
A Multi-Agent Based Simulation Model of Consumer Behaviour - Food Choice and Cooking Attitudes During the Coronavirus (Covid-19) Outbreak

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Abstract:

Purpose: The primary scientific goal of the article is to present the results of research which aimed to build a multi-agent simulation model of consumer behavior during the coronavirus Covid-19 epidemic. The research investigation concerned finding an answer to the question: to what extent did consumer eating behavior change during the pandemic, and how did the risk of becoming overweight and obesity increase?

Design/Methodology/Approach: To gain deeper insight into consumer eating behavior amid the Covid-19 outbreak, a survey on food choice and cooking attitudes was carried out in the West Pomeranian region of Poland. Four hundred twenty respondents took part in the survey. The data obtained was used to elaborate a multi-agent model created by the author and the execution of simulation experiments. A multi-agent-based modeling and simulation (MABS) method was used to build the model.

Findings: The research shows that among the individuals participating in the study, three types of eating attitudes were distinguished, restrained eaters (41.9%), emotional eaters (34.8%), and external eaters (23.3%). These three groups reported different behavior, highlighting, for example, an increase in ready-made and ultra-processed food consumption within the non-emotionally responsive group. Empirical data was used to develop an agent-based simulation model that combined different eating styles represented by consumers with their food and cooking habits to simulate consumer behavior during the Covid-19 epidemic.

Practical Implications: The findings could be helpful in support of practical and social solutions for the identification of excessive weight and obesity risk factors and the preparation of strategies aimed at reducing the influence of pandemics on consumer eating behavior and increasing consumer awareness on this issue.

Originality/Value: The study can stimulate sustainable consumption and consumer behavior, especially in light of the current Covid-19 pandemic.

Keywords: Consumer behaviour, food choice, cooking habits, multi-agent-based modelling, and simulation (MABS), Dutch Eating Behaviour Questionnaire (DEBQ), COVID-19 pandemic.

JEL classification: D12, C63.

Paper Type: Research article.

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1. Introduction

In December 2019, an acute respiratory disease caused by the SARS-CoV-2 virus began to spread all over the globe, becoming a pandemic and being declared an “emergency of public health” by the World Health Organization in January 2020 (WHO, 2020). The arrival of the COVID-19 pandemic was an exceptional situation that forced most consumers to change their behavior.

In March 2020, the first case of SARS-CoV-2 infection was diagnosed in Poland. National quarantine and restrictions, including small home working and education, harmed the bodyweight of Poles. Obesity is a serious socio-economic issue, and the pandemic exacerbated this problem.

To explain why some people gain weight and lose control of their food intake habits, three theories have been proposed to assess various aspects of the motivation to eat that could impair adequate food consumption and body weight control. These are psychosomatic theory (Bruch, 1973), externality theory (Schachter, 1964), and restrained eating theory (Herman and Polivy, 1980). Each of these theories has been subsequently linked to three predominant eating styles: emotional, external, and restrained eating (Van Strien *et al.*, 1986).

According to psychosomatic theory, those who need to eat can be triggered by emotion (fear, anger, or anxiety); those individuals cannot recognize this stimulus, and therefore they consume too many calories (Bruch, 1973). They are known as emotional eaters, and they often choose food high in fat and sugar and therefore tend to be at higher risk of diabetes and heart disease (Frayn and Knäuper, 2018). Eating while influenced by emotion is mainly related to negative feelings. Emotional eating is an atypical response to distress (Cebolla *et al.*, 2014; Elfhag and Morey, 2008).

In contrast to those influenced by internal emotional factors of the psychosomatic theory, externality theory focuses on the outside environment as a determinant of eating behavior. This eating theory emphasizes eating in response to food-related stimuli, such as the sight, smell, and taste of food, regardless of the internal state of hunger and satiety (Schachter, 1964). These eating behaviors are of particular relevance to those who are overweight or obese. Emotional and external eating can be considered problematic eating styles as they are associated with higher body weight and more unhealthy food intake, such as sugar-based foods, like confectionery (Elfhag and Morey, 2008). Emotional and external eating are highly intercorrelated (Dakanalis *et al.*, 2013; Van Strien *et al.*, 1986).

Restraint theory focuses on the possible psychological side effects, precisely a disinhibition effect (Herman and Polivy, 1980). Dieters suppress feelings of hunger through cognitive control, though if this cognitive control is disrupted, restrained eaters tend to eat more than non-dieters. This form of consumption is associated with

higher and lower body weight (Elfhag and Morey, 2008) and healthier food intake (Beiseigel and Nickols-Richardson, 2004).

It has been said that different consumer types can be identified depending on their eating style, “Emotional eaters” are those whose eating behavior changes depending on their emotional state, “External eaters” experience varying consumption behavior depending on external cues (intrinsic and extrinsic food properties and context, etc.), and “Restrained eaters” those whose eating behavior depends on their physical stage (e.g., weight) (van Strien *et al.*, 1986; Cebolla *et al.*, 2014). Because of the stress/discomfort situation caused due to the confinement of lockdown, some consumers may have behaved differently than usual, emphasizing their behavior related to their emotional or restrictive attitudes.

This research aimed to determine consumer perception of their own food choices and cooking habits through the lockdown period and identify potential food-related habits that could be seen as imprudent.

2. Methodology

The main goal of this research was to build a multi-agent simulation model to map consumer behavior during the Covid-19 pandemic. The critical characteristic of agent-based models is that they are decentralized. Multi-agent modeling and simulation (MABS) take a bottom-up view when producing a reflection of the natural world in the form of models. MABS focuses on individual behavior rules, which lead to the emergence of a global behavior model by studying a significant number of individual activities. Agents in consumer market models typically represent people (e.g., consumers or employees), companies, other organizations, or projects. Each agent has variables, parameters, and behaviors. A network of contacts between agents may exist, which is used to model communication, and there is a defined environment affecting the agents and being affected by them (Garifullin *et al.*, 2007).

Within this study, the research methods were made up of the following steps:

- The formulation of the research problem and the clarification of the modelling aim,
- A definition of the simulated environment within the studied area,
- A collection of empirical data - conducting the survey,
- The creation of a multi-agent model of the system to be analysed ,
- The initiation of the agent population,
- The creation of a graphical model (state diagrams) and a mathematical model,
- The execution of a simulation model,
- The validation and verification of the model,
- An analysis of simulation results and the formulation of conclusions.

The data that formed the basis for the creation agent behavior rule database was collected using the survey method. The three styles of eating behavior (restraint, emotional and external eating) can be reliably and validly measured using the Dutch Eating Behaviour Questionnaire (DEBQ; Van Strien *et al.*, 1986). The DEBQ is extensively used to assess eating behavior in normal-weight, overweight and obese individuals (Flament *et al.*, 2012; Goossens *et al.*, 2009). It is an internationally recognized measuring tool to gauge eating behavior - the DEBQ has been translated into many languages and has been validated globally (including France, Spain, Poland, Brazil, and China) (Bailly *et al.*, 2012; Cebolla *et al.*, 2014; Malesza, 2019; Wu *et al.*, 2016). The DEBQ consists of 33 items and includes a 5 point scale from "never" to "very often" (see Van Strien *et al.*, 1986, for a complete list of questions). To classify the eating style of the respondent, the scores of the items of the DEBQ belonging to the different categories were averaged, and the individual could then be classified about the mean values.

The second part of the questionnaire used in the current paper consisted of 27 statements related to food and cooking attitudes during the pandemic. A 5-point scale was used for the questions where; 1=completely disagree, 2=disagree, 3=neither agree, disagree, 4=agree, and 5=completely agree. Additionally, this part of the questionnaire included six questions relating to the frequency that food was ordered or cooked at home (before and during the pandemic) and two questions regarding the respondent's nutritional knowledge and a diet assessment during the pandemic. The last part of the questionnaire focusing on demographics, which included, among others, questions about age, gender, place of residence, education, employment, and household size.

A database of behavior rules was implemented in the agent population created from the statistical analysis of the collected empirical data. The answers given by the subjects of the Dutch Eating Behaviour Questionnaire and responses to the food and cooking attitude questions were analyzed with the application of a Hierarchical Cluster Analysis (HCA), using Euclidean distance and Ward's aggregation criterion. An HCA was conducted to identify different population attitudes further and connect these to food and cooking habits during the lockdown period. Three different clusters were identified:

- emotionally responsive (ER), with higher scores in statements related with emotional attitudes;
- non-emotionally responsive (NE), with significantly lower scores in statements related with emotional attitudes;
- self-controlling (SC), with higher scores in statements related with restrained attitudes.

These clusters were used as a factor in the 3-way ANOVA conducted to determine any differences among food and cooking habits during the pandemic. Significant differences ($p < 0.05$) were detected among the clusters. The last stage of the study

was to build a multi-agent simulation model of consumer behavior during the Covid-19 pandemic.

3. Results and Discussion

After analyzing the responses of the DEBQ as recommended by van Strien *et al.* (1986), consumers were divided into three groups according to their eating style. The largest group were those respondents who were categorized as Restraint eaters (41.9%). Emotional and external eaters represented 34.8% and 23.3% of the sample population, respectively.

Responses to the food and cooking habits questions enabled the identification of 3 different consumer clusters; ER (emotionally responsive, n=114, 27.1%), NE (non-emotionally responsive, n=98, 23.4%), and SC (self-controlling, n=208, 49.5%). Statements related to cooking engagement received significantly higher scores for respondents of clusters SC and ER. They were less valued by those belonging to cluster NE, who marked statements such as “My spending on ready-made food has increased” and “My consumption of highly processed products has increased” with significantly higher values than the other clusters. So, cluster NE could be considered a low-cooking-engagement group.

Clusters SC and ER were characterized by having higher food and cooking involvement, but a remarkable different attitude regarding health habits, cluster SC were highlighted by choice of foods due to their health value, going to local shops more often than supermarkets, and avoiding unhealthy attitudes, such as ultra-processed food consumption (only 5.7% of those asked claimed that their consumption of highly processed products had increased).

On the contrary, cluster ER was characterized by having unhealthier attitudes, maybe due to the lower emotional mood of respondents belonging to this cluster. Consumers of the ER cluster scored significantly higher statements relating to snacking, eating more often, increasing consumption of ultra-processed food, and stimulant drinks (coffee, tea, or energy drinks, etc.). Due to the different health-related attitudes, the SC cluster was seen as a group that focussed on their health, and the ER cluster group noted as the most emotional, having little regard for their health.

Consumers belonging to the Restraint eaters category planned their shopping list more carefully in the epidemic (40.9%). Despite the popularity of supermarkets, they also visited local stores (15.2% did not shop in supermarkets). 33.3% tried to do most of their food shopping online. When choosing food, they were guided by whether it was healthy (81.8%). They declared that their diet had not changed during the pandemic (53.0%), and they did not eat more often or more (84.8% and 79.3%, respectively). Only 10.6% ate more often between meals. They did not increase the consumption of highly processed products (81.8%). They slightly increased

stimulant drinks and alcohol (15.2% and 16.7%, respectively). Their behavior can mainly be classified as self-controlling. They preferred to cook new dishes. The vast majority did not like to share cooking information on social networks (83.3%). 74.3% assessed their nutritional knowledge as good and very good. They similarly perceived their diet during a pandemic (only 15.2% rated it as bad). Women constituted 56.8% of this group.

Equally, half of the consumers belonging to the Emotional eater's category planned their shopping list in more detail during the pandemic. They mostly shopped in supermarkets (90.9%), and 79.5% did not shop in local stores. They ate more often than before the pandemic (52.3%) and snacked more frequently between meals (45.5%). In this group, consumption of stimulant drinks (47.7% say that they consumed more) and alcohol increased (27.3% of respondents admitted to consuming more). Their behavior was primarily Emotionally responsive (46.6%). They spent more time cooking (54.5%) and found it enjoyable and could become a hobby (34.1%).

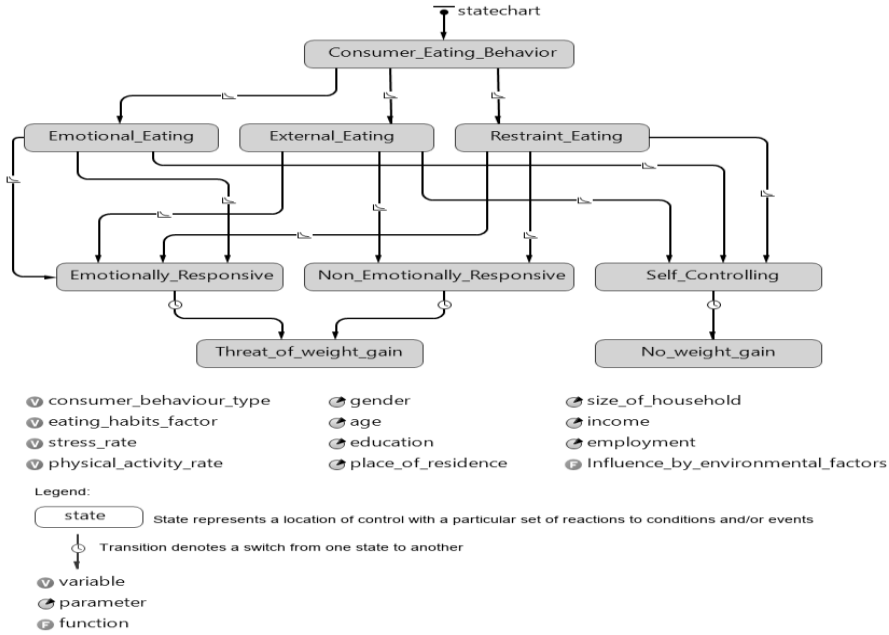
However, 70.5% preferred to be alone in the kitchen while cooking, saying that it is not an activity they wanted to share with their relatives, partners, or roommates. Most assessed their nutritional knowledge as good and very good (59.1%), but as many as 34.1% assessed their diet as bad during the pandemic. Women constituted 58.9% of this group.

Consumers belonging to the External eater's group increased their ready meals (46.2%) and increased highly processed products (28.8%). Only 42.3% chose food that was healthy (30.8% do not take this into account). They mostly shop in supermarkets (82.7%). They did not declare an increase in the volume and frequency of meals. Only 11.5% liked to cook and had discovered that it could be their hobby. Their behavior was most often classified as non-emotionally responsive (36.7%) and self-controlling (34.7%). Only 48.1% of consumers rated their nutritional knowledge as good and very good. 30.8% of this group of consumers assessed their diet as bad. The share of women and men in this group was equal (49.0% and 51.0%, respectively).

At the next stage of the research, based on the adopted multi-agent-based modeling procedure, a simulation model was created, consisting of two state diagrams. The first diagram included consumer eating behavior types, in this case for a consumer-agent (with transition rules extracted by statistical analysis), which were further divided into three types of food and cooking habits during the Covid-19 pandemic (Figure 1).

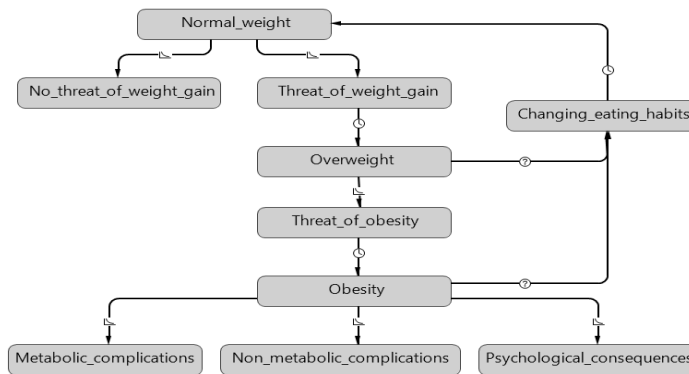
The second state chart contained an overweight/obesity cycle. The model presented here rests upon the notion that the initial body weight can factor in the mechanisms by which weight cycling might predispose people to increase their weight (Figure 2).

Figure 1. Main state chart of multi-agent simulation model of consumer behavior



Source: Own creation.

Figure 2. Overweight/obesity cycle state chart



Source: Own creation.

The basic concepts underlying this modelling of weight cycling from normal to being overweight rests upon several findings from our previous analysis of data from the questionnaire. These are summarized below:

- People with an initially normal body weight may be exposed to weight gain with certain probability.

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- The threat of weight gain in certain circumstances may result in becoming overweight, it may include possible stressful life experiences, worsening bad eating habits or decreased physical activity, etc.
 - Becoming overweight may result in the problem worsening over time and lead to the risk of obesity, though it can also lead to the individuals deciding to alter their eating habits (e.g. go to a diet) and return to their normal weight.
 - The threat of obesity in the long-term ends with obesity, which can lead to serious metabolic and non-metabolic complications, as well as psychological consequences. Obesity and its effects may also be factors that lead to a decision to change eating habits and lose weight, which in turn results in returning to a healthy weight for some individuals.
 - Returning to normal weight is not always permanent and periods of normal weight and overweight / obesity may occur throughout the individuals-life.

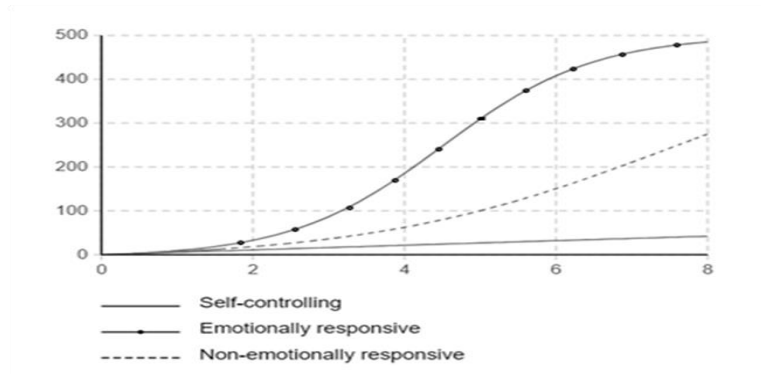
The behavioral rules of individual agents defined in this way enabled the author to construct a mathematical model. The next step of multi-agent-based modeling was a computer simulation, which meant activating a simulation model. Simulation results (so-called base flow) showing the behavior of a studied sample in time were compared with available knowledge regarding the sample (the questionnaire survey results), and the verification of the model took place. The model was verified until it satisfactorily reflected actual consumer behavior. The next step of the procedure was to simulate potential behavioral change effects in the agent (during this step, simulation experiments were conducted). The simulation results were subsequently statistically analyzed, and on their basis, charts illustrating the evolution of the chosen phenomena in time were generated.

Experiment 1: This experiment assumes that lockdown will begin after the second month. Consumers could be influenced by environmental factors, which will increase the risk of weight gain. These included: changes in eating habits and the type of food consumed, decreasing physical activity, and chronic stress. Figure 3 presents the simulation results for eight months. As can be seen below, the Emotionally responsive cluster was most exposed to weight gain, and the Self-controlling cluster was the least exposed.

Experiment 2: The stacked chart (Figure 4) shows the number of consumers at different stages of being overweight or the obesity cycle (simulation results for six years). According to the assumptions made, in 2021, there was an increase in the risk of an increase in weight resulting from the introduction of lockdown, which will increase the number of overweight individuals. Due to a significant reduction in physical activity (staying at home, studying, and working remotely), excess weight will rapidly turn into obesity. In the second half of 2021, it was assumed that the number of Covid-19 infections would be reduced to a controlled level, and there would be no need to introduce other lockdowns. In two years, the situation will improve, but there will be other waves of weight gain and weight loss in the following year's thanks to changing eating habits (the so-called yo-yo effect). The

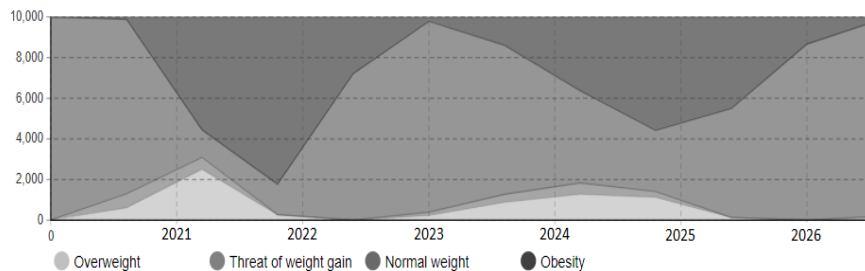
situation will only improve after 2026 - at that time, most individuals will return to their average weight.

Figure 3. Behaviour variation experiment results - Increased threat of weight gain



Source: The Author.

Figure 4. A stacked chart of the individuals states



Source: Own creation.

4. Conclusions

The present study provides an overview of the food-related behavior of the Polish population (the West Pomeranian region) during a period of confinement about the Covid-19 sanitary emergency:

1. An agent-based simulation model was developed in this research which combined different eating styles represented by consumers with their food and cooking habits to simulate consumer behavior during the Covid-19 epidemic. This could be used to explore how the consumers react to specific emergencies and how food consumption and eating and cooking habits can change at critical junctures.

2. This research attempted to apply agent-based model and computing simulation parameters to simulate consumer behavior in the context of the threat of weight gain, including both being overweight and obese. The research combined empirical data with a computer simulation technique to obtain the most reliable results.
3. Considerations presented in the article meant it was possible to conclude that a multi-agent-based simulation is one method that can be successfully applied to study consumer behavior.

Regarding the simulation model constructed following the suggested procedure, using an appropriate simulation system, it is possible to conduct a virtually unlimited number of experiments in a short period, enabling the study of the influence of many combinations of rules that are the basis of consumer decisions.

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