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Theoretical modelling of diet shifts towards more sustainable and healthy choices

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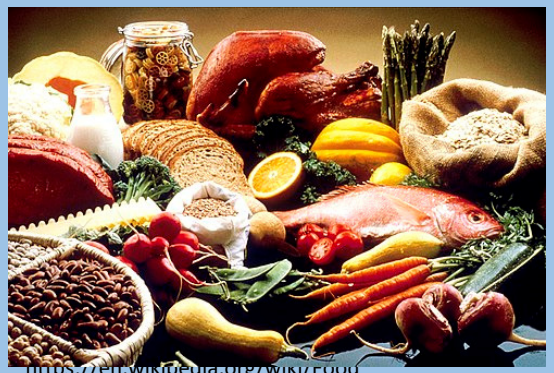


https://en.wikipedia.org/wiki/Food

https://en.wikipedia.org/wiki/Freedom_of_choice

Contents

Project's driving question

What general factors make policy interventions successful in changing dietary choices?

In this project we abstracted from specific choices (e.g. a meat-free diet) and specific contexts (e.g. work place interventions) that have been addressed in other research in the project to ask whether it is possible to identify general characteristics of a population and of an intervention that together determine the level of impact that we could expect an intervention to have.

As a secondary goal, we wanted to understand how this impact might change between settings where one or a small number of factors differ. In complex social phenomena, such as behavioural choices, we expect many different factors to change simultaneously and in potentially conflicting directions over time. We may not be able to detect or measure many of these factors. This makes it difficult to understand how key factors interact to produce the outcomes that we can observe or to be able to forecast what could occur in the future.

The outcomes of this project can be useful to help interpret more specific predictions, and to help guide the underlying thinking in policy design and policy-driven interventions.

https://www.un.org/sustainabledevelopment/blog/2015/12/sustainable-development-goals-kick-off-with-start-of-new-year/

Our approach – a ‘toy’ model

We built a ‘toy’ model that is sufficiently flexible to represent a general context of policy interventions that are designed to influence individual choices within a population. The essential processes of choice are represented in the model using mathematical equations.

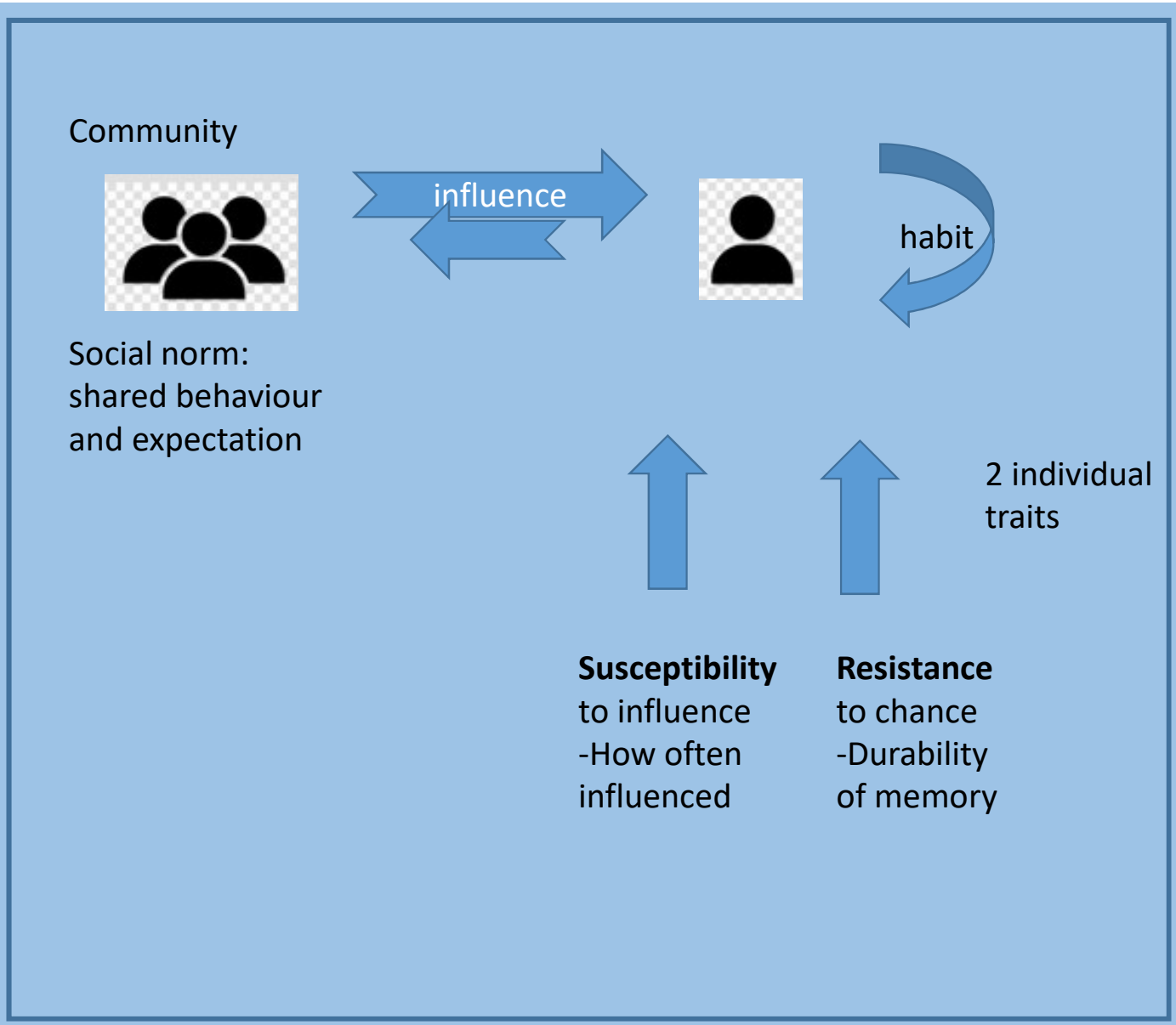
A model is a simplification of reality that we can study more easily. If the model was as complex or difficult to study as the real world then we’d gain no insight. But our model is an abstraction, meant only to capture the most essential elements of decision making. This is why we call it a ‘toy’ model; it is not meant to represent the complexities of the real world, but to give insights into how key characteristics interact and into what might happen if conditions change. We are looking to explore scenarios in which these components interact to produce a range of different possible outcomes regarding the impact of interventions in different populations.

It is preferable for a model to be as simple as possible because we seek basic understanding, and because we know very little of the processes actually happening in a real population. We can often measure some outcome(s), but our observations are limited, and, moreover, we don’t know what processes generated them or if they are the best outcomes to measure. Therefore, we can make simple plausible assumptions about processes that, when combined together, lead to outcomes that we assume approximate what we observe and, because they depend on clearly defined conditions, are tractable and interpretable.

What is the model?

The healthiness of the diet for each individual is scaled to an index from 0 (unhealthy) to 1 (healthy), similar to the Diet Quality Index (DQI).

The index changes through choices made every meal, determined mostly by the interplay between social influence and habit.



https://www.iconpacks.net/free-ico/nperson-295.html

What is the model?

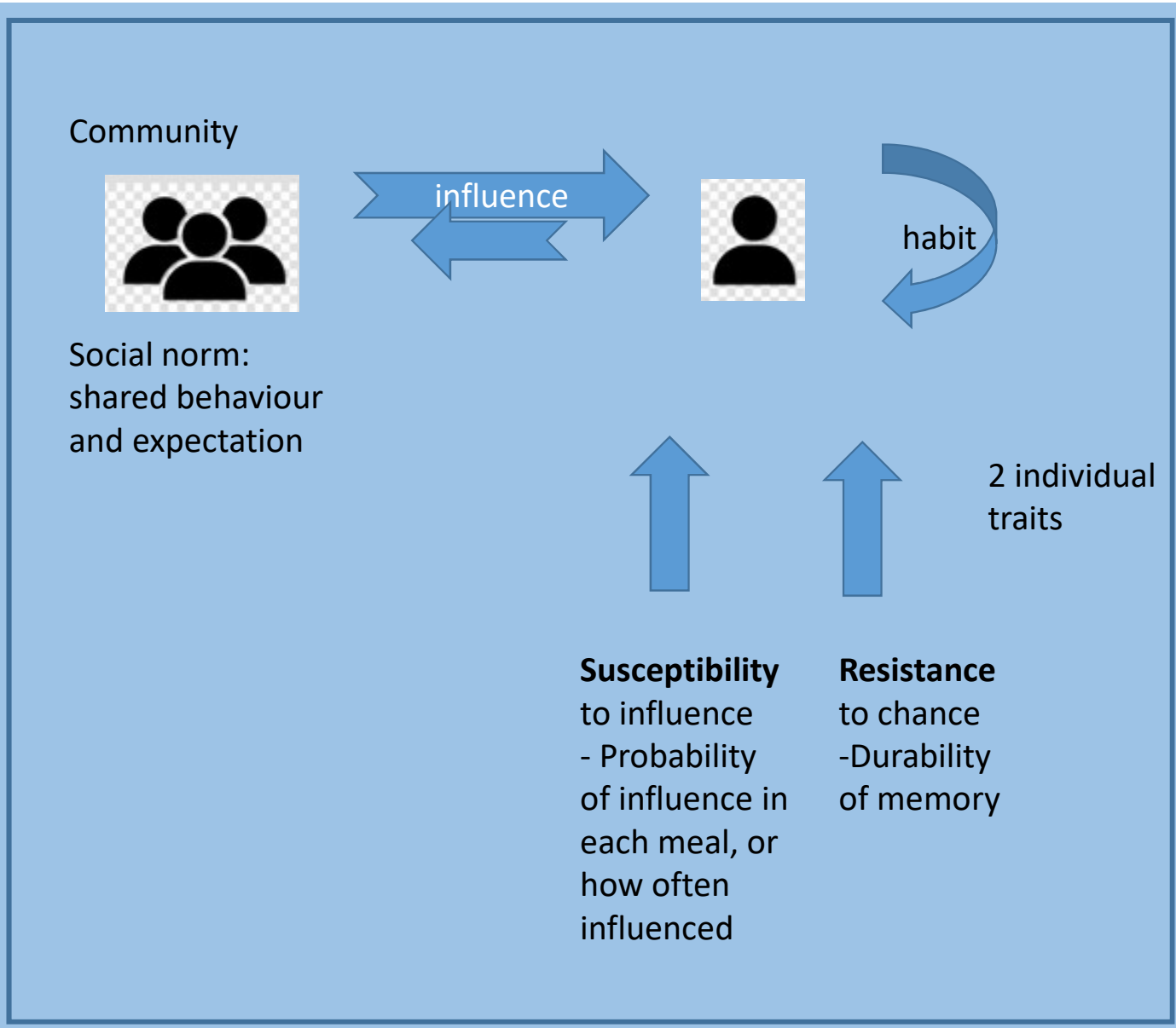
Current state of a person is set by:

- Current diet choice
- Current memory of choices
- Who influenced by

Choice in every meal is based on:

Susceptibility: probability that the person is influenced by others.

Resistance: if choice is based on habit rather than social influence, resistance is the duration of the memory of past choices. Short memory: habit is dominated by recent influences. Long memory: habit is dominated by old choices and influences.



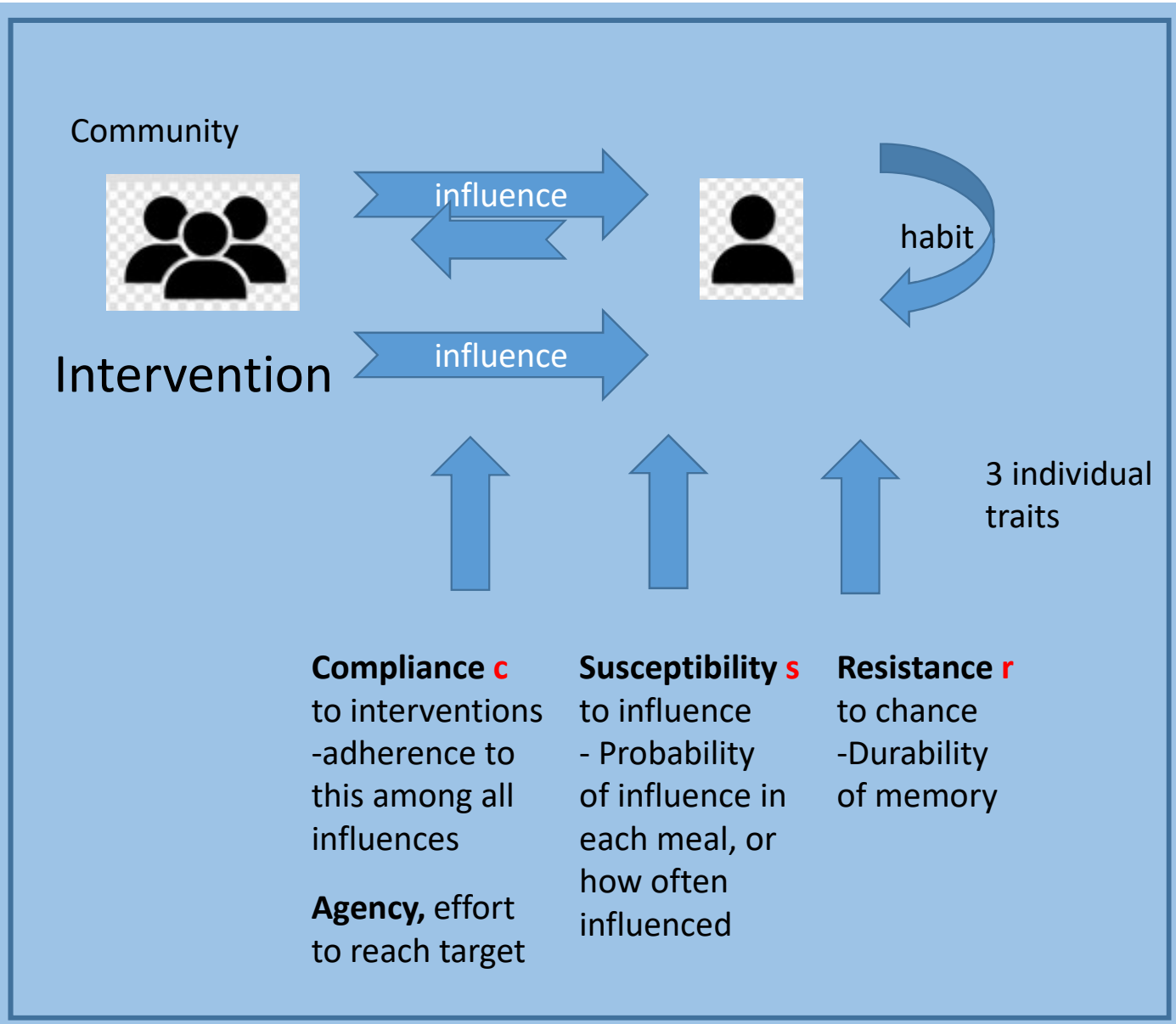
What is the model?

Actions or interventions (e.g. by government agency, charity, food company, supermarket) aim to encourage people to increase the healthiness of their diet choices.

For example, people are encouraged to choose diets with index above a target 0.7 in a social media campaign lasting 40 days.

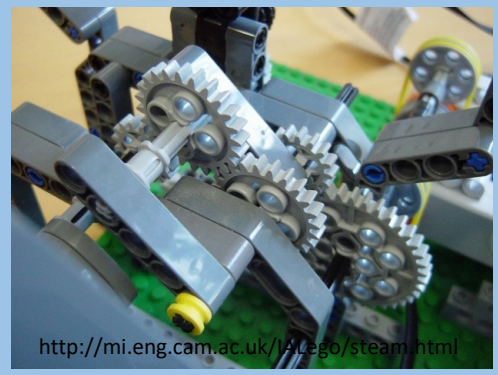
Influences on individual choice:

- Social influence
- Intervention, if the individual is **compliant**, i.e. puts in enough effort to meet the target
- Habit



How does the model actually work?

The mathematics defining the model, and the computations required to make predictions, are described by reproducible code available from the authors written in the language R.



It isn't necessary to examine the computer algorithm to understand the rest of the work; in the same way that we can drive a car without having to look under the bonnet. However, for clarity, the change in the index (Y_i) of individual i, from a meal at time t to the next meal at t+dt, is given by[1]:

$Y_i(t+dt) = Y_i(t) + dt\ \beta\ [\ s\ [(1-c)(N_i - Y_i) + c\ \text{Intervention}] + (1-\ s)\ (A_i - Y_i)] + \sqrt{(dt)}\ \beta\ \varepsilon$	Change in index
s	Susceptibility
r	Resistance
c	Compliance
β	Frequency of meals
ε	Random variation
$N_i(t) = \sum_{j \neq i} K_{ij}\ Y_j(t)$	Influence by the norm
$A_i(t) = Y_i(0)\exp(-t/r) + \int_0^t dt'(1/r)\exp(-(t-t')/r)\ Y_i(t')$	Average of diet index over time (memory)

[1] The model is stochastic. Some equation elements are written in simplified symbolic form, e.g. s and c stand for binomial random variables with probabilities s and c.

Our findings and conclusions from the model

1. Role of population susceptibility and resistance in the impact of interventions

2. Role of population compliance in the impact of interventions

3. Response to interventions of differing intensity

Take home messages: National policy and implications from our findings

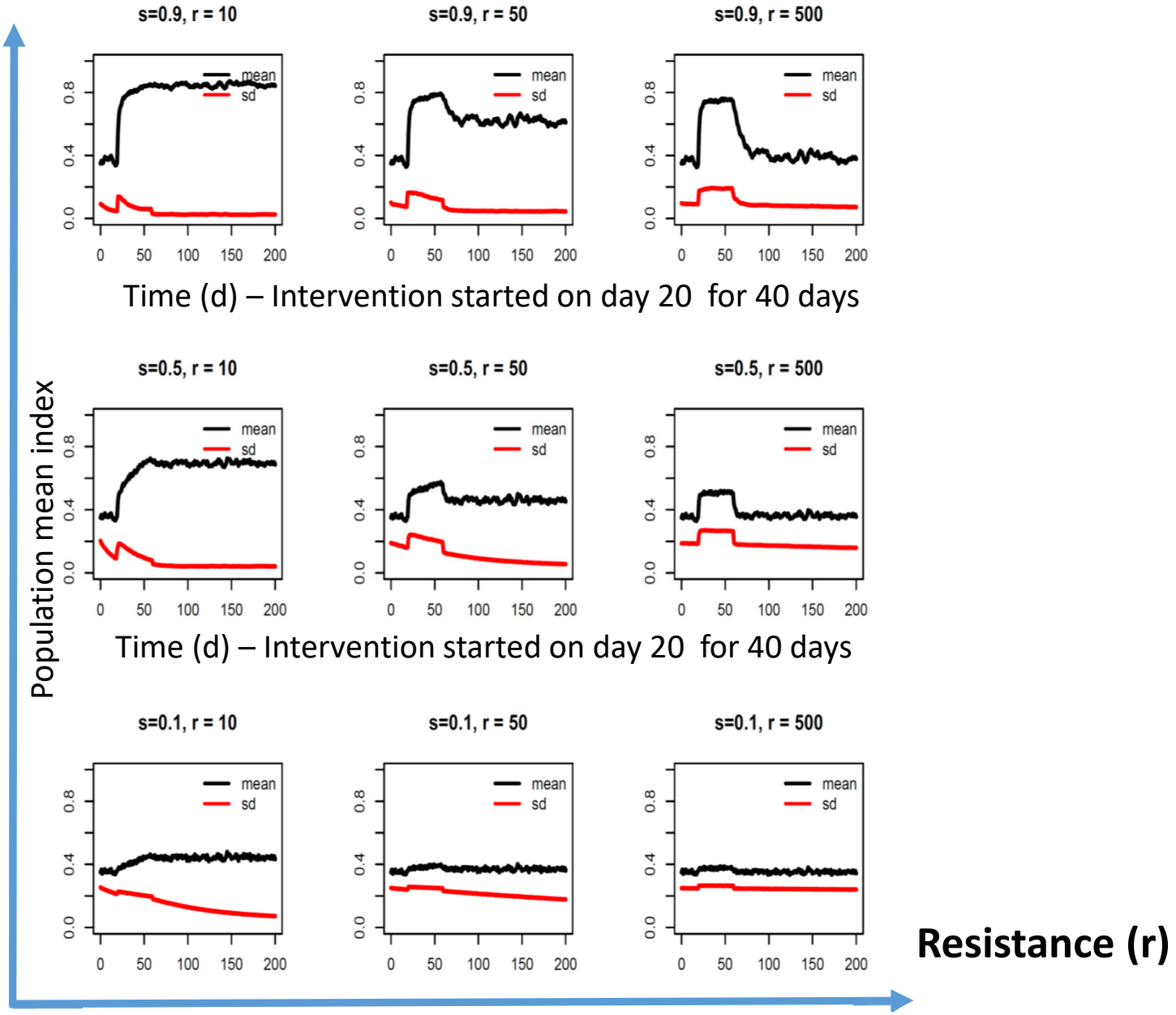
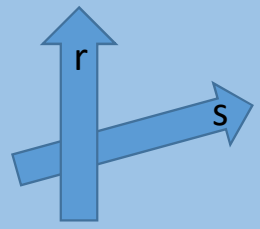
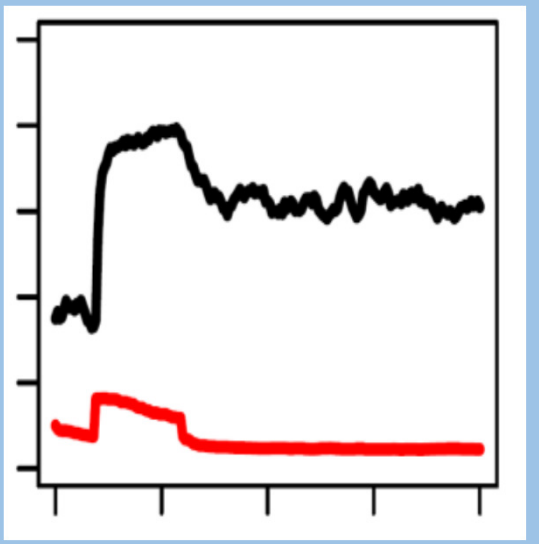


Fig. 1. Role of population susceptibility and resistance in the impact of an intervention. Scenario of maximum compliance.



1 - Role of population susceptibility and resistance in the impact of interventions (Fig. 1)



Short-term: The average impact of an intervention depends on the individual effort (agency) required to adhere to a policy and the **level of susceptibility** of the population

Maximum impact: Determined by a cumulative increment over the duration of the intervention. This increment is crucially limited by the **level of resistance** of the population and the duration of the intervention.

Long-term: After the intervention, the impact declines to an extend determined by the **resistance** of the population. In a durable intervention, choice returns to a level above the pre-intervention level.

Conclusion: A wide spectrum of impacts can be understood as an interaction of the susceptibility and resistance in the population together with the duration and required agency of the intervention. Such combinations of interacting individual behaviours are emergent population behaviour. In the examples, substantial long-term impacts required > 50% susceptibility and < 50% resistance.

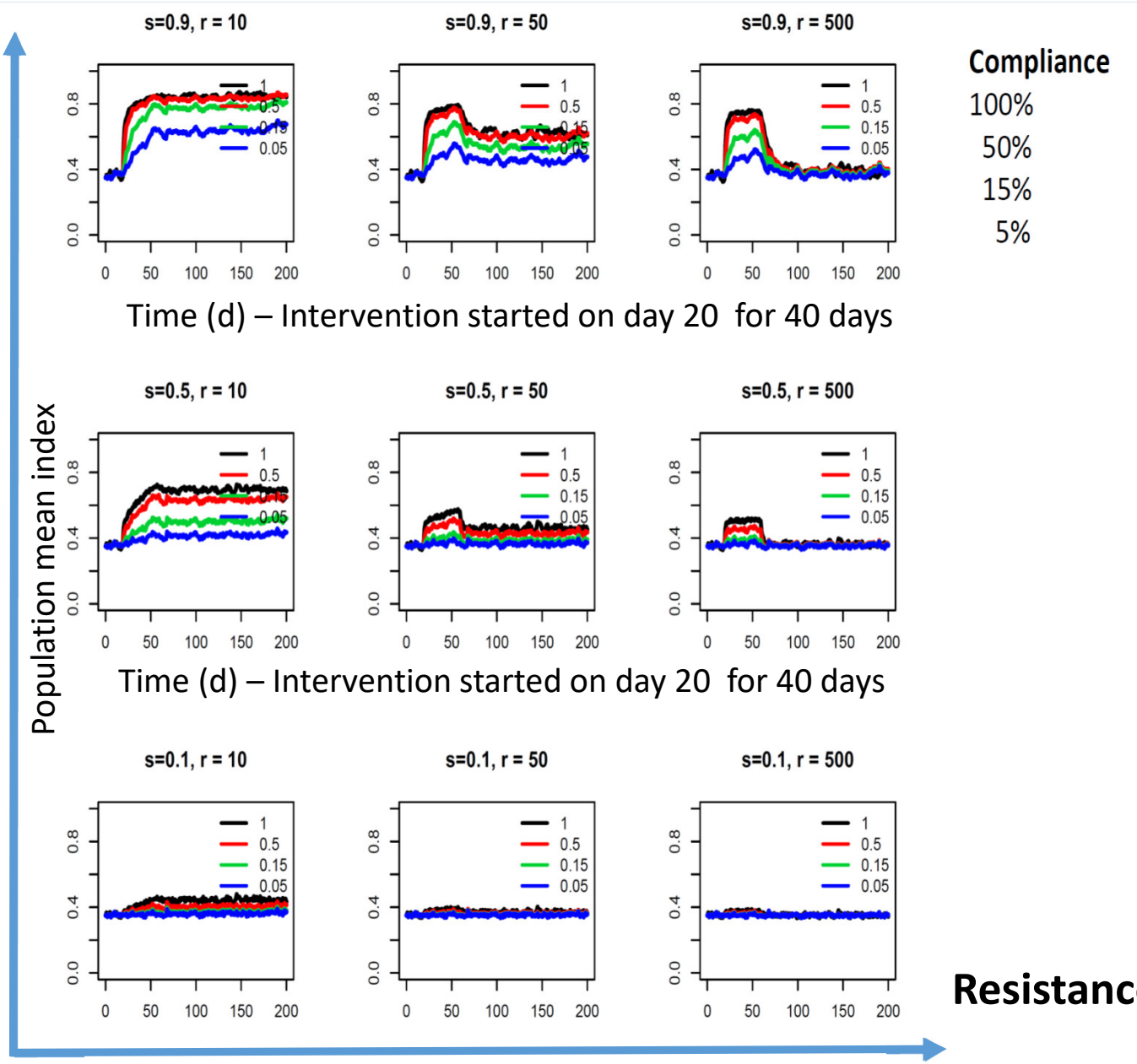


Fig. 2. How partial compliance affects the impact of an intervention across populations with differing susceptibility and resistance.

2 - Role of population compliance in the impact of interventions (Fig. 2)

How does partial rather than full population compliance affect intervention impacts?
How much non-compliance can be accommodated before undermining an intervention?

Partial compliance can cap the impact of an intervention, making substantial impacts unattainable. Susceptibility is the main determinant of this effect; hence, the level of non-compliance that undermines an intervention depends on the susceptibility.

https://en.wikipedia.org/wiki/List_of_vaccine_topics

The drop in impact increases nonlinearly with compliance; the system is more sensitive to low levels of compliance. Non-compliance reduces susceptibility to interventions in an analogous way that vaccination coverage reduces susceptibility to infectious disease and reduces epidemics.

Conclusion: Compliance can be critical to the impact of an intervention. The reduction in impact can be very moderate in the higher range of compliance, but highly variable and uncertain in the lower range of compliance. This behaviour may, therefore, have associated tipping point behaviour. In designing and assessing the feasibility of interventions, knowledge of the likely levels of compliance is essential to ascertain how far the real system will be from the optimal impact (Fig. 1).

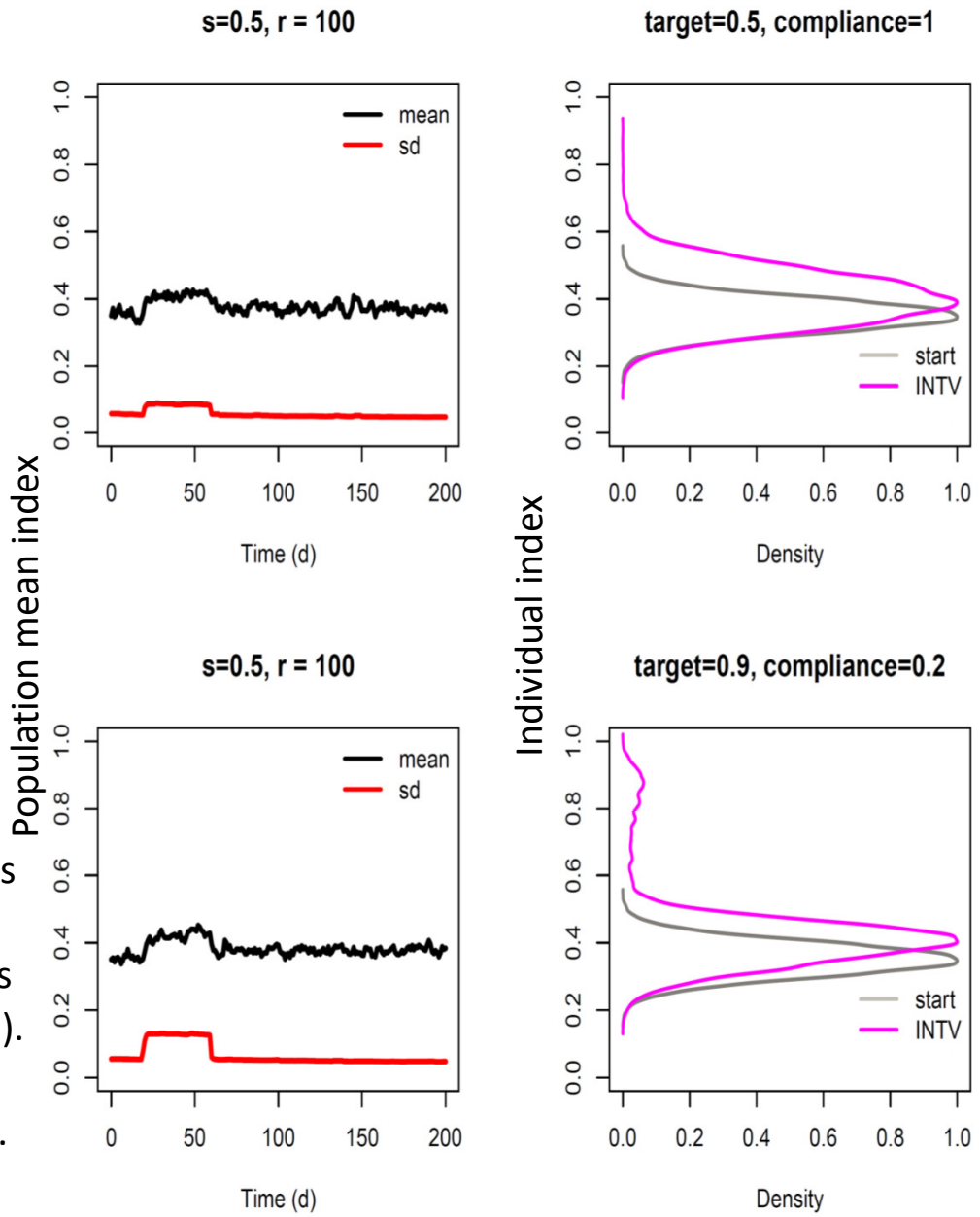
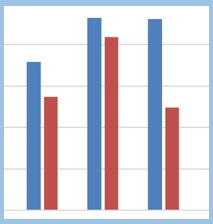


Fig. 3. Impact of interventions with low or high intensity: required agency (target 0.5 vs 0.9) and compliance (1 vs 0.2). Distribution of choice at the start and end of intervention.



3 - Response to interventions of differing intensity (Fig. 3)

We have shown the impacts of interventions on the average population choice. It is also useful to examine the distribution of choices, for example, when comparing the effects of interventions with differing intensity. Intensity relates inversely to the required level of agency, i.e. individual freedom of choice and personal responsibility to follow policy recommendation.

A high-intensity intervention, requiring low agency (low target 0.5) and high compliance (0.9), leads to a fairly equalitarian albeit modest improvement in choice for all.

A low-intensity intervention, requiring high agency (high target 0.9) and low compliance (0.2), yields a bimodal distribution with substantial, but local improvement . This local improvement suggest that, in a population with, for example, socio-economic or other structure where agency is associated with specific groups, the intervention would accentuate inter-group difference.

Conclusion: A low-intensity intervention, involving high agency and low compliance, can split the population into a large group of non-compliers that do not contribute or benefit from a change in choice, and a small group of compliers that contribute or benefit to a high degree. This outcome suggests that the intervention could aggravate social differences that correlate with agency.

https://www.nhsggc.org.uk/media/253299/scottish-diet-pdf.pdf

Take home messages

National policy

The Scottish Dietary Goals[1] describe the diet that will improve the health of people in Scotland and are used by officials to assess the current diet and direct policies that aim to improve it. For example, the Eatwell Guide is a translation of dietary recommendations[2]. However, since 1996 there has been little or no progress towards achieving the goals[1,3,4]. This outcome could be due in part to factors identified in this study and, therefore, it may be useful to investigate if some could be further investigated, leading to their measurement and potential use in policy design and implementation.

Implications from our findings

1 - Role of population susceptibility and resistance in the impact of interventions. It could be useful to measure the susceptibility and resistance characteristics in populations to ascertain the resources and feasibility of successful interventions, including duration required for lasting impact.

Take home messages (cont.)

https://www.foodstandards.gov.scot/consumers/healthy-eating/eatwell

2 - Role of population compliance in the impact of interventions.

Efforts should be made to anticipate and maximise likely compliance. In addition to persuading compliers to follow policy rather than norm, it would be important to also attempt to convert non-compliers, e.g. by averting known barriers like limited access to intervention information or logistics.

3 - Response to interventions of differing intensity. A low-intensity intervention, involving high agency and low compliance, while preserving individual freedom of choice and personal responsibility, could aggravate social differences that correlate with agency.

References

[1] https://www.foodstandards.gov.scot/downloads/Scottish_Dietary_Goals_-_Adapt_it_sheet.pdf

[2] https://www.foodstandards.gov.scot/consumers/healthy-eating/eatwell

[3]https://www.foodstandards.gov.scot/news-and-alerts/tackling-scottish-diet-at-heart-of-food-standards-scotland-new-5-year-strategy

[4] https://www.nhsggc.org.uk/media/253299/scottish-diet-pdf.pdf