discovery of feedback loops (Blokhuis et al., 2024; Waterlander et al., 2020). The existing archetypical structures nonetheless guided the interpretation of feedback loops. Second, the DONE framework provides a large number of determinants at individual level. Thus, new determinants, not validated by experts, had to be created. Third, this study focused on the protein transition. Therefore, articles aimed solely at health and/or sustainability aspects of the food environment were not included, even though health and sustainability are relevant to consumption of either animal- or plant-based foods. Fourth, interpersonal-level variable relationships were underrepresented in the dataset (Figure 2), despite various literature sources reporting on the importance of social interaction in food decision making (Higgs and Thomas, 2016; Middleton et al., 2023; Rozin, 1996), and in particular for the choice of protein sources (Ge et al., 2022). Consequently, specific SAs for social interaction were not discovered. Social interaction was, however, included in several of the SAs (Fixes that fail, Escalation, and Supply and demand) as maintaining the status-quo.

The last limitation is the potential bias in selected literature. Unintentionally, a substantial amount of time elapsed between database searching (autumn 2022) and synthesis of the archetypes (spring 2024). Potentially, more recent relevant literature might therefore not be included. Because the ASReview algorithm (ASReview LAB developers, 2022) is inherently conservative, as it has been trained with user-specified paper selection in the past but asked to present the most relevant papers in the future, bias is created against studies with characteristics that deviate from most studies (Checco et al., 2021). Expert consultation served as a validation of the identified SAs, thereby addressing any potentially missing relationships. The massive number of studies (n = 55 463) obtained from database searching made it

nevertheless inevitable to rely on the advantages of an AI-based tool.

4.3 *Recommendations*

Three particular challenges exist for future systemic research in the food environment using SAs. First, as the SAs identified in this study represent qualitative structures of the food environment, further analysis is required to validate the SAs. For example, for the Success to the successful archetype, it was assumed that meat currently outcompetes meat alternatives, but a quantitative analysis of retail data should provide evidence to verify this. In addition, the qualitative nature of SAs cannot provide insight into the magnitude of the effect of one system component on the other. Quantification of relationships, using either numerical data (Epstein, 2008) or expert consultation in the case of soft variables and/or data scarcity (Pluchinotta et al., 2024), is suggested to validate the system dynamics identified through this study. Finally, the SAs do not reflect any decision-making mechanisms underlying observed behavioural patterns. Agent-based modelling is a suitable approach to simulate the several actors in the food environment and their objectives, knowledge, and power to achieve change (Gotts et al., 2019).

Second, more research is required to identify system archetypes that could not be validated through the present study's data set. The experts consulted for this study work in research and all recognize the necessity of shifting towards more plant-based consumption and production; other stakeholders, for example politicians, citizens, farmers, or policymakers, could have varying perspectives on the system and its drivers for the behaviour of interest (Cassidy et al., 2022). An alternative data collection method, such as group model building, facilitates the inclusion of diverse stakeholder perspectives and enables interaction and debate, thereby fostering collaborative model development (Hovmand, 2014).

Third, empirical data collection methods that support conceptualization of SAs must be developed and applied. Extracted variable relationships for the present study were not evenly represented across the individual, interpersonal, environmental, and policy level; the individual level was mined most (Figure 1). An uneven distribution of causal relationships at different systemic levels complicates their application in system conceptualization (Blokhuis et al., 2024; Waterlander et al., 2020). Consequently, SAs operating entirely at the interpersonal, environmental, and policy level might remain unnoticed. Moreover, the uneven distribution of variable levels indicates that research on the food environment and consumption of protein sources is conducted predominantly within an ontological reductionist paradigm (Mittelstraß, 2018; Pigliucci, 2014; Verschuren, 2001). A more holistic approach, which tends to look at objects as a whole (Verschuren, 2001) and favours the assumption of reciprocal rather than linear interaction (Pigliucci, 2014), would guide data collection in support of system conceptualization.

5 Conclusion

This study developed SAs to capture the complexities of both the food environment and consumer behaviour in simple structures, highlighting obstacles that hinder, as well as solutions that might accelerate, the transition towards more plant-based diets. From the six system archetypes (SAs) identified in this study, it can be discerned that high levels of meat consumption in the European population are sustained through several reinforcing and balancing feedback loops. The archetypes explain why programmes aiming to reduce meat consumption can lead to the opposite (Fixes that fail); how burdening consumers with adjusting their food choice directs attention away from a more fundamental solution (Shifting the burden); how activities to promote meat alternatives can result in more demand for meat (Escalation); why meat continues to gain popularity over meat alternatives in retail stores (Success to the successful); why excessive consumption of meat results from a disconnect with environmental degradation (Tragedy of the commons); and how deviating from the free market paradigm by subsidization secures high supply and demand of meat (Supply and demand). By employing SAs, this study revealed both the structural barriers and possible strategies for decreasing meat consumption. Structural barriers include temporal delays that obscure the relationship between the implementation of actions and the manifestation of their effects, and the persistence of a socio-political context favouring individual responsibility and limited governmental interference. As only one of the possible strategies is currently implemented as policy, significant opportunities remain for progress in accelerating the protein transition. We recommend using SAs as a blueprint for designing and implementing policies, stakeholder engagement, and simulation modelling. Future research should aim to bridge knowledge gaps regarding the role of interpersonal dynamics in food choice and accommodate system conceptualization. This study has shown the underlying mechanisms responsible for observed

dietary patterns, highlighting the value of systems thinking for understanding and advancing the transition towards more plant-based diets.

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Author contributions

Christa Blokhuis: Writing (original draft), visualization, software, project administration, methodology, literature review, data extraction, formal analysis, data curation, conceptualization. Marga Ocke: Writing (review and editing), supervision, conceptualization. Sofia Wolfswinkel: Writing (review and editing), literature review, data extraction. Gert Jan Hofstede: Writing (review and editing), supervision, conceptualization. Emely de Vet: Writing (review and editing), supervision, project administration, methodology, conceptualization.

Conflict of 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.

Data availability

All final data sets and R-scripts are available through a repository of Open Science Framework: https://osf.io/fsep6/.

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