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CO-CREATE

Mapping obesity: structures for modelling
Deliverable 4.5

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Executive Summary

This report presents selective results of the qualitative study that was a core primary research component of the CO-CREATE project: Work Package 4 (WP4) Obesity System Mapping, organised by The London School of Hygiene and Tropical Medicine. System mapping workshops were conducted with adolescents in Poland, Portugal, the Netherlands, Norway and the United Kingdom to represent key factors perceived by them to be driving obesity in young people. Subsequent stages of CO-CREATE use the system maps as a starting off point for developing – with adolescents under the auspices of Youth Alliances (WP5) – obesity prevention policy ideas, which will be discussed in dialogue fora with other stakeholders (WP6). Finally, the policy ideas will be simulated in a system dynamics model, to be developed by researchers at the University of Bergen as part of WP7. Described here, therefore, are feedback loops from the system maps generated in WP4 by adolescents, that will contribute to the building of the SD model. The feedback loops presented show how factors such as the commercial environment, social media, mental health and celebrity influencers can reinforce unhealthy eating and physical activity.

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List of acronyms / abbreviations

CLD	Causal loop diagram
EASO	European Association for the Study of Obesity
ECO	European Congress on Obesity
FBL	Feedback loop
GMB	Group model building
STICKE	Systems thinking in community knowledge exchange [software]
SD	Systems dynamics
UK	United Kingdom
WP	Work package

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Introduction

Deliverable description

In line with the European Commission Research Executive Agency/ Horizon 2020 Grant Agreement number 774210 — CO-CREATE, this report fulfils the requirement of Deliverable 4.5 from Work Package 4: ***"****A report describing obesity system structures will be provided, to provide a framework for the agent-based modelling in WP7****."***

Objective of deliverable

The objective of the deliverable is to present data for use by researchers at the University of Bergen who will build stock and flow diagrams and subsequently, system dynamics (SD) simulation models, to test anti-obesity policy ideas generated by CO-CREATE youth participants. The data is extracted from the causal loop diagrams (CLD) generated by adolescents in group model building (GMB) sessions during Work Package 4 (WP4) activities. The work-flow from WP4 to WP7 is such that WP4, wherein the CLD are created, leads into WP5, where adolescents in 'Youth Alliances' develop policy ideas based on the CLD, to WP6, where the feasibility of policy ideas is assessed in dialogue fora with other stakeholders, and finally to WP7, where the potential impact of policy ideas is tested in an SD model.

Background

The aim of CO-CREATE is to ultimately reduce adolescent obesity and its co-morbidities by generating, with young people, evidence-based, obesity prevention policies. In order to account for the multiple factors associated with obesity and how they interact at various levels from the structural to the individual, this project is using a complex systems framework. Indeed, obesity is recognised as a product of the complex interaction of many factors - social, economic, commercial, environmental, biological and others (Butland 2007; Swinburn et al. 2011). More detail on this approach is presented in Deliverable 4.1 which also introduced and presented the CO-CREATE Work Package 4 system mapping, for which the 'group model building' (GMB) method (Vennix 1996) was used.

GMB is a commonly used method in the system dynamics process – system dynamics is a computer-aided approach to policy analysis and design in complex dynamic systems (Richardson and Pugh 1981). Several factors contribute to building a SD model, such as existing literature, interview data and data gathered in system maps with relevant stakeholders in the issue. System maps are often represented in the form of causal loop diagrams (CLDs). In the case of this report, the CLDs represent the views of adolescents on the drivers of obesity.

This report presents structures from the CLDs developed with adolescents during CO-CREATE WP4 group model building workshops that will contribute to the WP7 system dynamics model.

Group model building

Group model building is a methodological approach to system dynamics modelling in which a group of stakeholders come together around an interest in a particular challenge to participate actively in the stages of the model construction (Richardson and Andersen 1995; Vennix 1996). GMB follows guidelines to structure group sessions in which participants' views of the problem are recorded and shared in an atmosphere that promotes constructive divergence, a common learning experience and understanding of the problem, its causes and possible solutions (Hovmand 2014). Key to the process is the level of 'ownership' by the group, of the model in question (Akkermans 1995). Therefore, by involving the participants in structured group techniques, GMB attempts to create collaborative commitment towards implementation efforts by negotiating a shared vision of reality.

In GMB, a causal loop diagram is a representation of the system studied and its outcomes; subsequently, the SD model it is also a "socially constructed artefact" that helps stakeholders to gain an understanding of the system by exploring "what happens if?" thereby extending from a representation of the system to examining potential outcomes (Andersen et al., 2007, p. 692).

Causal loop diagrams

A causal loop diagram (CLD) represents variables deemed by GMB participants to be determinants of the 'seed' problem, connected by arrows indicating cause-and-effect relationships between the variables. The arrows demonstrate the polarity between the variables, either positive (indicating that a change in x, *ceteris paribus*, causes y to change in the same direction) or negative (indicating that a change in x, *ceteris paribus*, causes y to change in the opposite direction). Some such links form circular relationships known as feedback loops, or "closed sequence[s] of causes and effects, that is, a closed path of action and information" (Richardson and Pugh 1981 p4). Within the given system, dynamics result from the interactions of two possible types of feedback loops: reinforcing loops that amplify the behaviour and balancing loops that neutralise or oppose change. The qualitative data representing the mental models of the participants provides a source of data for the formulation of a simulation model. It is in the feedback loops that the behaviour of the system essentially plays out; hence the focus on feedback loops in a CLD for the process of developing a simulation model.

System dynamics modelling

System dynamics (SD) is a structural theory of dynamic systems (Lane 1999) based on the main hypothesis that the behaviour of the system stems from its structure (Forrester 1961) and that the structure of social systems can be broadly characterized by feedback loops i.e. circular relationships that drive the outcomes of the system, accumulation processes, and delays between cause and effect (Richardson 2011). SD uses a set of coupled, first-order, non-linear differential equations to relate qualitative and quantitative factors within and across time periods and is based on principles

developed by Forrester to study managerial and dynamic decisions using control principles (Forrester 1961; Homer and Oliva 2001; Sterman 2000).

System dynamics facilitates the generation of insights about dynamically complex problems through an approach that helps identify causal structures that drive a system's behaviour from an endogenous perspective (Forrester 1961; Repenning 2003; Sterman 2000; Vennix, Akkermans, and Rouwette 1996). While qualitative SD techniques provide a structural understanding of the system from the perspective of relevant stakeholders, quantitative computer simulations are used for learning about dynamic behaviour, analysing scenarios, and testing policies for the future (Coyle 2000; Sterman 2000). It is only through SD simulation modelling that valid inferences can be drawn about a structure and the behaviour of that structure (Hovmand 2014) given that humans struggle to infer dynamic behaviours over time from even relatively simple causal loop diagrams and that in many cases it is simply not possible to run real-world experiments on such complex issues (Sterman 2000). An SD model can be a powerful tool in developing policy insights into dynamic, complex socioeconomic problems which have poorly understood underlying structures characteristic of many public health problems (Homer and Hirsch 2006; Sterman 2000, 2006) including obesity.

System dynamics can therefore play an important role in gaining insights about a system's structure and the leverage points at which policies may effectively be introduced. By identifying causal explanations and supporting them with computer simulations, SD allows policymakers to examine feedback loops in the system in hand and to explore policy options that could improve the system's performance by potentiating or breaking the loops.

The causal loop diagrams that emerged from the CO-CREATE group model building sessions therefore acts as a starting point for building a simulation model.

Methods

The CO-CREATE researchers working on the SD model have been set the task of creating the model based, in part, on the CLD generated with adolescents as part of WP4 (see Annexe 1, CO-CREATE Grant Agreement, page 41):

> *"A system dynamics core model will be developed based on a review of existing public health models and previous systems approaches to childhood obesity, a consensus map drawing on all the system maps made in WP4, a translation of the consensus map into a stock and flow diagram, and quantification of the diagram using values from the literature and WP3. The resulting simulation model will be used to simulate the direct and indirect, short- and long-term consequences of 1-3 of the most commonly suggested co-created policies."*

This description illustrates the arc of CO-CREATE from the system maps, incorporating literature reviews from WP3, policies developed by adolescents in Youth Alliances as part of WP5, to the SD model to be built as part of WP7. The process of merging the CLD generated in the workshops with

adolescents as part of CO-CREATE WP4 is described in Deliverable 4.6. The WP7 model will be formalised and tested but an important element of the model validation and analysis process will be to distil structures that are generic across all case studies and that, with appropriate calibration of initial values and exogenous variables, will reproduce the main behaviour trends observed or feared in the different case studies. Figure 2 shows the CLD resulting from the amalgamation of the five country maps, which were, in turn, the result of merging the individual maps created in each country (see Appendix 2 for larger version).

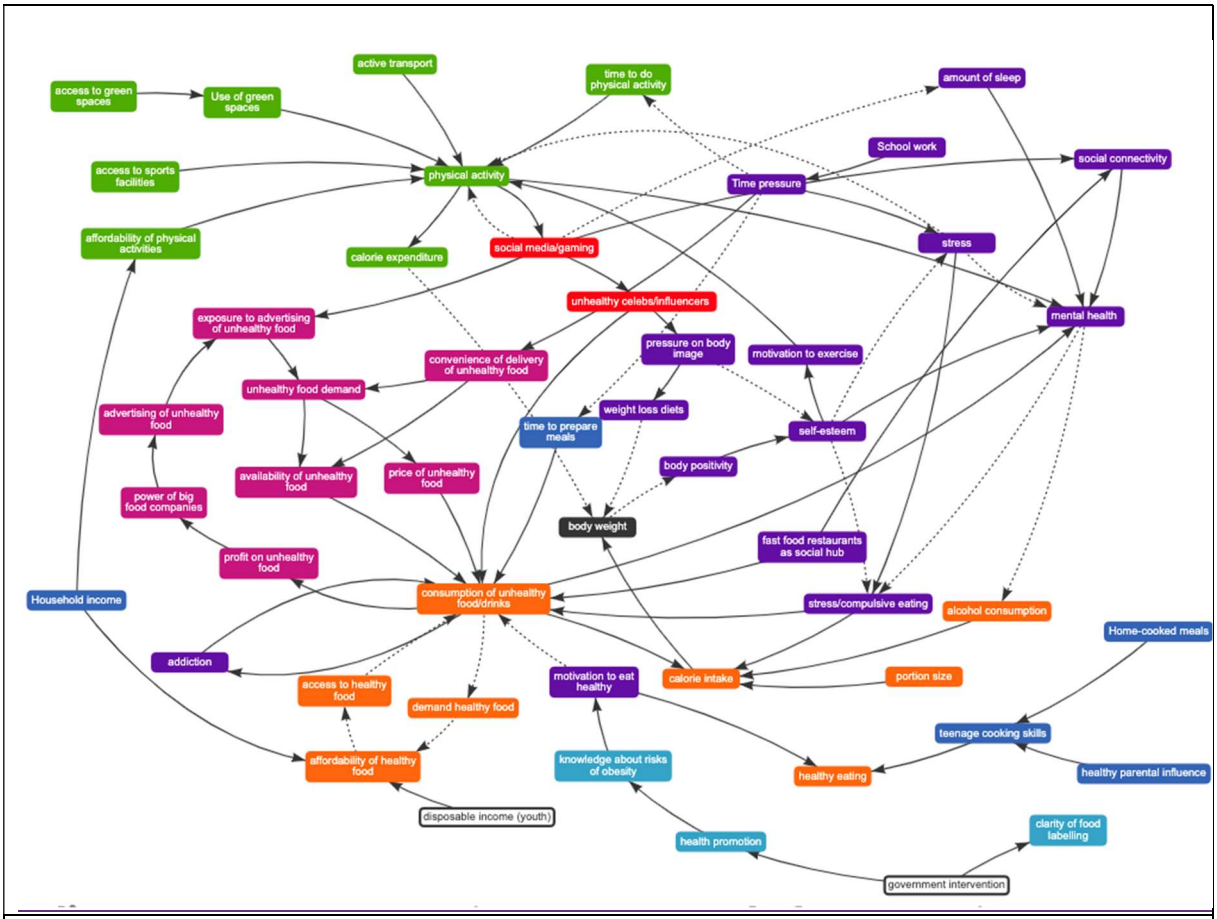

Figure 1: CO-CREATE master map

A fruitful way to use data from causal loop diagrams for the development of a quantitative simulation model is to examine the CLD for the most relevant stocks and feedback loops in the system that best "tell the story" that is told in the CLD (Hovmand 2014); it is not the extensiveness of a model that best determines its ability to reflect the problem, rather the relevance of the components to the problem; when these essential components are present in the model – as parsimoniously as is possible to reflect the problem – then it is most likely to generate the problem behaviour and the predictive ability of the model is at its highest (Luna-Reyes and Andersen 2003). The work presented in this report therefore consists of the identification and the extraction of feedback loops that were common across the CLDs. This is shown in a distilled version of the master

map, shown in Figure 3 (see Appendix 3 for larger version) which shows only variables within feedback loops. In doing so, it provides the modelers with useful data on which to build a stock and flow diagram to inform the SD model.

The following section presents selected feedback loops (FBL) from the causal loop diagrams created by young people in group model building sessions as part of WP4.

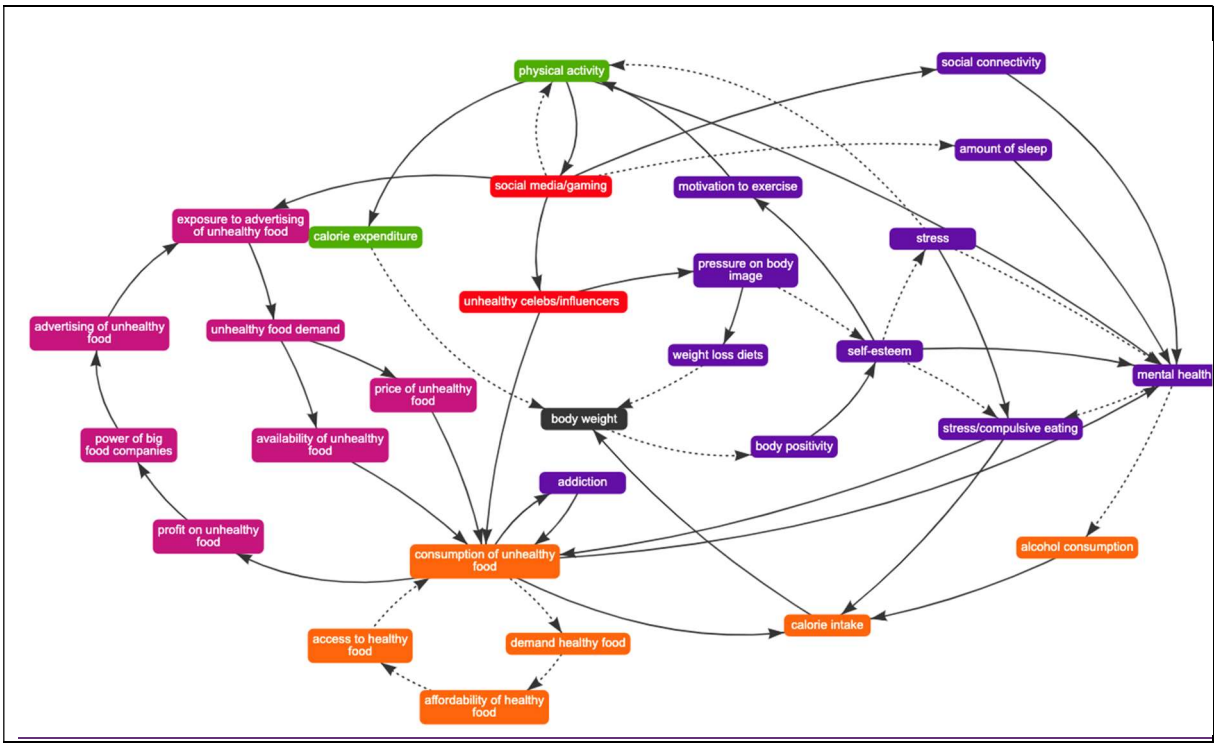

Figure 2: CO-CREATE master map showing feedback loops only

Results

The results presented are feedback loops, as per Figure 3, that represent a sample of key domains from across the final, master causal loop diagram: the roles of the commercial food environment, social media/gaming, mental health and physical activity, and celebrity influencers in an unhealthy diet. A full list of FBL is provided in Appendix 1.

They are hybrid versions of feedback loops, incorporating common themes across the maps showing the perceived drivers of diet and physical activity, and hence, obesity in adolescents. The FBL show variables and connections from different CLD, amalgamated to present the overall themes, as identified by the young people. The purpose of this amalgamation was to maintain fidelity to each of the maps, while ensuring that all common themes are represented.

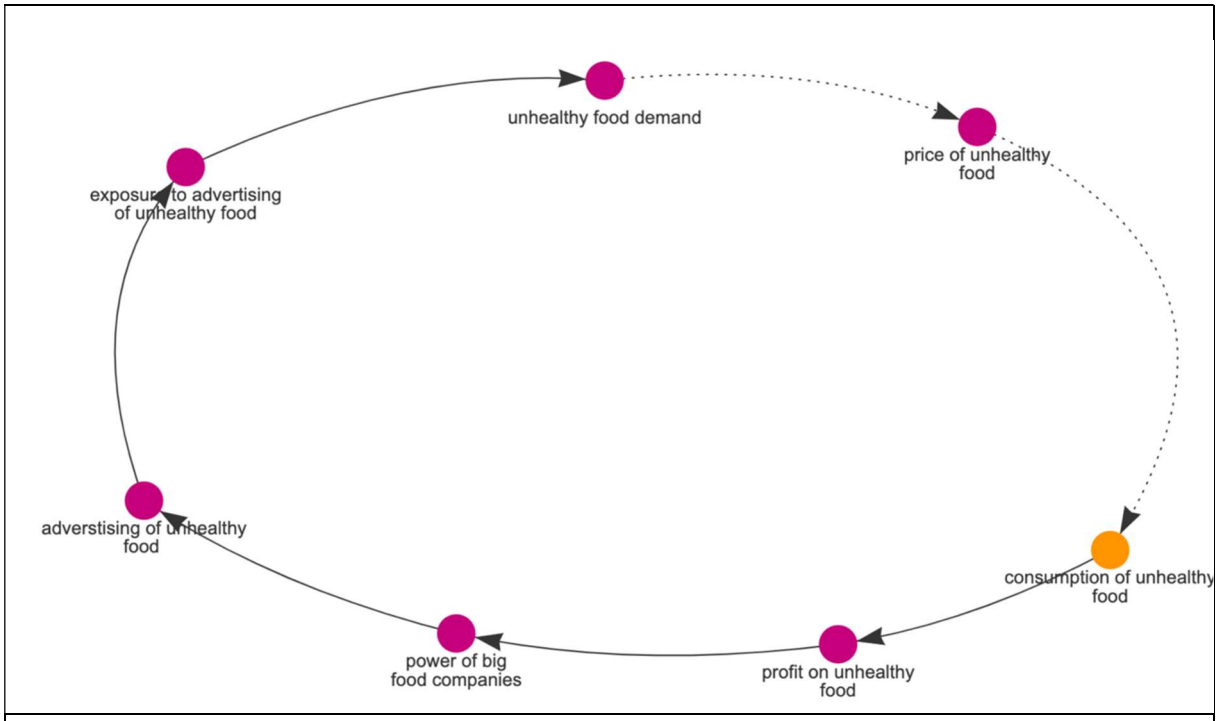

Figure 3: the role of the commercial food environment in unhealthy food consumption

(Feedback loop 1, see Appendix 1)

Figure 3 depicts the young participants' views of how the commercial/economic elements of the food environment – including the influence of large food manufacturers and advertisers – drives the consumption of unhealthy food among adolescents. Specifically, the consumption of unhealthy food leads to profits and the power of unhealthy food producers; this in turn increases their capacity for advertising of these foods, which increases exposure to, and demand for, them; this finally works to decrease the price of the unhealthy foods, thus increasing consumption (by making them more affordable). From the feedback loop it is possible to see how the advertising of unhealthy food choices reinforces the power of big food companies. Feedback loops are described as either 'reinforcing' whereby they give rise to a 'vicious' circle of increasing effect; or 'balancing' in which case the actions are tempered and do not spiral. All the feedback loops presented in this section are 'reinforcing'.

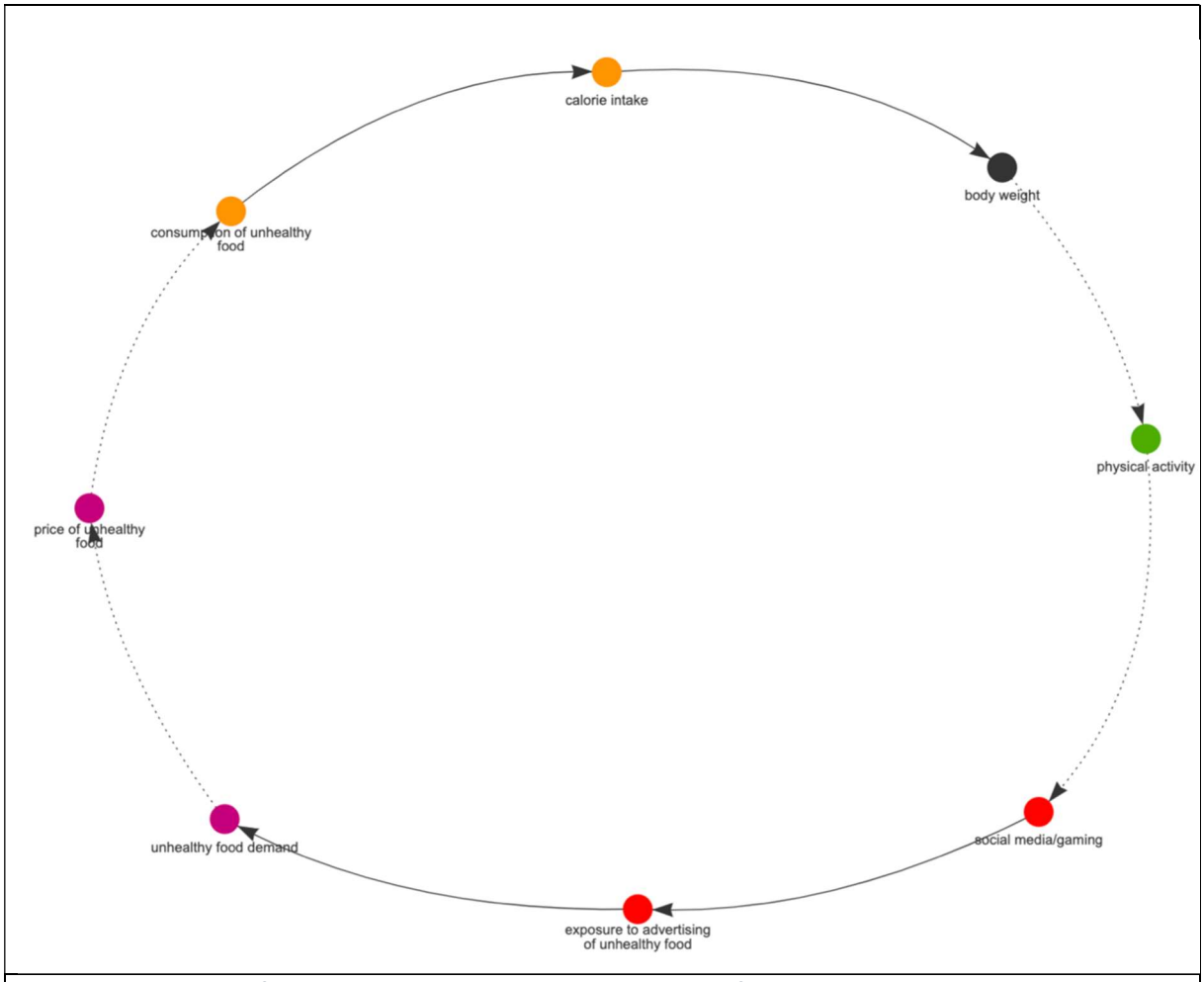

Figure 4: the roles of social media and gaming in unhealthy food consumption

(Feedback loop 9, see Appendix 1)

Figure 4 builds on Figure 3 in that it expands the 'story' explaining the consumption of unhealthy foods by bringing in the roles of social media and gaming, introducing the concept of the online food environment (which supports the physical food environment). Thus, here social media and gaming increase the opportunities for unhealthy food advertisers, and thus young social media users' exposure to advertising, in turn increasing demand for unhealthy foods. This has the effect of reducing the price of the unhealthy foods, making them more affordable and thus more consumed; this leads to greater calorie intake, excess weight gain, which works to reduce young people's propensity to be physically active, returning more easily to social media and gaming, which are sedentary activities. This feedback loop is also a 'reinforcing' one.

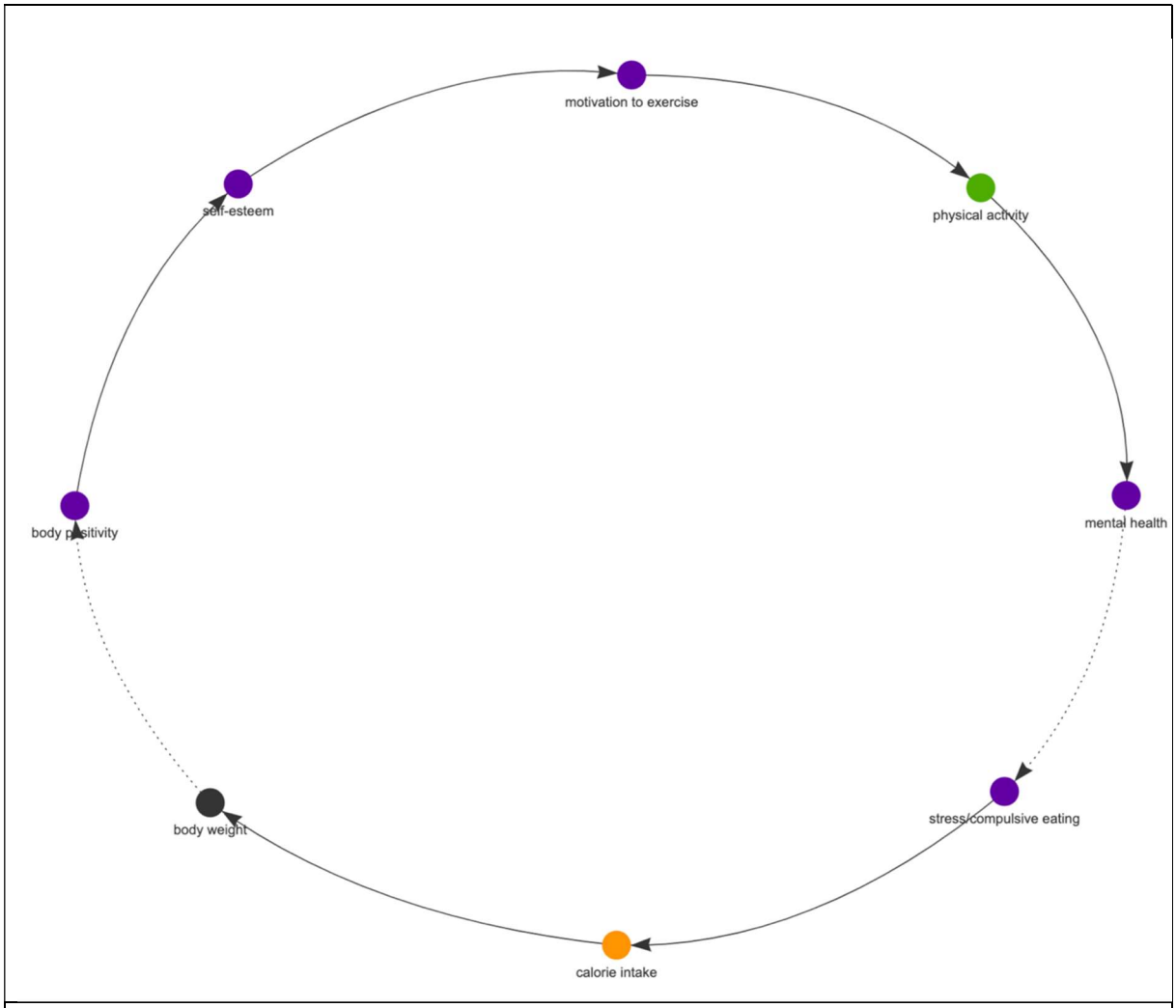

Figure 5: the roles of mental health and physical activity in energy balance

(Feedback loop 15, see Appendix 1)

Figure 5 focuses on the relationship between physical activity and mental health, and highlights the role of low self-esteem of young people as a driver for weight gain, mediated through a range of factors. Thus, starting where Figure 5 left off: sedentary behaviour or low physical activity leads to worse mental health, which in turn was felt by young participants to increase stress and related compulsive eating, increasing calorie intake and body weight. Higher body weight was thought to decrease body positivity and self-esteem, in turn decreasing the motivation to exercise, and exercise itself. Figure 5 again shows a reinforcing feedback loop, whereby calorie intake and body weight can be caught in a 'vicious circle'.

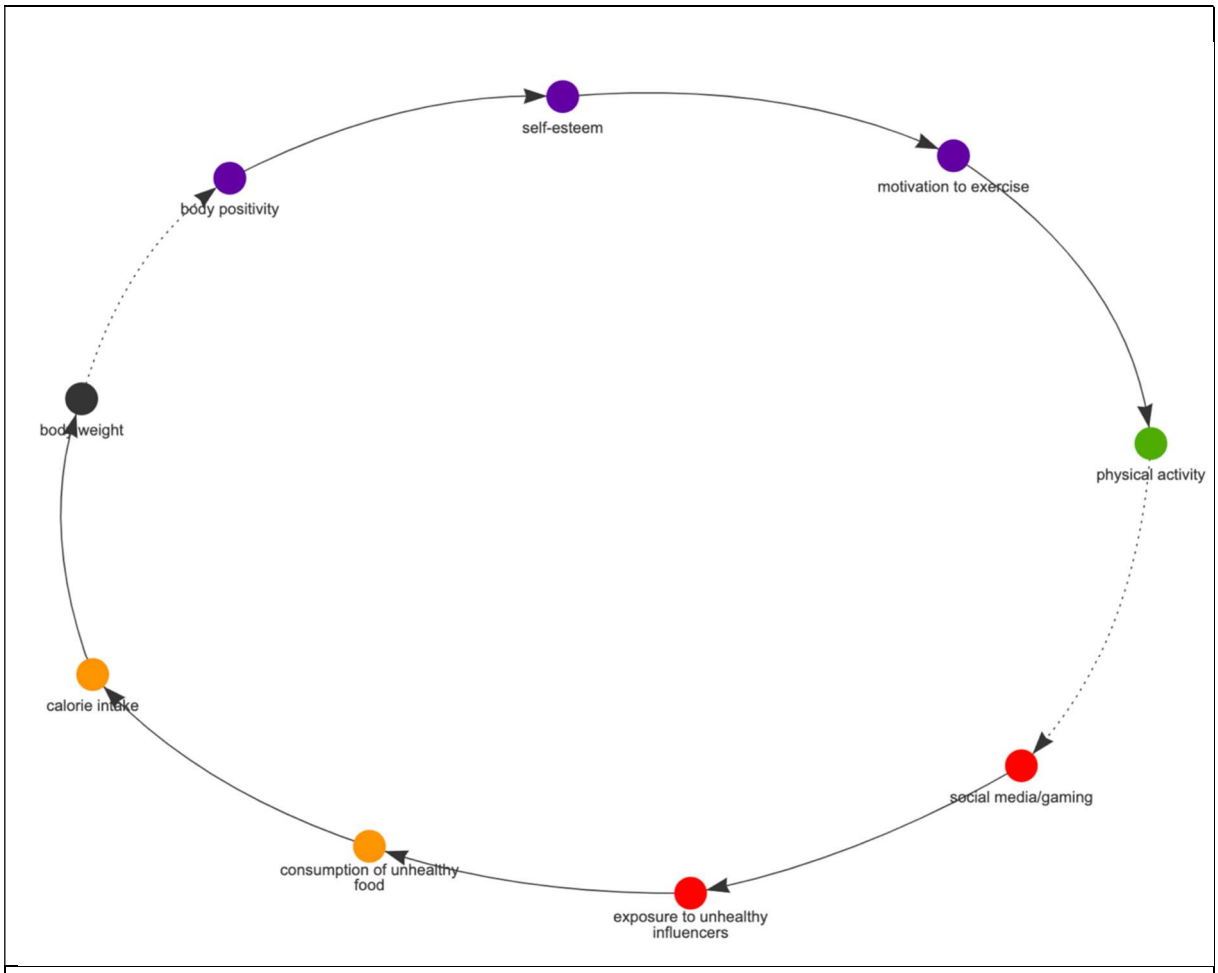

Figure 6: the role of social media influencers in an unhealthy diet

(Feedback loop 25, see Appendix 1)

Figure 6 explores the other ways in which social media and gaming drives obesity in young people, highlighting the role of 'influencers' of unhealthy food on social media. Influencers were considered to be enormously important in affecting young people's behaviour. They are another form of advertising, increasing consumption of unhealthy foods (sponsored by influencers), thus increasing calorie intake and body weight, reducing body positivity, self-esteem, motivation to exercise, and exercise itself, leading to an increase of social media and gaming (a sedentary behaviour), and further exposure to social media influencers pushing unhealthy foods. This is yet another example of a reinforcing feedback loop.

Conclusion

The purpose of the work presented in this report is to examine the causal loop diagrams generated with adolescents about their perceptions of the drivers of obesity such that they can help inform the construction of a system dynamics simulation model to test obesity prevention policy ideas developed by adolescents in Youth Alliances. While causal loop diagrams (CLD) are a useful tool for representing the structures constituting a given problem, and provide important information *per se,* that information can be further exploited by feeding into a system dynamics model. For this, the CLD structures can be calibrated to inform a stock and flow diagram which is then used in a system dynamics (SD) model to simulate and test the structural assumptions underlying the CLD. As such, the CLD provide a convenient way of representing feedback loop structures before formalising them to develop a simulation model.

As described above, the pertinent feedback loops have been extracted from the CLD representing adolescents' views on the drivers of obesity. The nature of causal feedback loops is such that they are a powerful tool to help define the system's boundary and to differentiate what should and should not be included within the simulation model. Besides demonstrating the variables or factors to be included in the analysis, FBLs encapsulate the causal influences that are most important in generating and controlling the problem. Because the loops are themselves interlinked and reinforce and/or counteract each other, they generate an aggregate representation the problem's behaviour.

The structure of a system is determined by the network of causal feedback loops necessary to explain why certain key elements in the system behave over time as they do. FBL are thereby seen as the 'engines' of the model together with stocks that represent accumulations, non-linearities and delays. The behaviour of the resulting SD model will be determined therefore by the interaction of these loops because they allow the modeller to endogenously recreate the dynamic behaviour that we want to reproduce. The nature of the main feedback loops is such that there seem to be a number of powerful reinforcing feedback loops, which act as vicious cycles in driving unhealthy diets, physical activity and body weight. This has implications for the boundary of the WP7 model – in order to break the vicious cycles identified in the maps, the model needs to make sure that it also represents the balancing feedback loops that could shift loop direction/change loop dominance.

Identifying the feedback loops and hence, leverage points inside them at which interventions could influence the problem – adolescent obesity - is an essential part of developing and testing potential policy options. The results of this report will therefore be used by researchers at the University of Bergen to build a system dynamics model to simulate policy ideas developed by young people in the work package 5 Youth Alliances.

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Appendix 1: Feedback loops identified in the CO-CREATE CLD

What follows is a list of the feedback loops identified in the CO-CREATE master CLD (see Appendix 2) that will be used to help construct a stock-and-flow diagram to inform the simulation model. Those in bold were illustrated in Figures 4, 5, 6 and 7.

1. **Consumption of unhealthy food → profit on unhealthy food → power of big food companies → advertising of unhealthy food → exposure to advertising of unhealthy food → unhealthy food demand → price of unhealthy food → consumption of unhealthy food**

2. Consumption of unhealthy food → profit on unhealthy food → power of big food companies → advertising of unhealthy food → exposure to advertising of unhealthy food → unhealthy food demand → availability of unhealthy food → consumption of unhealthy food

3. Consumption of unhealthy food → addiction → consumption of unhealthy food

4. Consumption of unhealthy food → demand of healthy food → affordability of healthy food → access to healthy food → consumption of unhealthy food

5. Physical activity → social media/gaming → physical activity

6. Physical activity → social media/gaming → unhealthy celebs/influencers → pressure on body image → self-esteem → motivation to exercise → physical activity

7. Physical activity → social media/gaming → exposure to advertising of unhealthy food → unhealthy food demand → price of unhealthy food → consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → stress → physical activity

8. Physical activity → social media/gaming → exposure to advertising of unhealthy food → unhealthy food demand → availability of unhealthy food → consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → stress → physical activity

9. **Physical activity → social media/gaming → exposure to advertising of unhealthy food → unhealthy food demand → price of unhealthy food → consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity**

10. Physical activity → social media/gaming → exposure to advertising of unhealthy food → unhealthy food demand → availability of unhealthy food → consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity

11. Mental health → stress/compulsive eating → calorie intake → body weight → body positivity → self-esteem → mental health

12. Mental health → alcohol consumption → calorie intake → body weight → body positivity → self-esteem → mental health

13. Mental health → stress/compulsive eating → consumption of unhealthy food → mental health

14. Mental health → alcohol consumption → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity → mental health

15. **Mental health → stress/compulsive eating → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity → mental health**

16. Stress → mental health → stress/compulsive eating → calorie intake → body weight → body positivity → self-esteem → stress

17. Stress → mental health → alcohol consumption → calorie intake → body weight → body positivity → self-esteem → stress

18. Stress → physical activity → social media/gaming → unhealthy celebs/influencers → pressure on body image → self-esteem → stress

19. Stress → physical activity → calorie expenditure → body weight → body positivity → self-esteem → stress

20. Stress → physical activity → social media/gaming → unhealthy celebs/influencers → consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → stress

21. Physical activity → social media/gaming → unhealthy celebs/influencers → pressure on body image → self-esteem → stress/compulsive eating →calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity

22. Physical activity → social media/gaming → unhealthy celebs/influencers → pressure on body image → self-esteem → stress/compulsive eating →consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity

23. Physical activity → social media/gaming → unhealthy celebs/influencers → consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity

24. Physical activity → social media/gaming → unhealthy celebs/influencers → pressure on body image → weight loss diets → body weight → body positivity → self-esteem → motivation to exercise → physical activity

25. **Physical activity → social media/gaming → unhealthy celebs/influencers → consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity**

26. Physical activity → social media/influencers → amount of sleep → mental health → stress/compulsive eating →consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity

27. Physical activity → social media/influencers → amount of sleep → mental health → alcohol consumption → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity

28. Physical activity → social media/influencers → amount of sleep → mental health → stress/compulsive eating →consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → stress → physical activity

29. Physical activity → social media/influencers → amount of sleep → mental health → alcohol consumption → calorie intake → body weight → body positivity → self-esteem → stress → physical activity

30. Physical activity → social media/influencers → social connectivity → mental health → stress/compulsive eating →consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity

31. Physical activity → social media/influencers → social connectivity → mental health → alcohol consumption → calorie intake → body weight → body positivity → self-esteem → motivation to exercise → physical activity

32. Physical activity → social media/influencers → social connectivity → mental health → stress/compulsive eating →consumption of unhealthy food → calorie intake → body weight → body positivity → self-esteem → stress → physical activity

33. Physical activity → social media/influencers → social connectivity → mental health → alcohol consumption → calorie intake → body weight → body positivity → self-esteem → stress → physical activity

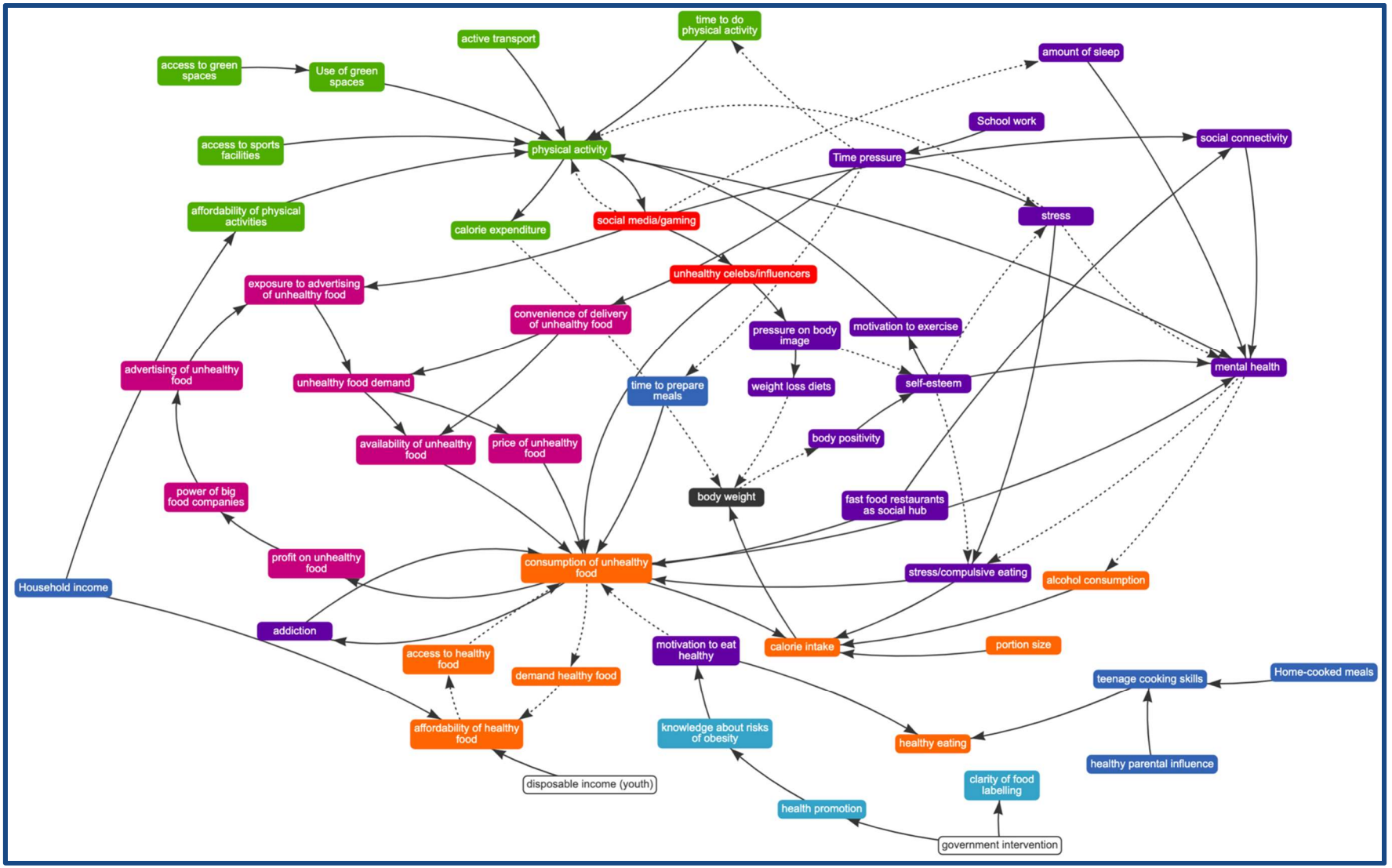
34. Physical activity → calorie expenditure → body weight → body positivity → self-esteem → motivation to exercise → physical activity

35. Physical activity → calorie expenditure → body weight → body positivity → self-esteem → stress → physical activity

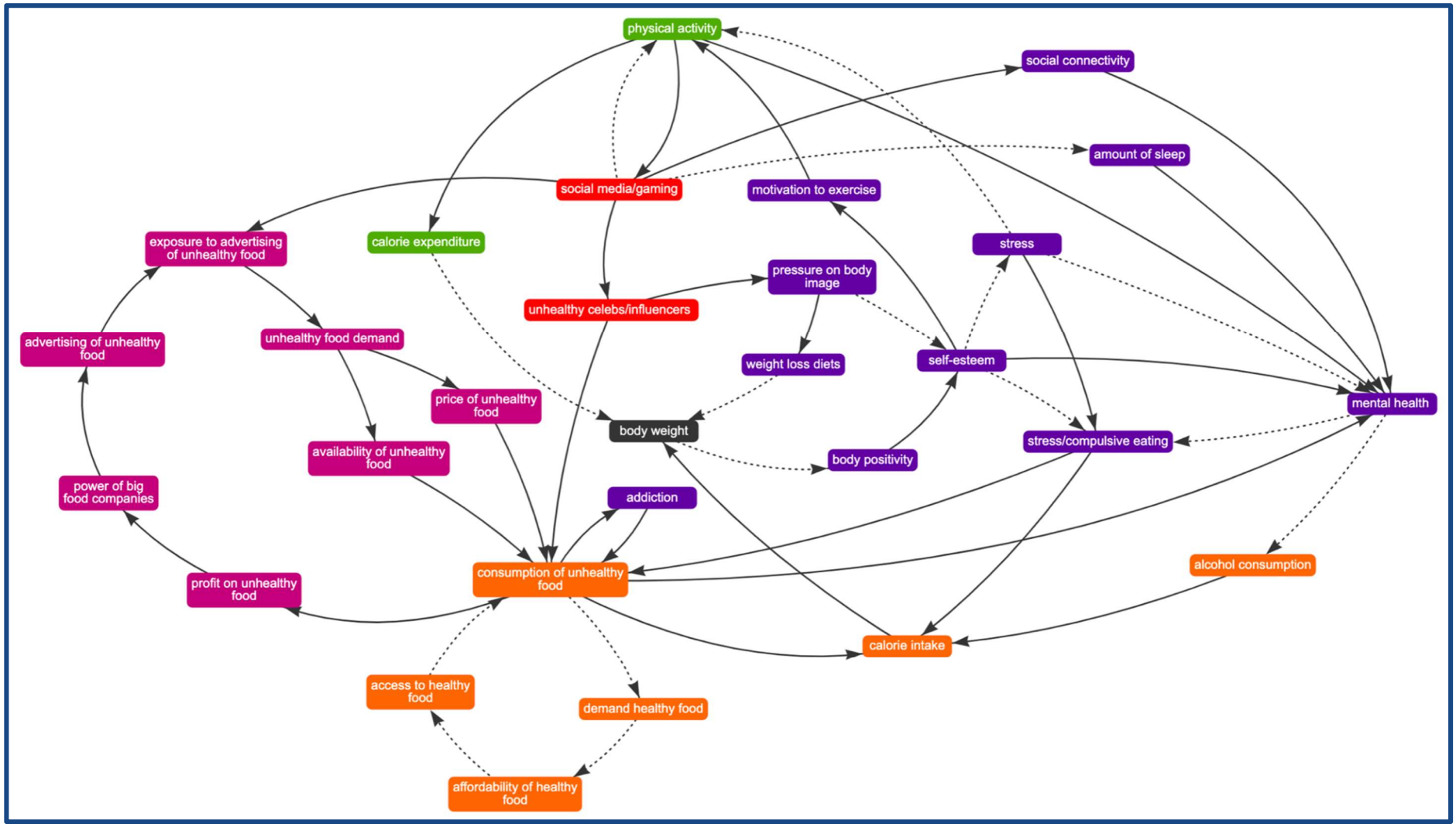
36. Body weight → body positivity → self-esteem → stress/compulsive eating → calorie intake → body weight

37. Body weight → body positivity → self-esteem → stress/compulsive eating → consumption of unhealthy food → calorie intake → body weight

Appendix 2: CO-CREATE master map



Appendix 3: CO-CREATE master map – feedback loops only



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