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NutriMine - A serious game modification for Minecraft to support people keeping a healthy diet

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***Abstract*—The escalating issue of obesity, a huge risk factor for contracting non-communicable diseases (NCDs), in industrialized countries necessitates innovative intervention strategies. Serious games designed to impart educational and transformative experiences have emerged as a potential solution. This research identifies the critical elements required for serious games to effectively influence behavioral change, specifically through a novel medium: a serious game developed as a modification for the popular video game "Minecraft." This modification was constructed based on identified requirements from a nutritional expert through a qualitative interview, and a preliminary evaluation was performed in a pilot study with eleven users. The results revealed a reasonable level of engagement with the serious game. On a scale of one to five, participants rated their diet confidence at an average level of 2.91. Satisfaction with their diet was generally average, with most participants rating it between three and four. Notably, a few participants acknowledged experiencing mental or physical health issues due to their diet. The participants' familiarity with video games, particularly Minecraft, was relatively high, with mean values of 3.82 and 3.72, respectively. These findings suggest that the novel serious game, implemented as a modification for the video game "Minecraft," has the potential to influence behavioral change and thus help prevent NCDs.**

***Index Terms*—serious games, nutrition, ncd prevention, behavior change, health promotion**

I. Introduction

Making conscious decisions about one's eating habits is not a trivial task. Switching to a healthy diet and especially sticking to it for an extended period feels challenging. This work tries to support a healthy diet by creating a serious game as a modification (mod) for the popular game "Minecraft" to support behavior change.

Following an unhealthy diet promotes overweight and obesity, a huge problem, especially in industrial countries. Both are huge risk factors for contracting so-called Non-communicable diseases (NCDs). NCDs are diseases that are not contracted via infections but are, according to the World Health Organization (WHO), a combination of genetic, physiological, environmental, and behavioral factors [1]. According to the WHO, 59% of adults living in Europe are overweight or obese. In Austria, the number of overweight people has also increased significantly, as was shown in a study by Gensthaler et al. about the trends of overweight and obesity in male adolescents [2].

Serious Games can be defined as games not designed solely for recreation but also for serious purposes. They are used in various scientific fields, including education and health, and usually comprise textual, graphical, and haptic elements and audio content [3]. Behavior change games (BCGs) are a subset of serious games. They are mainly designed to support attitudes and changing behaviors [4], [5] and have similarities to persuasive games [6]. Serious games are used in various domains and application areas. They can be used for prevention [7], hand rehabilitation support [8], [9], knee rehabilitation support [10], cerebral dysfunction [11], simulation and education [12], [13] and can even accompany novel sports devices [14], [15].

This work aims to create a serious game to help adults and adolescents stick to a healthy diet and change their eating habits. According to the state-of-the-art analysis conducted by the authors, some solutions addressing similar problems already exist, including "Foodbot Factory," a story-based serious game meant to educate Canadian children aged nine to twelve in nutrition [16], "FoodPyramidEscape," a serious escape game that teaches all stages of the Austrian food pyramid [17], Nutrition Garden, a gamified nutrition tracker [18], Helperfriend, a serious game designed to educate Mexican children on healthy nutrition [19], "fooya!" a mobile nutrition intervention game targeted at children [20] and "Squire's Quest" a serious game in the field of nutritional education [21]. Most analyzed games and applications focus on learning aspects, specially developed for children. Their gameplay is mostly

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linear, providing little motivation to return and play them again. Minecraft is a very popular game with a multi-million active player count [22], [23]. The game has a huge replaying value because of its several game modes and procedurally generated worlds. The multiplayer part also plays a big role in Minecraft's popularity. Because of those facts, the authors of this work believe that a popular game like Minecraft can be very effective with behavior change by keeping the player engaged for a long period and, therefore, propose a Minecraft mod to support behavior change regarding nutrition targeting, especially for adolescents and adults. The authors see adding serious game elements to a popular "leisure" game as a novel approach.

This paper is organized as follows. The second chapter will overview the comprehensive state-of-the-art analysis conducted and showcase the relevant work identified. The third chapter will provide an overview of the methodology used. The following chapter will present the results by describing the specified requirements and main game mechanics implemented in the prototypical modification. It will also show the results of the playtest that was conducted. The fifth chapter will discuss the results. The final chapter aims to conclude and gives an outlook on future work.

II. Related Work

As stated in the introduction, this research included a comprehensive state-of-the-art analysis. This chapter overviews the most significant projects evaluated and highlights their contribution and novelty.

Designed to educate children aged nine to twelve in Canada about nutrition, "Foodbot Factory" is a narrative-driven serious game. The project's focus on this specific age group was strategically chosen by a collaborative team of dietitians and teachers, recognizing the potential for the knowledge acquired during gameplay to establish a solid foundation for healthy habits during adolescence and adulthood. The "Foodbot Factory" narrative unfolds in a town where foodbots guide local villagers toward healthy dietary choices. However, when a malfunction occurs in one of these robots, two nutritional experts join forces with the player to embark on a knowledge-packed adventure in nutrition. The game's content is organized into five modules dedicated to a distinct nutritional topic. These modules, equivalent to levels, explore beverages, grain foods, vegetables and fruits, animal-based proteins, and plant-based proteins [16].

"Helperfriend" is a serious game crafted to teach Mexican children about healthy nutrition. What sets this game apart is its comprehensive approach, addressing not just food but also two additional dimensions: physical activity and socio-emotional behavior. In "Helperfriend," players take on the role of secret agents tasked with aiding children struggling with their dietary choices after an infamous chef erases their memory of a healthy lifestyle. Players must guide each child towards a healthful lifestyle by introducing them to the importance of physical activity, healthy nutrition, and socio-emotional well-being [19].

"Embodied Games for Learning, LLC" has developed a notable exergame, "Alien Health," designed to engage elementary school children. Utilizing the "Microsoft Kinect" sensor, this interactive game educates players on the nutritional profiles of everyday foods and the vital functions of the five major macro-nutrients. The primary goal is nurturing a foundling alien by making informed food choices. The game features four distinct modes: "Forced Choice" requires players to select the healthier option between two presented foods, transforming the alien's state from exhausted to super fit. In "Quick Sort," players must swiftly choose the healthier option in pairs of foods. The game concludes when all pairs are sorted, or a countdown timer reaches zero. "Build a Meal" challenges players to construct a three-course menu from provided food options, with healthier choices earning bonus shields for the alien's ship. "Ship Runner" involves steering the spaceship by jumping left or right to avoid collisions. This mode aims to collect coins and seeds while evading obstacles, which impact the shields obtained in the "Build a Meal" game mode. An evaluation involving 108 children revealed that playing Alien Health can effectively enhance the participant's short-term nutritional knowledge. However, the study indicated that these improvements lasted only a short time. Additionally, no discernible changes in eating and consumption behavior were observed due to engaging with "Alien Health" [24].

"Nutrition Garden" is a mobile application developed collaboratively involving field experts and members of the target user group. This app promotes healthy eating habits by emphasizing fruits, vegetables, nuts, seeds, and fish oil. The main goal is to mitigate Non-Communicable Diseases (NCDs) while enhancing users' understanding of nutritional science. Integrating gamification elements aims to support user motivation over an extended period. Simultaneously, the app employs a focused approach by curating specific food items, presenting what the authors consider a substantial strategy for a mHealth application within nutritional science [18].

"Food Pyramid Escape" is a project offering potential benefits for health promotion in Austria and on a broader scale. It is a serious escape game strategically designed to impart nutritional knowledge through a cohesive narrative, diverse riddles, and engaging mini-games, catering to a diverse audience. This game can serve as an independent nutrition intervention method or seamlessly integrate with supplementary informational resources and workshops for more extensive intervention initiatives [17].

"Squire's Quest" has proven to be a highly successful serious game in nutritional education, positively impacting many students. Developed by the Child Nutrition Research Center in 2000, this educational game was specifically crafted for fourth-grade students in elementary schools. The game revolves around supporting the besieged king and queen of the kingdom of "5Alot" and comprises ten sessions, each lasting 25 minutes. Faced with the threat of enemies seeking to destroy the kingdom's fruit and vegetable crops to weaken its rulers, players support the knights in their fight against the villains. This support is achieved by preparing healthy meals

from fruits, vegetables, and juice in a virtual kitchen. The game's primary goal is to encourage participants to increase their consumption of fruits. In an experiment involving 1578 students, on average, those who engaged with "Squire's Quest" consumed one additional portion of vegetables and fruit. The success of the initial game led to the release of its sequel, "Squire's Quest 2!" in 2009, which was considered an improvement. The sequel primarily expanded the narrative and incorporated over 60 minutes of cut scenes. Both games are rooted in the social cognitive learning theory [21].

"Fooya!" is a mobile nutrition intervention game targeted at children focusing mainly on implicit learning. The game was designed as an action game where the player steers an avatar fighting robots representing different food items considered unhealthy. Children should implicitly memorize the robot's food items as "bad" or "unhealthy." The game features 80 levels with increasing difficulty to keep the player engaged. Another game mechanic will change the player's avatar by consuming specific food items. For example, if the avatar eats large portions of unhealthy food, the body shape will change, and the movement will also be affected. Destroying enemies will earn the player coins that must be collected to finish levels within the game. The effectiveness of "fooya!" was tested in a study with 104 children aged 10 to 11, showing positive results [25].

Many analyzed serious games and gamified applications focus solely on children or teenagers. Their main goal is to teach and increase nutritional knowledge playfully. Also, except for the application "Fooya!", these games can be described as linear, meaning that the user plays through a predefined story from start to finish.

III. Methodology

The methodology of this work consisted of four phases. First, a comprehensive literature review and state-of-the-art analysis were conducted to find current solutions and identify the baseline for the following steps. The second phase interviewed a nutritional expert to gather further information about healthy nutrition, especially obesity interventions. The interview partner was female, 53 years old, and a nutritional science and therapy expert.

Within this phase, requirements were derived based on the interview, which were used for an initial concept. The third phase consisted of finalizing the concept and developing the prototypical modification for Minecraft. An extensive playtest and evaluation of the prototypical modification were conducted within the final phase.

To evaluate the Minecraft mod developed for this study, a select group of individuals played the mod and shared their feedback. Post-gameplay, they were asked to complete a survey covering various aspects, including demographic information, the mod's impact on their gameplay behavior, and any new learning or behavioral changes resulting from the mod. The survey used a Likert scale, with statements related to their experience with the Minecraft mod and changes in nutritional behavior. Participants were asked to rate their level of agreement on a scale of one (strong disagreement) to five (strong agreement).

A total of 11 individuals responded to the survey. Demographically, all but one participant was between 16 and 30 years old, with one participant being over 45 years old. The group consisted of nine males and two females. Educational backgrounds varied: five had completed high school, five held a bachelor's degree, and one had a master's degree. Dietary confidence scores ranged widely, with an average of 2.91. Regarding diet satisfaction, six participants rated it a three out of five, while five rated it a four. Three participants reported experiencing mental or physical health issues related to nutrition. The average score for general video game experience was 3.82, with specific experience in Minecraft averaging 3.72.

IV. Results

The state-of-the-art analysis and the interview with a nutritional expert led to a handful of requirements that were part of implementing a successful behavior change serious game. These included providing fun and challenging game mechanics, clear goals, rewarding desired behavior, giving players cues on their behavior, and simulating the consequences of healthy and unhealthy diets. These requirements were then transformed into a prototype of a modification for the popular computer game "Minecraft." Within that game, the player controls a character from the first-person view placed in a fully interactive 3D world of blocks created using a special retro pixel art style. Core game mechanics include collecting resources and crafting objects out of them, e.g., wood can be harvested and later used in preparing wooden tools and weapons. A second major game mode is "survival." In this mode, there is a day-night cycle. At night, hostile creatures will spawn that attack the player, who must defend themselves using weapons crafted from the abovementioned resources. A food strategy is already built into the core game, a so-called "hunger system," where the player needs to consume various food items to survive. However, as it is a very rudimentary nutrition model, the authors believe it should include essential aspects of diet and health. It does pose a challenge for the player but does not educate the player about nutritional information nor aims to improve dietary behavior. The "hunger system" within Minecraft is one of the major aspects this work is trying to improve.

The developed modification for Minecraft incorporates the following core features:

- Adding relevant food items and nutritional data.
- Grouping food items according to the German food pyramid.
- Tracking of food consumption from the food groups.
- Calorie and weight tracking (abstract weight classes within the game were also defined).
- Adding positive and negative in-game effects from consuming specific food items within the game (e.g., gaining +1 health when consuming vegetables and fruits or decreasing movement speed when the game character becomes overweight).

TABLE I
REQUIREMENTS

Req. #	*Description*
R01	Is an adaptation of an existing game
R02	Does not interfere with base game mechanics excessively
R03	Provides fun and challenging game mechanics
R04	Provides clear goals
R05	Rewards desired behavior
R06	Is not overly complex
R07	Gives players cues on their behavior
R08	Simulates consequences of healthy/unhealthy diet

- Improvements in the difficulty system of Minecraft.

The finished prototype was evaluated by a group of 11 participants between 16 and 45 of age. The mean time of playing the modification was about 70 minutes. Even though a substantial change in nutritional behavior could not be observed after one session, all participants stated that they believed the modification could change their dietary behavior over an extended period. The mod helped most participants to think about their diet more actively, and many learned some new aspects about how nutrition can impact the human body.

A. Requirements

As described in section III, different methods were used to identify the requirements for the initial concept. Eight requirements have been determined through a comprehensive literature review and an interview with a nutritional expert. The derived requirements can be seen in table I.

B. Game Concept

The following section describes the concept for the developed Minecraft modification, starting with an explanation of Minecraft's nutritional model and continuing with a detailed explanation of changes made to promote a better diet among adults and adolescents.

As already described in section I, the developed serious game is based on the popular game Minecraft, which has been modified to support behavior change. In general, Minecraft's hunger and food system is not intended to provide nutritional information or to improve behavior, as it ignores essential aspects of a healthy diet. For example, players can survive by only eating cakes in the game or eating foods that would lead to severe poisoning in real life (e.g., raw meat). Therefore, the nutritional concept of the game has been modified. The focus was laid on preventing weight gain and supporting overweight individuals. The player's in-game diet now has a significant impact on the game. If a player consumes excessive calories on an in-game day, the unhealthy nutrition causes the avatar to gain weight. It leads to various in-game effects, such as decreased movement speed. However, it is not only the number of calories that is decisive. In order to maintain a healthy diet, the quality of the food consumed and its nutrients play a significant role, which is why the nutritional values, as well as the calories of the consumed food items, are monitored. The German food pyramid is used to evaluate the player's diet. The pyramid consists of seven food categories, to which the Minecraft food items were assigned based on nutritional attributes. For the state of simplicity, every food item was assigned to one food group only. Additionally, food items that do not help to promote responsible dietary habits and do not exist in real life, except sweet berries, were removed from the list of consumables. Furthermore, a new food item, pecan nuts, was created and added to the game since no food item suitable for the pyramid category "fat and oil" existed. An overview of the food items used in the game can be seen in table II.

TABLE II
FOOD CLASSIFICATION

Category	*Food*	*kcal/100g*	*Portion (g)*
Drinks	Water	0	250
Animal Products & Alternatives	Cooked Chicken	204	300
	Cooked Cod	105	300
	Cooked Mutton	309	300
	Cooked Porkchop	265	300
	Cooked Rabbit	197	300
	Cooked Salmon	206	300
	Rabbit Stew	121	300
	Cooked Beef	306	300
Bread, Grain & Sides	Baked Potatoe	93	150
	Bread	245	100
Dairy	Milk	60	300
Extras	Cake	323	1000
	Cookie	487	50
	Honey Bottle	314	20
	Pumpkin Pie	210	200
Vegetables & Fruits	Apple	52	150
	Beetroot	43	150
	Beetroot Soup	43	300
	Carrot	40	150
	Dried Kelp	200	50
	Melon Slice	30	150
	Mushroom Stew	56.6	300
	Sweet Berries	68.5	150
Fats & Oils	Pecan	691	60

Throughout an in-game day, the system keeps track of how many food items from each of these seven categories have been consumed and provides an overview of the players eating behavior at the end of each in-game day. Players can see their consumption rates for each food group in the newly implemented GUI, as shown in figure 1.

Adhering to the recommended consumption of essential foods positively affects the players, while excessive or insufficient consumption of certain food groups leads to negative effects. Positive applied effects would be "Haste" (increased mining speed), "Strength" (greater attack damage), and "Absorption" (four permanent health points). Additionally, five new in-game effects have been implemented, as shown in table III. The "Veggie and fruit rush" effect will be applied if the player consumes the fifth food from the "vegetables and fruit" group of the food pyramid. The added effects will come into force if the player reaches the BMI classifications overweight or obesity type I-III. Some of the new in-game effects applied to the avatar can be seen in figure 2. The player moves up a weight class if a calorie surplus is detected. Conversely, if a player reduces his calorie intake, his weight class is reduced

Fig. 1. Newly implemented GUI showing the player an overview of the eating behavior summarizing an in-game day.

TABLE III
NEW IN-GAME EFFECTS

Effect name	*Description*
Overweight	20% decreased movement speed
Obesity type I	30% decreased movement speed
Obesity type II	40% decreased movement speed
Obesity type III	50% decreased movement speed
Veggie and fruit rush	30% increased movement speed, and 30% increased attack for five minutes

by one class. The weight class with which the player starts the game depends on the selected start mode. Minecraft's inherent difficulty system has been adapted for three different starting scenarios. If the player chooses the hard mode, the game starts with a weight class of eight (BMI category: obesity type I), the normal difficulty level starts with a weight class of four (BMI category: normal), and the peaceful mode sets the player's weight class to zero (BMI category: normal).

Fig. 2. Applied "Overweight" and "Veggie & Fruit Rush" effects

Prompts have been implemented to provide feedback to the players on their diet behavior of the previous day. These notifications are displayed in the chat window, as seen in figure 3. The prompts provide information on the food pyramid categories in which the amount consumed was too much or too little. In addition, compliments are made if the player adheres to a healthy diet.

Fig. 3. Prompts provide feedback on the player's diet of the previous day.

C. Evaluation

In the playtesting phase, participants engaged with the mod for an average of 70 minutes, ranging from 30 to 120 minutes. Generally, players found it straightforward to manage their character's hunger. The modification influenced their resource management strategies, emphasizing farming and food preparation. Preferences emerged for certain foods, with apples, carrots, and other fruits and vegetables being favored by eight participants, while steak, bread, and milk were less popular. Conversely, foods like cookies, meat, and cake were often avoided.

The average enjoyment rating for the mod's added complexity was 4.18. This complexity also prompted reflection on dietary habits, as indicated by an average agreement score of 4.09 to the statement, "The mod made me think about my diet." While a direct change in nutritional behavior was not immediately evident, with an average score of 3.09, all participants believed in the mod's potential for long-term behavioral change.

Participants reported learning new aspects of nutrition, such as the benefits of good nutrition, the need for reduced meat consumption, and appropriate food portion sizes. Game mechanics like the veggie and fruit rush effect, the caloric system, and the diet user interface were noted for their positive influence on behavior. However, some aspects were considered cumbersome or impractical, such as the need to drink liquids, rapid weight gain, difficulty losing weight, and the inability to consume raw meat.

V. DISCUSSION

The presented research within this paper proposes a novel modification for the popular game Minecraft that supports people's adherence to a healthy diet and lifestyle. A key outcome of the study is that the mod enhances the Minecraft gaming experience by introducing enjoyable game mechanics, indicating its potential for voluntary play in an informal, serious game context. Additionally, participants believe that extended gameplay could positively impact nutritional behavior. The most effective game mechanic for behavior change was the positive reinforcement of healthy choices, particularly through the veggie and fruit rush effect. Another notable aspect was the improvement in the character's health when adhering to dietary guidelines, further emphasizing the mod's effectiveness in positive reinforcement.

Beyond influencing behavior, the serious game prompted many players to reflect on their dietary habits. This reflection is a significant achievement, as considering and evaluating one's diet is crucial for better nutrition. The authors believe the modified version could be quite effective since Minecraft is a very popular game due to its "sandbox" nature, low entry barrier, and focus on entertaining the player. In contrast, more traditional serious games like "FoodPyramidEscape" were designed as supplement measures and should normally be played as part of a therapy or intervention [17].

VI. Conclusion and future work

The study suggests that further research with a larger, more diverse group over a longer period and a more detailed questionnaire is needed to fully assess the mod's effectiveness in altering nutritional behavior. Enhancing the mod with more content and mechanics, such as a wider variety of food items and additional consequences for dietary choices, could increase its impact. Adjusting the mod's difficulty level to provide tailored feedback and information could also improve its effectiveness.

However, the study's limitations must be considered, including a small participant pool and short duration. Most participants did not report adverse dietary effects on their health, limiting insights into the mod's impact on such issues. Despite these limitations, the study indicates the mod's potential to make players more mindful of their diet and nutrition, especially if used over longer periods and with other interventions. Further development and testing are necessary to confirm its actual behavioral influence.

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