# A Serious Game for Nutritional Education of Children and Adolescents with Neurodevelopmental Disorders

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**Abstract.** Children and young people with neurodevelopmental disorders seem to be more susceptible to developing obesity and eating disorders. To prevent this, therapeutic programs including nutritional education are, therefore, needed. Serious games (SGs) represent a promising solution to improve adherence to the treatment in different populations, including children/adolescents with Attention-Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD). The present paper describes the design and development of a SG to promote a healthy diet and lifestyle. To the best of our knowledge, this is the first SG specifically focused on nutritional education developed for young individuals with ADHD or ASD. The SG is made of four mini-games contextualized within a single narrative frame. Through his/her avatar, the player has to challenge four opponents, one for each educational topic, with the help of a wise character that educates him/her throughout the story. The SG can be experienced with a tablet or a PC, and with the supervision of an adult. A pilot study will be carried out to evaluate the feasibility, engagement, and usability of the SG, involving children with ADHD, ASD, and a group of typically developing peers. Based on the results, some adaptations will be implemented to improve the SG before conducting a larger trial to evaluate the effectiveness of the SG in promoting a healthy diet and lifestyle.


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# 1 Introduction

## 1.1 Background and Significance

Attention-Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD) are among the most common neurodevelopmental disorders in childhood, affecting 8.4% of children (in the case of ADHD) [1] and 1.8% of children in the case of ASD [2]. ADHD is characterized by impairing symptoms of inattention and/or hyperactivity and impulsive behavior, hampering the child's development. ASD presents a constellation of early-appearing social communication deficits and repetitive sensory-motor behaviors and it is associated with a strong genetic component (and other causes).

Literature suggests a significant association between both ADHD and ASD and obesity [3, 4] and an increased risk of developing eating disorders [5] due to abnormal eating patterns, sedentary lifestyle, and possible common genetic alteration. Diet plays a crucial role in physical and mental health, especially for growing children, and some studies suggest a healthy diet can help in ameliorating symptoms of ADHD and ASD [6, 7].

Serious games (SGs), based on technologies of video-gaming, have been proposed for the assessment and treatment of ADHD and/or ASD [8, 9]. It could be expected that children with ADHD and ASD present difficulties engaging with video games due to their shorter attention span; however, children with ADHD and ASD can focus for long periods of time on activities they enjoy, a phenomenon referred to as hyperfocus [10]. SGs are therefore a promising tool to enhance engagement and motivation and promote adherence to therapeutic interventions.

According to these premises, the goal of the SG described in this paper is to educate and encourage healthy eating in children with neurodevelopmental disorders in an engaging way, consequently promoting symptoms amelioration and overall health. The SG is designed considering the needs of the specific target population, such as short attention span and need of positive-feedback to increase motivation.

## 1.2 Related Works

Two recent reviews of SG interventions for children with neurodevelopmental disorders [8, 9] reported that the main type of intervention for ADHD children was cognitive training, i.e. a series of tasks aimed at improving executive functioning, such as attention, working memory and reaction time. Most studies used a PC as a platform, with a minority using a tablet or Xbox Kinect. SGs for children with ASD are aimed at assisting them in acquiring emotional competencies [11] or promoting reading skills [12]. Therapeutic interventions based on SGs were well accepted and generally effective in improving cognitive functions and ameliorating ADHD/ASD symptoms. This appears to be due to the mechanism of *gamification*, which enhances children's engagement and possibly promotes neuroplasticity. Despite this, Peñuelas-Calvo et al. [8] identified some limitations of currently available applications and suggested strengthening the collaboration

between developers and healthcare professionals to further improve the potential of this technology.

In the field of nutritional education, many mobile applications and games have been developed for typically developing (TD) children and adolescents: to increase vegetable consumption [13], to teach about digestive health [14], to encourage healthy eating [15, 16], to improve the measurement of their food consumption [15]. SGs were generally well accepted and effective in increasing children's knowledge about healthy diet and lifestyle, however, the limitation of these studies is that only short-term effects are assessed, which means it is not known whether the positive effects will be maintained in the longer term.

To the authors' knowledge, no SG for nutritional education of children or adolescents with ADHD/ASD has been previously developed.

## 2 The Serious Game "Captain Chomp and the Great FoodAdventure"

### 2.1 Design

The design process was carried on throughout a collaboration between biomedical engineers, neuropsychiatrists, psychologists, nutritional experts, and designers. All these professionals collaborated to define the characteristics of the SGs to develop, in terms of graphics, educational content, and interaction. The definition of requirements took place through brainstorming sessions during which collaborative design tools, in particular Figma[1] and Miro[2], were used to support the creative process. Indeed, the process of developing a serious game for a fragile category of users takes seriously the focus on the usability concept, i.e., how easy a System Interface (SI) is to use. Factors to consider in order to achieve usability are Effectiveness, Efficiency, Satisfaction, Learnability, Memorability, Low Error Rate and Cognitive Load; the category of final users, their characteristics, their need, and their preferences; what type of goal needs to be achieved while using the app, and finally the context of use [18–20].

The target users are 6–16-year-old children and adolescents with ADHD or ASD, as well as their parents, who are the primary gatekeepers to children's food intake. The SG is designed for the parent and child to use jointly, either in the clinics or at home, according to the therapeutic path defined by the clinical personnel. The SG has been developed in Unity and deployed for Windows OS personal computer and Android OS tablet, to accommodate the devices already available in children's homes.

The SG "Captain Chomp and the Great FoodAdventure" consists of four different mini-games, which have been framed in the same narrative. The child chooses an avatar and follows the adventures of "Captain Chomp", a positive leading character, defeating four enemies and learning lessons about food and healthy diet along the way. The player starts from the first mini-game, and as the levels are completed, the following mini-games are unlocked. A schematic wireframe of the SG structure is presented in Fig. 1. Each mini-game covers a different topic: food categories, the food pyramid, the

[1] Figma: the collaborative interface design tool. https://www.figma.com.

[2] https://miro.com.

importance of physical activity, and the Healthy Eating Plate, recommended by Harvard University [21]. A more detailed description of the content of each mini-game is provided in Sect. 2.2.

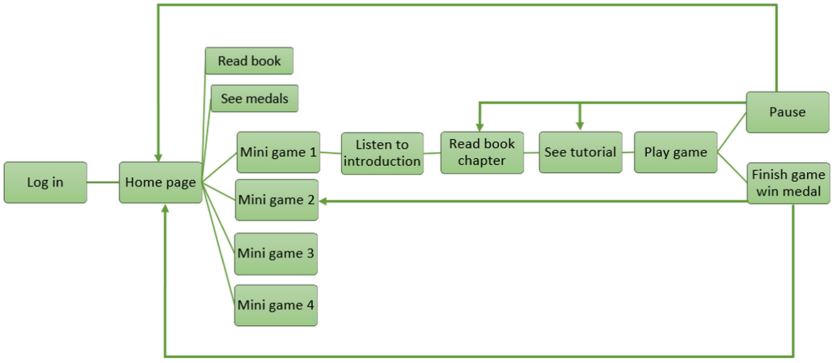


**Fig. 1.** Wireframe of the Serious Game structure. After the log-in, the user is directed to the home page, where he/she can read the educational content, or see the medals he/she has won, or go to one of the mini-games. Before playing each mini-game, the user listens to an introductory explanation, reads the educational content related to the nutritional topic and sees the tutorial. During the game, the user can pause the game to go back to the home page, or review the book or the tutorial. When the user finishes the mini-game, he/she wins a medal, and can either play the following mini-game, or go back to the home page.

The graphics of the SG have been developed focusing on the needs of the target audience. The graphics are 2D, simplified, with flat colors following the wide list of characters liked by children analyzed during the research phase, such as *Peppa Pig*, *La Pimpa*, etc. The leading character, the four enemies, and the avatars are drawn with the same style and technique (see Fig. 2), with four available options for the avatar (male/female, white/dark skin), to help player identification of the child [22].

On the other hand, to display the food, we chose 3D realistic images to promote the transfer of the knowledge acquired during the use of the SG to the real world. We selected more than 200 food images, from different countries and cultures.

In order to simplify the learning process, each mini-game provides a tutorial where gestures and tasks are shortly introduced. We expect this feature to maximize the Learnability and Memorability process, consequently reducing the possibility to commit errors (Low Error Rate). By adding a recorded audio clip to each written message, we aimed to keep the attention level high and increase Efficiency (resources expended to achieve the goal).

To further promote Learnability, we collected all the diet-related information in a unique and easily-findable place. A dedicated section of the app, "The Book of Captain Chomp", gathers educational content about each of the four topics, with short sentences and images. The child needs to read the corresponding pages of the diary before playing a game; such pages are available throughout the whole game as well. During each mini-game, educational information is delivered through short messages. As reinforcement improves cognitive performance, especially in children with ADHD/ASD [23,

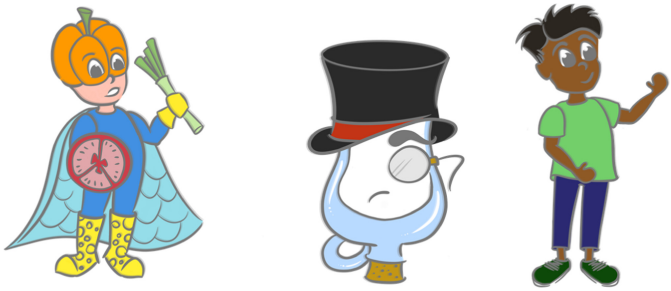

**Fig. 2.** The leading character, "Captain Chomp", the enemies and the player avatar are designed with 2D, simplified graphics.

24], we focused on positive, encouraging messages throughout the mini-games, instead of penalties. If the player makes a mistake, a different message is displayed based on the gravity of the error: a "yellow light" if it's a minor error, a "red light" if it's more serious. Moreover, after completing each game, the players win a medal, and they are encouraged to complete the four mini-games to collect all the medals: this is expected to increase Effectiveness and Satisfaction. In order to reduce the Cognitive Load, children are expected to use the app in a focused environment, sitting in front of the PC or with a tablet, with the supervision of an adult, who is supposed to help them with the educational content, and at the same time learn with them.

Importantly, the SG communicates a *flexible* food culture underlining the importance of varying diet, i.e. there are no strict rules or banned food, but food that should be eaten more or less often. This first version of the SG does not include specific diets for each individual, e.g. vegetarian or vegan diets or allergies have not been considered. Instead, the content has been selected to adapt to the most widespread diet in Italy, i.e. the Mediterranean diet.

### 2.2 Development

As previously mentioned, the SG is composed of four mini-games: "Food in the Cart", "Playing with Pyramid Blocks", "Fit and Healthy", "The Food Puzzle, the Fuzzle" (Fig. 3). For each game, the application generates a report file (XML format) including information on the child performance. In particular, information about the player (age, sex, traditional cuisine), total playing and reading time, and the performances of each mini-game (completion time, number and type of errors) are included.

**Food in the Cart.** The goal of the first mini-game, "Food in the Cart", is to learn to recognize which nutritional category the foods belong to. In the first level there are 10 carts, each labeled with a category: fruit and vegetables, meat and fish, legumes, tubers, oils and fats, cereals and derivatives, milk and derivatives, eggs, sweets and packaged foods, and water (see Fig. 4). In the second level, the two categories of carbohydrates and proteins are introduced. One food at a time is shown, and the child needs to drag and drop it into the correct cart. Twenty foods need to be correctly placed in their corresponding cart to complete the level. Such foods are picked from a pool of over 200

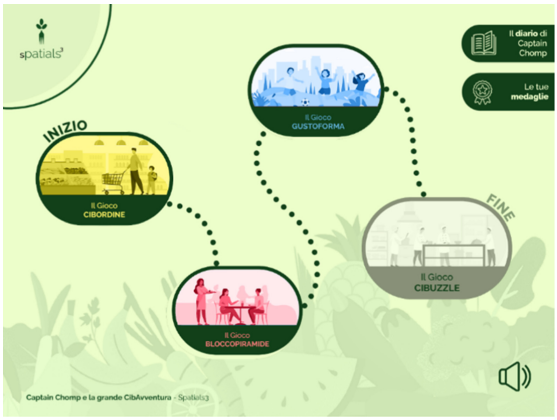


**Fig. 3.** Screenshot of the Home Page of the Serious Game, when the player has unlocked the third mini-game by completing the first two. The fourth is still locked. Each mini-game has a different color and graphic. On the upper left, the logo of the project, on the upper right, the player can visualize the medals he/she has won already and read the educational content.

elements, in a pseudo-random way (e.g. there are always 3 items belonging to the "fruit and vegetables" category, 2 items of the "legumes" category, etc.). When one food is correctly or incorrectly placed, a message is displayed, congratulating or encouraging the child to retry, and giving further information about "tricky" food (e.g. "*Potatoes are not vegetables, as you might think, but belong to the tubers family. They provide carbohydrates and must be eaten after cooking.*").

**Playing with Pyramid Blocks.** The goal of the second mini-game, "Playing with Pyramid Blocks", is to learn about the Food Pyramid and how often we should eat some foods. The Food Pyramid is a visual representation of how different foods contribute towards a healthy balanced diet. The Food Pyramid organizes foods into 5 blocks, starting from water and physical activity at the base of the pyramid, and decreased advised frequency of consumption in the upper blocks ("every meal", "every day", "twice a week or more", "twice a week max", "the least possible") [25]. The game has 3 levels of increasing difficulty. In the first level, the pyramid is full of food, and the child has to choose the correct food item between three options, and insert it in the highlighted pyramid block. In the second level, one block of the pyramid is empty, and the child has to select the food item belonging to the empty block. In the third level, the pyramid is empty, and the child has to drag and drop the food items on the correct blocks (see Fig. 4). Every time a food is placed, a congratulating or encouraging message is displayed, suggesting to the child if that food should be eaten more or less frequently.

**Fit and Healthy.** The goal of the third mini-game, "Fit and Healthy", is to take a break from the educational content while conveying the information that physical activity is important for our health. The child's avatar is running in a field, and the child has to make it jump – by tapping on the screen or clicking the mouse – to avoid the enemy, "Chef Atica", a chubby and lazy chef (see Fig. 5).

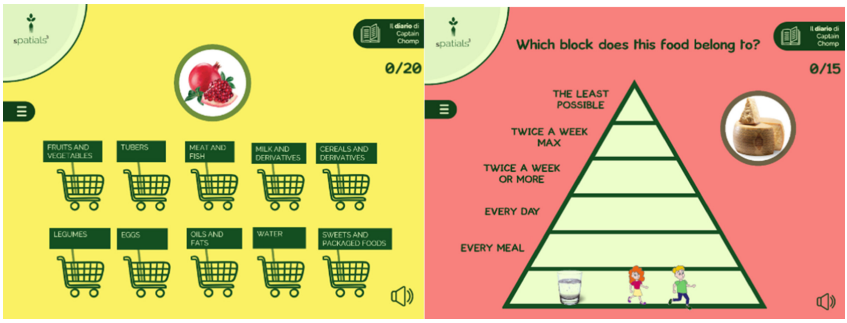


**Fig. 4.** On the left: Screenshot of the first mini-game, "Food in the Cart". An image of a food, e.g. a pomegranate, is displayed, and the child has to drag and drop it in the cart labeled with the category the food belongs to, e.g. "Fruit and Vegetables". On the right: Screenshot of the third level of the second mini-game, "Playing with Pyramid Blocks". The child has to drag and drop the food, i.e. parmesan cheese, in the correct pyramid block, i.e. twice a week max.

**The Food Puzzle, the Fuzzle.** The goal of the fourth mini-game, "The Food Puzzle, the Fuzzle", is to recognize and learn how to compose a Healthy Eating Plate. The Healthy Eating Plate is a guide for creating healthy, balanced meals: ½ of your plate should be vegetables and fruits, ¼ whole grains and ¼ protein [26]. In the first level, the child can choose the healthy plate from three options. While one of the incorrect options is "almost correct", with 2 food items out of 4 belonging to the same category, the other one is unbalanced, with 3 food items of the same category. The plates represent balanced main meals, as well as breakfasts and snacks. In the second level, an empty plate (accompanied by a glass of water and a bottle of oil) and 12 random foods are displayed: the child needs to compose a healthy plate with 4 food items (see Fig. 5). If the child chooses a plate with 2 food items of the same category, a "yellow light" message is displayed, while with 3 food items of the same category a "red light" is displayed, explaining the error and encouraging the child to try again.

## 3 Protocol of the Pilot Study

At first, in order to evaluate the feasibility and the engagement related to the SG "Captain Chomp and the Great FoodAdventure", the research group will present it to a small number of children and adolescents.

Participants with a diagnosis of ADHD and/or ASD, according to DSM-5 criteria [27], will be recruited from the Child Psychopathology Unit of IRCCS E. Medea Scientific Institute. The participation will be proposed to a group of TD peers. We estimate to recruit 10 children with ADHD, 10 children with ASD and 10 TD peers between 6 and 16 years of age. The exclusion criteria will include the presence of intellectual disability, neurological diseases, epilepsy, genetic syndromes, and treatment with psychotropic drugs. A diagnosis of other psychiatric disorders (e.g., anxiety, specific learning disorders) will not be an exclusion criterion.

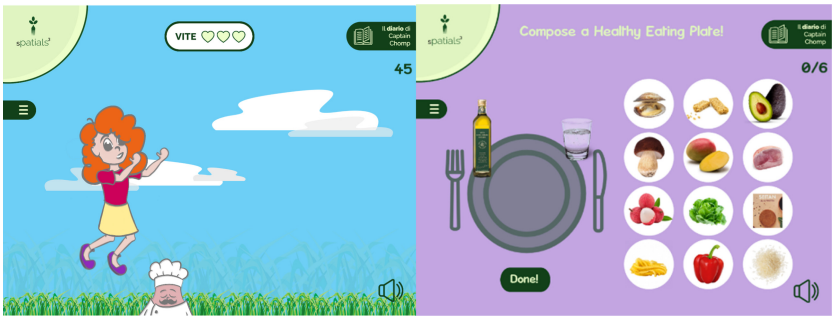


**Fig. 5.** On the left: Screenshot of the third mini-game, "Fit and Healthy". The player taps on the screen to make the avatar jump and avoid the enemy, Chef Atica. On the upper part of the screen, the number of remaining lives are displayed (three hearts), and the seconds left to finish the game. On the right: Screenshot of the second level of the fourth mini-game, "The Food Puzzle, the Fuzzle!". The child is asked to build a Healthy Eating Plate, by dragging 4 of the food items on the right inside the plate, accompanied by olive oil and water, on the left.

The primary aim of this first study is to collect preliminary observations about the feasibility of the proposed intervention both in the clinic and at home, the degree of satisfaction linked to the digital tool, and the SG effectiveness. Our secondary aim is to compare the degree of feasibility and of effectiveness between the recruited samples. To achieve these aims, the SG will be proposed to children and their parents.

Our pilot study has been approved by our institute's ethics committee, "Comitato Etico IRCCS E. Medea—Sezione Scientifica Associazione La Nostra Famiglia", in accordance with the Declaration of Helsinki (1989) as part of the sPatials3 study, which aims to develop instruments for food intake evaluation. Written informed consent and assent will be obtained from all caregivers and participants.

The SG "Captain Chomp and the Great FoodAdventure" will be administered during the first evaluation at IRCCS E. Medea Scientific Institute and will be installed on personal devices to also train at home for 1 week. After 1 week of home-fruition, each participant will be asked to return to the Institute. Researchers will hence save the output files that are generated during each game session, to evaluate each child's adherence and performances. Through the pilot study we will collect qualitative information regarding possible partial modifications to the SG that the participants' family would suggest. Finally, participants and their parents will fill in self-report questionnaires or tests to assess socio-economic status, behavioral and neuropsychological traits, the SG usability, the degree of satisfaction and involvement of the SG, and the learned knowledge about healthy eating. Specifically, we will use "System Usability Scale (SUS)" to assess the SG usability, which consists of a 10-item questionnaire with five response options for respondents from "strongly agree" to "strongly disagree" [28]. It allows the evaluation of a wide variety of products and services, and will be adapted for the SG application. It will be filled out by parents or adolescents. In addition, we will use an observation grid to qualitatively assess execution time, errors, questions and spontaneous comments of children or adolescents during the use of the SG. Furthermore, we will use questionnaires to assess involvement of the SG through "Game Engagement Questionnaire" [29]. We

expect the intervention to be feasible, usable and engaging for all children groups. We also expect to find significant differences in background knowledge and motivation about healthy eating between ADHD, ASD and TD groups, especially in ADHD and ASD groups with relative peculiarities. Finally, we expect to find significant improvements regarding the knowledge about healthy eating in all groups, possibly with inter-group differences.

## 4 Conclusions

This work offers an approach to improve knowledge of children and adolescents with ADHD or ASD about a healthy diet by developing a cross-platform SG. Therapeutic interventions for children and adolescents with ADHD or ASD based on SGs have been proved to be well accepted and effective, however, no SG aimed at nutritional education of this target population has been previously developed.

We expect that children who will be engaged in our study could improve their knowledge about healthy eating, and consequently improve their eating habits thus ameliorating their overall health. We also expect a high degree of satisfaction linked to the digital tool. Inter-age and pathology-dependent differences may arise.

Based on the results of the pilot study and on the suggestions of the children and their parents, the SG will possibly be adjusted to better respond to the target population's needs. For example, ASD children may respond abnormally to rewards and error-feedback during learning [24]. After the implementation of these modifications, the SG will be tested in a larger trial in order to assess its effectiveness in improving nutritional habits in children with ADHD or ASD.

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