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# OB CITY—Definition of a Family-Based Intervention for Childhood Obesity Supported by Information and Communication Technologies

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**ABSTRACT** Childhood obesity is becoming one of the 21st century's most important public health problems. Nowadays, the main treatment of childhood obesity is behavior intervention that aims at improve children's lifestyle to arrest the disease. Information and communication technologies (ICTs) have not been widely employed in this intervention, and most of existing ICTs systems are not having a long-term effect. The purpose of this paper is to define a system to support family-based intervention through a state-of-the-art analysis of family-based interventions and related technological solutions first, and then using the analytic hierarchy process to derive a childhood obesity family-based behavior intervention model, and finally to provide a prototype of a system called OB CITY. The system makes use of applied behavior analysis, affective computing technologies, as well as serious game and gamification techniques, to offer long term services in all care dimensions of the family-based behavioral intervention aiming to provide positive effects to the treatment of childhood obesity.

**INDEX TERMS** Childhood obesity, behavioral intervention, family-based intervention, gamification, serious games, applied behavior analysis (ABA), affective computing.

## I. INTRODUCTION

Obesity has become the most widespread non communicable disease in children and adolescents. The etiology is multifactorial with the factors involved being genetic, physiological, behavioral, environmental, financial and political. Childhood obesity is considered by the World Health Organization (WHO) as a new epidemic, it has been characterized as the number one health problem worldwide and it is considered as one of the 21<sup>st</sup> century's most important public health challenges [1]–[3]. According to the estimates of the WHO, the number of overweight or obese children will exceed 54 million in 2015 [4].

Childhood obesity can harm seriously children's health [5] and it is a potential cause for some social and

psychological problems [6]. It could also generate high direct or indirect economic burden for the family [7]. Therefore, there is an urgent need to overcome this problem from the roots with effective prevention and treatment approaches. Behavior intervention, medication and surgery are the common treatments approaches for childhood obesity [8]. The American Academy of Pediatrics guidelines target the reduction of total and abdominal obesity through increased physical activity and healthy nutrition [9]. Although, recent research has demonstrated the efficacy of these lifestyle changes on weight loss and weight maintenance, as well as, on the prevention of comorbidities, promotion and maintenance of such changes continues to be a challenge. Several systematic reviews have shown that web based interventions

are moderately effective in promoting weight loss. A personalized approach and intervention, with a two way feedback, sets a much more effective plan. There are several behavioral interventions that have demonstrated encouraging short-term results, but they do not have consistent results as far as the long-term maintenance of weight loss [10]. Thus, research for better models that can easily be delivered and sustained overtime, is needed. To that end, mobile health development intervention could greatly benefit from the application of the health behavior theory [11]. Behavioral intervention is the less invasive solution and, more important, their effects could benefit the long term. Nevertheless, the children's intelligence and psychology are immature, they are sensitive to the peer pressure and the new consciousness [12], so the behavioral interventions that aim at changing the child's eating and activity behavior through education and counseling, should be tailored to the specific needs and the characteristics of this target group [13].

There are many types of behavioral interventions for childhood obesity which have positive effects in the prevention and treatment of the disease, such as family-based, school-based, community-based interventions, etc. [14]. School-based intervention and other interventions involving professional personnel can provide children with the most appropriate support, but they hardly might be sustainable in the long-term. In contrast, almost all families always accompany children for the whole childhood, more than a teacher or a health care provider, so the family can offer to the children sustained helps and support. Furthermore, children at home have more time to perform various activities and they eat more than 2 meals every day with their parents, meanwhile parents can realize one-on-one observation and a more attentive interaction with their children. It has been demonstrated that parental involvement can lead to clear benefits in the treatment of childhood obesity [15]. The temporal flexibility, multiple opportunities, and parents' one-on-one care makes the stay at home and the home environment more suitable to apply technological solutions to provide parents with the appropriate tools and professional support to improve the result of any behavioral interventions.

Information and Communication Technologies (ICTs) have been largely used within the health-care context [16], the combination of health-care and ICTs, e-health, has a great impact on the health industry [17]. Several ICTs systems for the education and the behavioral intervention in the family environment have been implemented for childhood obesity. Serious games (using games for a primary purpose other than pure entertainment) and gamification techniques (using mechanism techniques outside game context) have been widely used and combined with social networks and monitoring technologies in order to let the children have a well-balanced meal, to know the correlation between the calories they eat and the calories they burn, and to exercise during their stay at home [18], [19]. Those existing game systems could result in an improvement of children's lifestyle for a limited time period, but they are not designed to be

a long-term planning and scheduling system to achieve a substantial and targeted behavior modification. In the case of family-based intervention, ICTs could also provide guidelines to parents education, e.g. online health information is provided to parents through generalized websites or search engines (Google, Wikipedia, etc.), but the information on these sites is usually general and complicated to be used in each particular case [20]. Two-end behavior modification systems based on family-based behavioral intervention let parents design behavioral tasks for the child, track the completion of tasks, and give incentives, and use gaming and social networks to activate children to perform tasks [21]. However, tasks' setting is too simplistic and unprofessional. More importantly, they are not intelligent systems, as they do not provide personalized behavior modification programs based on the characteristics and needs of the different children, they do not adjust the outcome based on the feedback from the completion of tasks, and they do not provide expert guidance.

A family-based behavior intervention is a long and complex course of treatment, there are various factors that can influence the treatment outcome, and the intervention requires the cooperation among professionals, parents and children. Hence, taking advantage of ICTs to resolve the difficulties met in a family-based intervention could improve its efficiency and optimize its result. The main goal of this work is to define an ICT system implementing a family-based behavioral intervention for the management and treatment of childhood obesity. To achieve this, a state of the art analysis of existing solutions and technologies available to this purpose was carried out; then, the results of this analysis were discussed with experts and a suitable model of family-based intervention of childhood obesity was derived, using the Analytic Hierarchy Process (AHP). Finally, a system prototype called OB CITY was designed, based on the intervention model and experts' advice. OB CITY is a technological platform that supports the management of childhood obesity by educating, helping and encouraging children to modify their behavior, and empowering their parents at the same time.

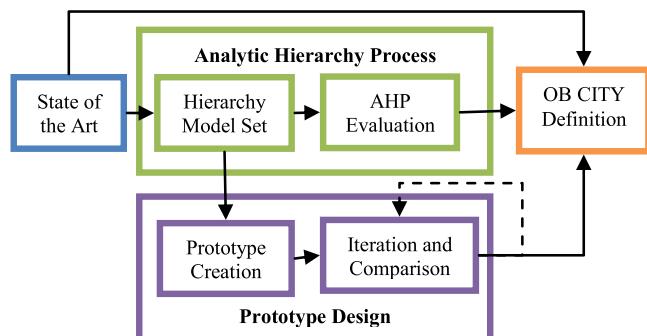
The remainder of the paper is organized as follows: in section II, the state of the art analysis, the Analytic Hierarchy Process and the techniques to implement the system are described, as well as the materials that are used to evaluate the user need and the prototype. In section III, the ICT system is described, and the childhood obesity family care model, the OB CITY's solutions and prototype and the result of the user need elicitation are provided. Finally, the possible optimizations, clinical applications of the system and future work are discussed in section IV.

## II. METHODS AND MATERIALS

### A. METHODS

We organized our in three phases: first, existing family-based behavior interventions were analyzed, and the related existing technological solutions were selected;

secondly, a family based childhood obesity care model was defined and evaluated through the involvement of experts using the AHP; and finally, a first prototype of the OB CITY system has been designed and iteratively updated with the help of user interaction experts. The workflow is shown in Fig.1:



**FIGURE 1.** The phases of our work.

### 1) STATE OF THE ART

The literature study and expert interview are performed in order to have a preliminary understanding of childhood obesity; to understand causes and consequences of child obesity, as well as existing prevention and treatment solutions; and to carry out an in-depth study of the working mechanism of behavioral intervention. Meanwhile, a research on current technological solutions was also performed.

The result of this process consists in a depth understanding of the family-based intervention of childhood obesity, a first approximation in describing the basic components of family-based interventions and a selection of the current ICTs solutions that can support them, in order to discuss and further elaborate it with the help of experts in the field.

### 2) ANALYTIC HIERARCHY PROCESS

To define a system that can provide service for all family-based intervention dimensions, the Analytic Hierarchy Process was chosen and used to elicit the intervention needs. On the AHP, the result of the literature study and the experts' interviews were used to establish a hierarchical model of family-based interventions as a reference for the prototype design. An evaluation of the elements of the model was carried out to obtain an accurate guidance for the development of the OB CITY system based on the integrated views of a group of experts in the topic.

AHP has been widely employed in different fields such as education [22] and health [23], [24] for complex decision making problems. AHP enables the elicitation and prioritization of users' needs by aggregating the opinion of domain experts providing a quantitative measure of their opinions and level of agreement. It also simplifies complex problems by breaking them into smaller and simpler decisions. Participants are requested to perform multiple pairwise comparisons between two elements of the hierarchy instead of ranking all the elements at once. For each pairwise comparison they are

asked to choose which one of the two options is more important and rank it in a 10-points scale. Using this information and due to the properties of the AHP, an inconsistency value is calculated in real time and provided to the participants to reconsider their responses. Usually a global value of 10% inconsistency is considered appropriate. Once the questionnaires are finalized, it is possible to extract the relative importance of each need per category (local weights, LW), the relative importance of each category (category weights, CW), and the importance of each need compared to all the others (Global weights, GW) [60], [61]. For all these reasons, AHP has been selected as the method to elaborate the hierarchy model of a family-behavioral intervention, since it is a complex problem that requires expertise and know-how from various domain experts [25]. At the beginning, the first version of the hierarchy was built based on the dimensions defined in the state of the art analysis. Then the hierarchy was refined and updated through the knowledge, experience, judgment, value, opinion and needs, of medical, educational and engineering experts. Finally, the hierarchy was ranked by other experts, in order to assist the development and evaluation tests: two nutritionists with more than 15 years of clinical experience and one primary school teacher with more than 20 years' experience have been interviewed; the final hierarchy was evaluated by 2 nutritionists, 1 endocrinologist, 3 primary school teachers and 3 biomedical engineers with experience in childhood obesity.

### 3) PROTOTYPE DESIGN

Another method employed within our work was the use early prototyping as a way to start a dialogue with experts and obtain their feedback. The prototype was designed according to the elements of the hierarchy and then it was shown and discussed with various experts. One nutritionist with more than 20 years' experience together with two bio-engineers with 2 years' experience tested the prototype display against the elements of the model to evaluate the system's functionality, and determine if the system was able to provide support for every important dimension of the treatment and if it can be accepted by both parents and children. With these evaluations, the prototype was constantly redefined and iteratively updated. This process was repeated for eleven times. Rapid iterators over a prototype yields valuable design insights for both the experienced and non-experienced participants [26] and it is a valuable tool for promoting the dialogue with experts and capture their feedback.

## B. MATERIALS

### 1) AXURE RP PRO

Axure RP Pro is an application designed for rapid prototyping, it can assist the designer to quickly design the prototype, combined with comments, notes, flow charts, frames and other elements and to obtain a complete product presentation. It is a tool that can construct highly immersive website and APP prototypes and generate an interactive display

specifications document. Employing the outcome of the AHP, the care model of family-based intervention, the OB CITY's system framework and function modules are designed and visualized through Axure and the prototype is presented to the experts, to evaluate it and to achieve continuous improvement.

## 2) BPMMSG AHP ONLINE SYSTEM

BPMMSG AHP Online System is a free web system developed based on the Analytic Hierarchy Process, and it can be used to support rational decision making. Users can define a hierarchy of criteria for a decision problem, calculate the priorities and evaluate a set of decision alternatives against those criteria. When the hierarchical model of family-based intervention is defined in the AHP step, we upload the objective and relevant criteria and structure them in a hierarchy in the BPMMSG AHP Online System. Then the experts are invited to realize a comparison of those criteria with respect to the objective of optimize the effect of the family-based intervention to find their weights based on pairwise comparisons. The result of the needs analysis of different experts is evaluated and is directly exported without any additional operation on the website.

## III. RESULTS

### A. THE BASELINE

Using our state of the art analysis several insights for the definition of a family-based behavior intervention are extracted. First of all, it is an event that occurs in the family environment, so the active participation of children and parents is necessary and essential. Second, the intervention for obesity focuses on two targets: letting children be healthy by eating less and doing more physical activity [8], consequently, the service needs to include nutrition and exercise components. Third, the behavior interventions are implemented through three pillars: education, counseling and motivation [13]. Forth, the intervention requires an accurate analysis of the individual and a modification plan has to be defined for each case, in order to obtain the desired objective [27]. And finally, the result of the behavior intervention should be maintained for a long time, therefore children can keep a long-term healthy without rebound. In conclusion, 9 dimensions of family-based intervention were defined as follows: provide *personalized nutrition* and *exercise* services to *educate*, *consult* and *encourage* both *children* and *parents* to obtain *long-term* effects of the childhood obesity treatment. At the beginning, existing ICTs products employed in the family-based intervention have been described and some simple evaluations have been presented. In this part a detailed analysis of the state of the art of the family-based intervention technological solution and its advantages and disadvantages are provided. These technologies have been evaluated, as described in Table 1, based on the 9 criteria defined at the beginning of this section.

There are 6 ICTs systems [18], [21] which are compared in Table 1, most of these systems provide services only for the

**TABLE 1. Comparison of existing applications.**

| Criteria     | Application |                 |            |         |        |                   |
|--------------|-------------|-----------------|------------|---------|--------|-------------------|
|              | Pick chow!  | Fitter critters | Your snack | Trainer | Google | Behavioral change |
| Child end    | ✓           | ✓               | ✓          | ✓       |        | ✓                 |
| Parent end   | ✓           |                 |            |         | ✓      | ✓                 |
| Nutrition    | ✓           | ✓               | ✓          |         | ✓      | ✓                 |
| Exercise     |             |                 | ✓          | ✓       | ✓      | ✓                 |
| Educate      | ✓           | ✓               | ✓          | ✓       |        |                   |
| Consult      | ✓           |                 | ✓          |         | ✓      |                   |
| Encourage    | ✓           |                 |            | ✓       |        | ✓                 |
| Personalized |             |                 |            |         |        |                   |
| Long-term    | ✓           |                 |            | ✓       |        | ✓                 |

children end, while two require the participation of parents. Children need to modify their diet and exercise habit in the intervention, which can be achieved through a similar pattern of behavior modification, but only 2 of them provide services in both areas. Education, consultation and encouragement are complementary to achieve the purpose of behavior changing, but just 1 of the systems has all those function. The concept of long term intervention effect is applied in 3 systems, but they are non-flexible, and there is not a gradual, evidence-based and scientific-grounded process. None of them provides personalized behavior modification programs based on the characteristics and state of the family members.

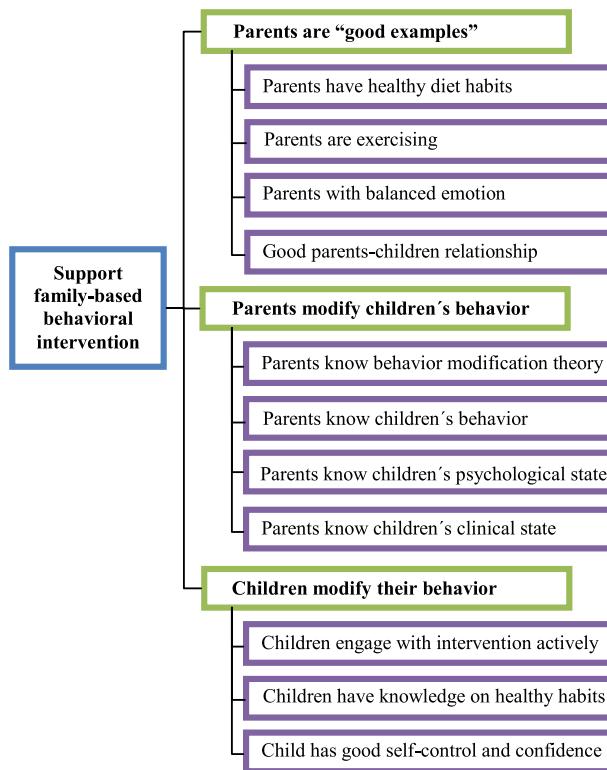
### B. CHILDHOOD OBESITY FAMILY-BASED INTERVENTION MODEL

In order to define an ICT system to overcome the weaknesses of the existing technology products, the 9 criteria obtained in the state of the art analysis have been further elaborated by experts. According to the medical experts' opinion, "emotion" [28] was added as the 10th criterion to the model because it affects childhood's weight as same as "nutrition" [29] and "exercise" [30], and these three elements can interact with each other.

Finally, the experts reorganized the 10 criteria and grouped them in three new categories: 1) Parents have a healthy lifestyle, and they become "good examples" to affect their children's behavior; 2) Parents know ways of behavior modification and make use of scientific methods to modify children's behavior; 3) Children are motivated to actively participate in the intervention. The hierarchy is shown in Fig.2.

#### 1) PARENTS ARE "GOOD EXAMPLES"

Parents' behavior can influence their children's behavior [31]. Children imitate almost everything that their parents do and integrate what they observe into their lives. It is important that parents become "good examples" for their children in the behavior intervention. Parents should have and show

**FIGURE 2.** Family-based intervention hierarchy.

good diet habits and exercise activities and create a healthy lifestyle environment; they should also have stable emotion to reduce children's psychological pressure. In addition, a close relation and communication between parents and children is required.

### 2) PARENTS MODIFY CHILDREN's BEHAVIOR

Behavior intervention is not a complicated process, but to achieve the desired goal of the intervention is not a simple task. Family-based behavior intervention requires parents to know about behavior modification techniques, such as how to give to the children a reasonable modification plan, how to properly motivate children, to realize better intervention results. During the behavior modification, parents need to be very careful to observe children, to understand accurately the children's various states (daily behavior, personality and clinical data), to judge the children behavior properly, and to improve the efficiency of the intervention.

### 3) CHILDREN MODIFY THEIR OWN BEHAVIOR

Children are indispensable part of the family-based intervention, and they are real actors of the behavioral change, so children's performance directly affects the result of the intervention. If they do not have the motivation to participate in the process, the whole behavior modification is completely pointless. And if in the course of the intervention, children do not have the ability to control themselves, or have very bad emotional state, they will not be able to adhere to complete

a series of tasks to achieve behavioral change. In addition, if the behavior modification solely let children correct some of their behavior, but they do not know the reason or they cannot distinguish correct or wrong behavior, it is not good for the children to establish a good behavior independently. So children have to participate actively in the behavior modification, adhere and place effort to change their behavior, and learn at the same time.

### C. ANALYTIC HIERARCHY PROCESS RESULT RANKING

The defined family-based intervention hierarchy model was presented to 2 nutritionists, 1 endocrinologist, 3 primary school teachers and 2 biomedical engineers to evaluate the importance of each element through the guidance of the BPMSG AHP System, the results are shown in Table 2 and Table 3:

**TABLE 2.** Ranking of global weights (GW).

| Ranking | Element                                     | Weights |
|---------|---|---------|
| 1       | Good parents-children relationship          | 14.9%   |
| 2       | Parents have healthy diet habits            | 13.9%   |
| 3       | Child has good self-control and confidence  | 12.8%   |
| 4       | Parents have balanced emotion               | 10.4%   |
| 5       | Parents are exercising                      | 9.6%    |
| 6       | Parents know behavior modification theory   | 9.4%    |
| 7       | Parents know children’s behavior            | 6.6%    |
|         | Parents know children’s psychological state | 6.6%    |
| 9       | Children engage with intervention actively  | 6.2%    |
| 10      | Children have knowledge on healthy habits   | 5.2%    |
| 11      | Parents know children’s clinical state      | 4.6%    |

**TABLE 3.** Ranking of categorical weights (CW).

| Ranking | Element                            | Weights |
|---------|------------------------------------|---------|
| 1       | Parents are “good examples”        | 48.7%   |
| 2       | Parents modify children’s behavior | 27.2%   |
| 3       | Children modify their behavior     | 24.1%   |

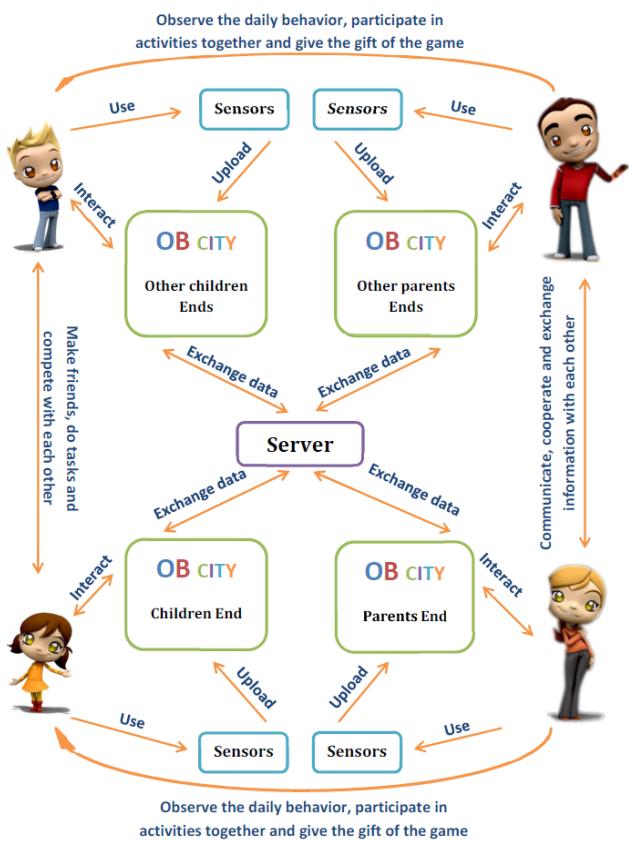
Based on the values from the Global Weights (GW), the three most important elements are Good parents-children relationship (14.9%), Parents have healthy diet habits (13.9%) and Child has good self-control and confidence (12.8%). In a second level of importance there are Parents have balanced emotion (10.4%), Parents are exercising (9.6%), and Parents know behavior modification theory (9.4%). Parents know children’s behavior (6.6%), Parents know children’s psychological state (6.6%), Children engage with intervention actively (6.2%) and Children have knowledge on healthy habits (5.2%) are en the third level,

the Parents know children's clinical state is the less relevant (4.6%). The analysis of the Categorical Weights (CW) provides information about the importance of the different categories. Parents are "good examples" has been highlighted as the most relevant category by all the responders (48.7%), followed by Parents modify children's behavior and The Children modify their behavior which scored very similarly (27.2% and 24.1%). The results show that parents play a leading role in the family-based intervention, but children's cooperation is also indispensable, especially the child's self-control is an important element that cannot be ignored.

#### D. DEFINITION OF OB CITY SYSTEM

According to family-based intervention hierarchy model, an ICT system called OB CITY is defined to provide the corresponding services to the elements in the model.

#### 1) SYSTEM STRUCTURE



**FIGURE 3.** The OB CITY system structure.

As shown in Figure 3, OB CITY is a two-ends system involving both parents and children. Each user end is a combination of user, sensor and application interface. Users wear the sensors (smart watch or smart bracelet) to measure and upload some detected data (heart rate, electro dermal activity and motion data) to the user end to realize the emotion and exercise state, and they interact with the user end to realize

some necessary behavior intervention operations. There is communication between the parents ends, between the children ends and between parents end and their child end to permit the users to interact with other users online and also off line.

#### 2) OB CITY's TECHNIQUES

##### a: GAMIFICATION

Gamification is the use of game elements and game-design techniques in non-game contexts to solve problems and engage users [32], [33]. It applies the game mechanics such as: collecting some goods, medals, etc.; earning points to get a better leaderboards, levels, etc.; system feedbacks with some movements and change; value exchange between users; customization and personalization in the real-life or other non-game systems combines the nature of the fun of the games, to increase the users' motivation and engagement [34]. Gamification techniques encourage people to achieve certain goals in non-game situations and feel the fun of the game. They are currently extensively used in health [35], education [36], [37], social networks and other industries [38], [39].

The parent end of OB CITY is a health management application which integrates the gamification techniques. It allows parents to earn points to get more level and redeem more advanced services; to perform different new challenges; to collect some relevant award medal; to rank in their circle of friends, compete and exchange experiences with other users in the network. It also provides the corresponding feedback to parents' each operation, to maintain the parents' active participation in the family-based intervention, and lets them to achieve self-management and to intervene in the children's behavior modification.

##### b: SERIOUS GAMES

A serious game is a game designed for the purpose of application, specifically speaking, refers to a game that has the main content of teaching knowledge and skills or providing professional training and simulation [40]. Serious games use the expression of game, through the interactive of edutainment, allow users gain knowledge, accept relevant information, get efficient skills training and even improve the efficacy of some medical applications. In the course of the game users can learn without the pressure. Serious games have been widely used in military, medical [35], industrial, educational [37], research, training [41] and other applications [42].

The OB CITY's children end is a serious game, a virtual city is created to let children simulate real life, communicate with social network friends and take care of their virtual pets in the game. OB CITY requires children to complete a variety of tasks related to their behavior modification, optimization of skills and improvement of lifestyle in real life. And it also teaches children healthy knowledge in the game. OB CITY mainly lets children form a very healthy habit and improve the obesity symptoms, and let them gain relevant knowledge, build self-confidence and establish a good personality at the same time.

### c: APPLIED BEHAVIOR ANALYSIS (ABA)

Applied Behavior analysis, also known as behavior modification, is a technique that requires a deep knowledge, research and work to achieve real change in the person's [43]. ABA's objective is to generate a change of a behavior by increasing or decreasing the frequency of certain sub-behaviors through implementing measures before (early warning or eliminate risk) and after (positive and negative reinforcement) the generation of these behaviors [44]. ABA is mostly utilized for children with an autism spectrum disorder [45], and it is also used in many areas such as: education [46], health and exercise [47], medical procedures [48], parenting [39], psychotherapy [49], etc.

The OB CITY system provides personalized services to support the family-based intervention according to ABA. It provides technical solutions for each step of the behavior modification, to help parents observe their children, find their behavior problem, formulate the behavior modification plans, take action to realize the intervention, evaluate the result and adjust plan, and motivate children to cooperate with the intervention.

### d: AFFECTIVE COMPUTING

The purpose of affective computing is to give to the computer the ability to identify, understand, express and adapt to the human emotions, to build a harmonious human-machine environment, and give the computer a higher and more comprehensive intelligence [50]. It uses a variety of sensors to get the physiological signal and behavioral characteristics caused by human emotions, and it establishes an "emotional model", and creates a personal computing system which is able to perceive, recognize and understand the human emotion.

Emotion and obesity have a great relationship, they have mutual influence and constraints [51], [52]. Meanwhile, parents' emotional state can also have a huge impact on children's emotions and behavior [53], [54]. Therefore, in the family-based intervention of childhood obesity, the emotional management of parents and children is a very important task. OB CITY combines affective computing technology, using sensors to obtain related physiological data, and combining the characteristics of the parents' and children's operations in the process of using the system to give personalized feedback to help them regulate their emotions.

### 3) OB CITY's SOLUTIONS

The OB CITY's functional modules are defined according to the family-based intervention hierarchy model, as it is shown in Table 4.

### E. OB CITY's PROTOTYPE

When the OB CITY system is defined, the first prototype was designed based on the described functional modules, and then it is constantly compared and iteratively updated by the game experts and interaction experts to the final version.

### 1) OB CITY's FINAL PROTOTYPE

OB CITY was provided for children aged 9 to 12, it has two user ends: parents end and children end. The two end users need to enter the system at least once a day to do some necessary operations. The main menu of the two ends is shown in Fig.4:



**FIGURE 4.** OB CITY parent end and child end main menu.

When parents enter the OB CITY's parents end the first time, they need to enter their children's basic information: age, sex, height, weight, obesity features, hobbies, character, etc. Then they can log into the system's main interface. There are six main modules in the parents end: diet, exercise, emotion, task, my child and notice. The module content is shown in Table 5:

Children need to select and personalize their avatar when they enter for the first time into the OB CITY. After a brief questionnaire, they can get into the world of the OB CITY to start a new and interesting virtual life. There are also six main modules of the children end: tasks, state, house, pet, shop and citizens. The module content is shown in Table 6:

All these modules in the parent end and child end contains the application of the technologies mentioned in the definition of OB CITY system, and collaborate to provide a variety of support for family-based interventions.

### 2) OB CITY's PROTOTYPE EVOLUTION

The prototype has been modified several times to improve the user experience and optimize the service quality. Next, some examples will be provided to show the prototype's update process.

#### a: OPTIMIZATION OF TASK MODULE OF PARENT END

As mentioned, the task module of the parent end permits parents to set tasks and to assign them to the children in their end. First, parents cannot choose difficult tasks to avoid placing

**TABLE 4.** Technological solutions to support the family-based intervention hierarchy model.

| Childhood Obesity Family-Based Intervention Needs   | OB CITY's Solution   |
|---|--|
| <b>1.1 Parents have healthy diet habits</b><br><p>It is proven that parents' eating habits will directly affect their children [56, 57]. If parents have a long-term heavy intake of high-carbohydrate and high-fat foods, children will be exposed to excessive intake of calories [58]. Personal dietary preferences, irregular schedule and lack of expertise make parents just buy and prepare what is their favorite, what is fast and easy to do and what they think is good for health without considering the practical nutritional value of food. To change their eating habits, they need to recognize the problems of their diet habit which may cause a series of serious health problems and have the motivation to correct them; then, they should study nutritional facts to know what a good diet is; finally, they try to change their diet, and stick with it.</p>  | <b>Provide nutrition, exercise, and emotional management system for parents</b><br><p>OB CITY provides services to permit parents manage their eating behavior, exercise behavior and emotional balance. It will let parents to improve their behaviors through education, guidance, and supervision.</p> <p>At the education part, OB CITY will periodically send professional information related to nutrition, exercise and psychology to parents, so that they can slowly learn relevant knowledge to know how to establish a healthy lifestyle independently.</p>   |
| <b>1.2 Parents are exercising</b><br><p>Children can spend a lot of leisure time at home to do more physical exercise than at school. The parents' exercise habits will influence their children [59]. The lack of physical activity is a frequent problem of our days, the economic growth, technological progress, and social changes have led many people to take public transport instead of walking, have sedentary jobs to carry out the work, watch TV, play video games and use the computer at home. To change this, parents must understand the benefit of physical exercise in a daily basis; also, they need to have access to relevant (and trustable) knowledge sources, so that they can efficiently carry out physical exercise according to their personal state.</p>  | <p>At the guidance part, OB CITY will offer directly to parent lifestyle programs personalized according to their preference to facilitate their work of behavior control. Based on the parents' choice of their life custom, the system will generate automatically a diet and activity plan, to let parent make the lifestyle healthier. At the same time, OB CITY uses affective computing techniques to detect the parents' emotion with sensors (heart rate and electrodermal activity), informs them the state of their emotion and gives suggestions, to let them understand better their mood and try to control it.</p> <p>At the supervision part, the system provides two mechanisms: self-supervision and supervision by others. First, the system uses the gamification techniques, to motivate parents to follow well the lifestyle program proposed by the system, to modify their emotion and lifestyle. It also takes advantage of the social network, let parents to supervise and compete with each other and the link between parents end and the children end permits children to supervise their parents.</p>  |
| <b>1.3 Parents with balanced emotion</b><br><p>Parents' emotion in family life affects directly the children's mental health. Parents often have bad mood at home, they fight and quarrel, even vent their negative emotion directly to the children, let children often live in tension and fear [53-55]. Children's psychological problems will affect their behavior, lose self-confidence and self-control, become easy to give up and do not take the initiative to improve themselves. Parents in daily family life must control their emotions: do not quarrel or fight in front of children, do not complain about life or show decadent emotion in front of children, do not scold or criticize others in front of children, do not express their views in an extreme way in front of the children, and most important, do not scold the children directly.</p>  | <b>Create interaction between parents and children</b><br><p>OB CITY includes the parents end and the children end and permits the mutual communication between the two ends. In this way, the system creates many opportunities for parents and children to realize online and offline interaction.</p> <p>Online interaction: several operations in the OB CITY's user ends require direct or indirect interaction between children and parents. OB CITY sets up mechanisms for mutual supervision of children and parents, the behavior and emotion management module of parents end needs the children confirm the lifestyle and emotional state of their parents in children ends; at the same time parents plan and intervene the behavior modification of their children through the parent's ends. OB CITY also sets different virtual roles for parents and children in the serious game, so that they might engage in a dialogue through their user ends to reach a mutual cooperation and encouragement in the game.</p> <p>Offline interaction: both parents and children ends will require from parents and children to complete some offline collaborative tasks, so that parents and children can exercise, change diet and learn together in real life, thus creating opportunities for them to communicate and understand each other.</p> |
| <b>1.4 Parents and children having good communication</b><br><p>The relationship between parents and children might influence the children's whole life, and also affect the inheritance of parents' good behavior. In order to establish good relation between parents and children, parents need to offer children real accompany. Parents should try to find enough time to be close to the children, to play with them, chat with them and do other things with them as much as possible; and take the initiative to express their love for children at the same time. Besides that, parents should pay more attention to their children, share the anguish and joy of their children's every problem and achievement. In the exchange and communication between parent and children, parents should offer enough freedom, respect, trust and patience, so that children can grow up in a comfortable home environment.</p> |  |
| <b>2.1 Parents know basics of "behavior modification"</b><br><p>Behavior modification is not a standard, step by step process, especially the behavioral intervention for childhood obesity [43]. Parents need to be able to deal with a wide variety of information, analyze it and provide feedback. Parents acquire a lot of information, not only about the children's body, mind and behavioral state, but also other environmental information. Some of this information is very important for behavior modification, but some is interference information or noise. Parents should learn to accurately filter information in order to make the correct judgments and learn to customize the</p>  | <b>Provide an intelligent Applied Behavior Analysis system</b><br><p>OB CITY provides professional support in every behavior modification step in strict compliance with the ABA operation.</p> <p>In the OB CITY, parents need to enter personal information and basic behavior of their children, the system analyzes and provides some options of target behavior to let parents choose, and then generates different behavior modification programs according to parental choice. Finally, parents decide a program and the system converts it into every day's tasks</p>  |

**TABLE 4. (Continued.) Technological solutions to support the family-based intervention hierarchy model.**

|   |  |
|---|--|
| <p>scientific program according to the children's state. At the same time, parents should choose the right incentive methods to motivate children. They also should know appropriately adjust their intervention programs to respond to all kinds of unexpected random events during the long time intervention process.</p>  | <p>and delivers them to the children end. It also offers punishment or reward to encourage children to do these tasks in real life. In the intervention process, the system measures automatically children's data by sensors (exercise and emotion data), and requires parents to record other children's information (exercise and nutrition behavior), in such a way to provide more comprehensive observation of children without costing many parents' time and energy. OB CITY also has an intelligent feedback system that not only shows to parents what the children have done, but also adjusts the behavior modification program automatically by learning the children's state and behavior, and provides parents with better programs. If parents are willing to become more involved in the whole process and to be more responsible of their children's behavior modification, they can freely give veto the system's recommendation and make their own decisions.</p>  |
| <p><b>2.2 Parents know children's clinical state</b></p> <p>Some children's health data, including the child's height, weight, Body Mass Index (BMI), Waist-hip Ratio (WHR) and body fat are related to the childhood obesity intervention. Parents need periodically to measure and record the physical data during the process, to get a better understanding of the treatment progress. Meanwhile, the children's physical condition is also very important for the intervention: parents should avoid children's inattention and anemia for the diet; and also avoid the fatigue and injury by overdoing exercise.</p>  | <p><b>Provide a comprehensive children monitoring system</b></p> <p>In the whole behavior intervention process, the parents are required to record a large number of children's related data: physiological data, daily behavior, the emotional state, and some related environmental inputs.</p>  |
| <p><b>2.3 Parents know children's behavior</b></p> <p>Parents record and observe the children's behavior throughout the entire process of behavior modification; they collect the children's behavior in all the processes of Applied Behavior Analysis: the preparation, design, intervention and evaluation. The observation of behavior should be long-term and detailed. The children's behavior can occur anywhere at any time. The parents should record it timely and accurately.</p>  | <p>OB CITY creates regularly notifications to parents to alert them to record manually the children's behavior and emotion every day, and to check the child's physiological state each time. Meanwhile, OB CITY uses a variety of methods to acquire relevant children's data directly: it is combined with various types of sensors (smart watches, smart bracelet) to detect the children's motor behavior; it uses the Near Field Communication (NFC) technique to create children's offline activity games and takes their motion data at the same time; it takes advantage of the social network, let the social members detect children's eating behavior through an online game. In addition, OB CITY incorporates affective computing technique, through a combination of physiological data acquired by sensors, children's performance in the life simulation game and the collected information from their online dialogue, helps in analysing the children's emotion state.</p>   |
| <p><b>2.4 Parents know children's character and mental state</b></p> <p>Without professional help, to understand children's personality and psychology is very difficult for parents, even they live together, parents cannot totally know their children's preferences and thoughts. Children's feelings and personality have a high impact on the behavior modification. Cheerful children participate actively in the intervention and have a higher degree of adaptability; and sensitive children are susceptible to get various influences, thus affecting the modification progress [52]. Therefore, parents should know the children's psychological status, in order to determine the most suitable plan.</p>  |  |
| <p><b>3.1 Children engage with the intervention actively</b></p> <p>The children have to try again and again to complete similar tasks in the behavior modification, they need to do something they do not like or they are not used in performing under strict requirements. Sometimes, children do not know the importance of the intervention, they cannot give up their favorite food and they do not want to exercise, so they will never begin to change their accustomed behavior. And if they cannot find the pleasure during the process, and just suffer to do what they do not want to do, they will drop out quickly. Hence, children should have the motivation to participate, they cannot start their behavior modification under pressure. Meanwhile, in the long and tedious intervention, they should find the delights and have strong motivation, and it is better they can even take the initiative to complete the tasks and enjoy the process of self-improvement.</p> | <p><b>Provide a social serious game to motivate children to learn and participate in the intervention.</b></p> <p>OB CITY uses the interactive multimedia, creates a life simulation game in the children end to let children participate actively in the behavior modification to develop healthier habits, and access some obesity-related knowledge through playing games.</p>  |
| <p><b>3.2 Children have good knowledge on healthy habits</b></p> <p>To let the children know the reasons, methods, and objectives of behavior modification is better than just let them change their behavior, so that they can modify behavior spontaneously without relying on the help of their parents or other adults. To know how to determine good or bad behavior, and know how to build a good behavior they have to learn the difference between the different eating habits, know the nature of different foods, and they have to understand the pros and cons of different exercise habits, which includes facts on nutrition and sport. Children develop a habit of correcting behavior themselves, which not only can play a significant role in the behavior intervention, while it will bring several benefits for their after life, and even affect their children.</p>  | <p>In the children end, every child can create a self-designed avatar and keep pets in the game. Children do the game tasks in the real life to modify their behavior, and gain game experience and coins, to make their avatar more powerful and wealthy in the game. To look after their pets, children need to know to modify the pets' diet and exercise to let their pets be healthy and strong, and they also improve their nutrition and sport knowledge in this operation. OB CITY creates an important virtual character, the "mayor" of the city, who conveys all tasks, reward and punishment to the children. As it is a fictitious character that is extremely powerful for the children in the game, it will provide a greater sense of mission to children and let them be more active in doing tasks and get more sense of honor when they get a reward. In the OB CITY, some children's information can be shared, ranked and organized in the social network, children can see the others' information, they can make friends, perform tasks together and compete with each other, they will be involved in the game more actively, and execute tasks aiming to develop a healthy lifestyle. With the social network, children can be more motivated and actively participate in the intervention.</p> |

**TABLE 4. (Continued.)** Technological solutions to support the family-based intervention hierarchy model.

|  |  |
|--|--|
| <b>3.3 Children have good self-control and self-confidence</b>   | <b>Establish a comfortable environment</b>   |
| Obese children usually have developed a lot of bad habits in a long period of time. These habits have been deeply integrated into their lives, since they cannot control themselves or they cannot avoid the temptation, they could show also this bad behavior again during the process of behavior modification. Moreover, the tasks in the intervention plan are challenges for the children. Some obese children have different degrees of psychological problems [53, 60], they do not have confidence and have a great negative emotion; it is easy to evade the issue when they face the difficulty, and it will lead to failure of the intervention. Hence, children should have a good self-control, to be able to concentrate on the task and not to be subjected to external interference. Meanwhile, they need to establish their self-confidence through a variety of methods, so that they believe they are excellent and they can solve the difficulties they face, so that they have a strong determination to achieve the intervention. | As mentioned before, OB CITY uses several affective computing techniques to detect children's emotion state, to try to maintain children's psychological balance, to reduce the influence of affective factors to the childhood obesity treatment.<br><br>Children need to do tests before entering the OB CITY system, which include several psychological questions, to obtain children's initial psychological assessment. Meanwhile, OB CITY is designed as a life simulation game, the behavior and performance (career choices, color preferences, and dialogue) of children's avatar in the game can be used to realize the data mining, and the result like children's personality and emotion state may be mapped to children's mental state in real life. In addition to obtaining information directly from children, OB CITY utilizes the parents' observations and feelings, to be a reference of the detection of children's emotion. Apart from adjusting the behavior modification plan according to children's state, OB CITY will give to others feedback. The utterance of the game will be changed depending on children's emotion, to make more effective to convey meaning. Children will note the difference of the system and feel more comfortable and respected. |

**TABLE 5. Parent end's module content.**

| Module   | Content  |
|----------|--|
| Diet     | Provide professional nutrition and exercise information in two forms: general related knowledge and personalized prescription according to the real needs. |
| Exercise |  |
| Emotion  | Provide general psychological knowledge, update parents' emotion state and give suggestions.   |
| Task     | Require parents to realize the basic task, behavior modification task, skills task, and gift task setting and task completion confirmation.                |
| My Child | Provide children's status, the task completion, the game behavior and the interaction with the friends in the child end.                                   |
| Notice   | Exchange the system's message and the friends' message.  |

**TABLE 6. Child end's module content.**

| Ranking  | Element   |
|----------|---|
| Tasks    | Provide basic task, behavior modification task, skills task, and gift task to children to be realized in real life.     |
| State    | Show the avatar's level, wealth, title and image, and the goods in the storeroom.                                       |
| House    | Provide furniture in the storeroom to do the house decoration.  |
| Pet      | Show the pet's level and different properties value, and permit children to feed and exercise the pet.                  |
| Shop     | Sell clothing, furniture and pet supplies to children.  |
| Citizens | Show social network rank and the new stars rank permits children to make friends and communicate with them in the game. |

too much pressure to children. But when their children have completed well these tasks, parents can increase the tasks difficulty. As it is shown in Fig. 5 this function is updated in the evolution process.

The behavior modification tasks permits parents to modify the task content according to children's performance.


**FIGURE 5. Optimization of the task module in the parent end.**

First, the system provides to the parents directly the modified choices, so that the parents just need to select the one they think is the most suitable. With the suggestion of the education professionals this interface is modified to provide to parents more references, so that they can understand the basis for the adjustment of the tasks and can have more material for the decision.

#### b: OPTIMIZATION OF PET MODULE OF CHILD END

In the pet module, children can choose one pet, such as a dog, a cat, a rabbit, or even a dragon and feed and exercise their pets. They need to choose the food that he has bought from the shop to feed the pet to increase its corresponding properties in the pet feed interface. As it is shown in Fig. 6 this function is updated in the evolution process.



**FIGURE 6.** Optimization of the pet feed module of the child end.

First, the evaluation criteria of food are set according to the traditional way: calories, carbohydrates, fat, protein, and fiber are chosen as the measure. Then, under the guidance of game experts, these terms are changed into: energy, power, strength, speed and intelligence, the value of these items also can be changed depending on the feeding, and at the same time they can be used in other pet modules such as pet training and pet battle. This change makes the education function more interesting for children and the knowledge is gained more intuitively.

#### IV. DISCUSSION

In a state of the art analysis on children obesity was carried out, supported by domain experts. As a result a hierarchy of user needs was conformed and used to assess the available technological solutions for the family-based intervention for childhood obesity. After that, the AHP method was used with experts to quantify the importance of each of the user needs in the hierarchy. This was also helpful to guide the dialogue with the domain experts and to get their views and feedback. Finally, an OB CITY prototype was designed and developed. The model was discussed with domain experts as well as experienced users in order to redesign and redefine it.

The most relevant results of this work are summarized in Table 2 and Table 4. There, the user needs have been identified, guided by the experts' opinions and then they have been quantified. Those needs can be used as a guideline not only in the developing process but also in the evaluation stage to judge the function implementation of OB CITY. Then, Table 4 offers a direct mapping between users' needs and Gammification, Serious games, Applied Behavior Analysis and Affective Computing tools developed using ICT.

In a later work, the OB CITY prototype will be deployed and validated on real users. The aim of this validation will focus on (1) studying the feasibility of ICT for the delivery of

this kind of intervention, and (2) studying the effectiveness of the intervention itself.

OB CITY will be suitable not only for the overweight children, but also for the normal children, and even the changes in weight and behavior of those children might be recorded.

The OB CITY is an application of the behavior intervention, so it can also be implemented in other cases of childhood diseases, such the autistic children or for children suffering from diabetes. It can even be used to help the normal children to develop good habits, build and establish a good personal quality and develop their hobbies and skills.

#### V. CONCLUSIONS

Management of childhood obesity is a complex issue that requires time commitment from a multidisciplinary team of health professionals and from the family. Given the cost and time constraints of the health systems worldwide as well as the time limitations the parents have and their inability to accompany their children, due to job time constraints, to clinic appointments, the need for a tool that can provide guidance to parents and their overweight or obese children is of outmost importance in addressing the obesity epidemic. In a clinic visit the aspects that are most frequently addressed are (1) behavioral motivation of the parents and the children in order to implement the changes suggested in their daily routine, daily physical activity and daily nutritional habits; (2) education of the parents regarding the principles of healthy nutrition practices, related to the number of meals, the variety of nutrients and food groups that have to be included in an age appropriate nutrition program and the age appropriate physical activity, duration, intensity and frequency, and (3) education of the children, regarding healthy nutrition, a task which is very crucial for children older than 10 years old and adolescents that make independent choices regarding snacks and sometimes lunch if they are engaged in afterschool activities.

Knowledge is very important but is not adequate to ensure that a change in practice will follow. Thus, there is a need for continuous reinforcement and psychological motivation. It is advised that the obese child is followed by a group of health professionals including the pediatrician or pediatric endocrinologist, the nutritionist, the psychologist, the physical therapist. Furthermore, besides the issues addressed in the clinic with the specialists, in everyday life, children and parents face challenges and they have to adjust their food intake accordingly, and often they are overwhelmed and they don't know how to make the appropriate changes.

The OB-CITY is designed in such a way to address the tasks mentioned above in a continuous manner, from a distance, so that the parents are not obliged to abstain from their work and children to miss school hours. Furthermore, parents and children can have guidance and answers regarding questions which arise on a daily basis. It is the tool that can augment the compliance of parents and children and thus improve the clinical outcome. The major issue for failure of most of the plans for obese children is noncompliance. The

user friendly presentation and the step by step approach is the potential answer. The use of the Analytic Hierarchy Process enables the prioritization of the user needs. The interactive parents and children platform is unique in the aspect that sets limits to parents and don't allow them to be unrealistic regarding their expectations for their children. The parents are given the rationale for the choices so they become aware of the reasoning as well as the needs, preferences and capacities of their children. Another very important aspect by which the use of OB CITY can increase adherence to the suggestions and improve clinical outcome is that it takes into account the emotional status of parents and the children, as well as the ability of psychological control of children and whether parents are aware of their child emotional state. The use of sensors by which the motor activity and emotion state can be recorded provides input of the daily alterations, which are taken into account for further suggestions and modifications of the management plan. The above features ensure that OB-CITY can be a significant tool to support clinicians not only for the management of overweight and obese children but also for normal weight children who were documented to have rapid weight gain and for children with other clinical conditions that need behavioral modification.

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