Fammeal: A Gamified Mobile Application for Parents and Children to Help Healthcare Centers Treat Childhood Obesity

Lisa Afonso, Rui Rodrigues, Eduardo Reis, Kylee Miller, Joana Castro, Nuno Parente, Carina Teixeira, Ana Fraga, and Sandra Torres

***Abstract*—Healthcare centers are ideal settings to identify and motivate parents to adhere to healthier lifestyles in order to reverse their child's excessive weight. However, such promotions are time- and resource-consuming, and primary health care needs new approaches to engage parents. In this article, we present an app for that purpose, with tailored recommendations for parents regarding young children's lifestyles (eating, drinking, moving, and sleeping habits) with gamification mechanics for parents, and a serious game for their children, aged 3–6 years. Healthcare center based questionnaires were used to assess parent's acceptance of the app. We also determined their enrollment and retention rates with a pilot study, in order to test the implementation of a randomized controlled trial (RCT) in the future (pilot trial registration: ClinicalTrials.gov NCT03881280). In the pilot study, we tested their engagement with the app during a four-week period through a monitoring website. In the acceptance test ($n = 13$), parents rated the app a median score of seven on a ten-point scale. In the pilot study ($n = 21$), all parents in the intervention group used the app. The retention rate was 71.4%. This study indicated some areas of improvement related to gaming mechanics in order to increase participation. Healthcare center's professionals and parents of children with overweight/obesity accepted this innovative approach. In addition, it is feasible to test its impact on children's lifestyle by conducting an RCT in the future.**

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Lisa Afonso and Sandra Torres are with the Faculty of Psychology and Educational Sciences and with the Center for Psychology, University of Porto, 4099-002 Porto, Portugal (e-mail: lafonso@fpce.up.pt; storres@fpce.up.pt).

Rui Rodrigues is with the Faculty of Engineering, University of Porto, 4099-002 Porto, Portugal, and also with the INESC TEC, 4200-465 Porto, Portugal (e-mail: rui.rodrigues@fe.up.pt).

Eduardo Reis is with the Faculty of Engineering, University of Porto, 4099-002 Porto, Portugal (e-mail: edujreis95@gmail.com).

Kylee Miller is with the Department of Pediatrics, Child Development and Rehabilitation Center, Oregon Health & Science University, Portland, OR 97239 USA (e-mail: millerky@ohsu.edu).

Joana Castro, Nuno Parente, and Ana Fraga are with the Maia/Valongo Health Center Group, Health Unit Viver Mais, Maia 4474-004, Portugal (e-mail: joanacastro@hotmail.it; nunomiguelpm@gmail.com; anafraga.med@gmail.com).

Carina Teixeira is with the Maia/Valongo Health Center Group, Health Unit Íris, Maia 4474-004, Portugal (e-mail: lisafonso@gmail.com).

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***Index Terms*—Children, gamification, mHealth, obesity (OB), parenting, serious games.**

I. Introduction

CHILDHOOD obesity (OB) is preceded by appetite-disrupting behaviors and unbalanced lifestyle habits and therefore it is crucial to act on these determinants as early as possible [1]. Programs to prevent or treat childhood OB should thus have a family-centered approach and should incorporate a combination of key lifestyle factors, namely related to healthy eating, drinking, sleeping, and moving habits [2]. A research field that has been growing, with regard to the promotion of better eating habits to improve children's weight status, is the one concerned with the way parents or caregivers manage the food environment (through strategies called food parenting practices) and how much they attend and respond to children's individual needs when feeding them [3]. Some experimental studies indicated that we are born with a natural ability to self-regulate our intake, adjusting food intake to energy expenditure [4], [5]. This capacity may be influenced by environmental factors early in life, such as parental attempts to impose rigid rules concerning when and how much the children eat, leading to poor self-regulation [6], [7]. Because poor self-regulation in eating is associated with higher intake and higher children's weight, training parents to apply strategies of responsive feeding seems promising for OB prevention and treatment [3], [8]. Therefore, programs to manage a child's weight may promote the training of parents on how to: 1) help the child recognize signals of hunger and fullness; 2) reconsider their child-feeding practices; and 3) manage environmental cues that may reduce natural hunger-driven eating behaviors [3].

A barrier to the adherence to and engagement with those programs in managing children's weight is that parents often misperceive their children's overweight (OW) and OB status, especially if they are between the ages of 2- and 6–years-old [9], [10]. Studies indicate that a child's excessive weight is only recognized by the parents if there is a substantial deviation in the child's body size from perceived normality [10]. The parental ability to recognize OW/OB status in children has been suggested as an important starting point to make changes in the family environment [11]. Healthcare centers can play an important role in this process because, during well-child visits,

clinicians assess the child's growth and development, providing this information to parents [2]. However, this procedure may not be enough to produce changes per se as parents may not be able or willing, to manage their child's weight status. This means that, in addition to weight status information, it is important to promote and support parental skills and to motivate parents to improve lifestyle-related family dynamics [12].

Motivating parents to adhere to a new lifestyle is challenging and time-consuming, thus, effective and engaging strategies are needed [13], [14]. Among relevant strategies to be considered, web and mobile-phone-based interventions have been shown to be effective in changing different health behaviors as they can incorporate interactive and engaging solutions, allowing the user to adopt them in a flexible schedule [15]–[17]. Their success depends on how much users consider the experience enjoyable, valuable, and adaptive to their needs. A promising approach of web-based weight management interventions is the delivery of personalized information, tailored to meet each participant's needs [18], [19]. To motivate participation, gamification methodologies, i.e., the integration of game components in nongame contexts, are now also increasingly being used [20]. Those strategies intend to reinforce the adoption or maintenance of behaviors by inviting the user to complete clear, meaningful, challenging, and rewarding tasks [21]. These techniques have already been associated with greater involvement in health promotion programs [20], [22]–[24]. Parents also recognize the need to directly involve their children in e-health programs to change their lifestyle [25]. The use of serious games—those developed with a purpose other than pure entertainment that is achieved in an enjoyable and intrinsically motivating way—has been increasingly considered to involve children in programs to improve their health [26]. Their use has been tested in several randomized controlled trials (RCTs) and a meta-analysis reported their positive effects both in lifestyle and in its determinants [27]. Social connectivity with health professionals and other participants may also enhance engagement and motivation to participate [28]. Health promotion programs delivered by internet also benefit from a design based on behavioral change theories. The Theory of Planned Behavior has shown to have greater effects on behavior when compared with others [29].

Currently, there are a large number of mobile applications directed to parents. However, to the best of our knowledge, no studies have specifically focused on the testing of an evidence-based mobile application (app) to support the treatment of childhood OW/OB in healthcare centers, by integrating recommendations tailored for parents regarding family dynamics, and engaging them and their preschool children through gaming strategies [30], [31]. Therefore, we developed an evidence-based intervention, through an app connected to a monitoring website, for parents and their children aged 3–6 years old and identified as OW/OB for age in healthcare centers. The app included two types of gaming strategies: gamification components for parents, to motivate them to watch tailored content; and a serious game for children, namely a virtual-pet game, in order to help them recognize their own internal cues of hunger and fullness. We used two studies with the target population in a healthcare center to test the solution: an acceptance test, which consisted of using the app and evaluating it by questionnaire; and a pilot test, which aimed to assess the processes of a RCT, by analyzing the feasibility of its procedures. Pilot studies constitute a unique opportunity to identify the challenges and improve upon an intervention; which is also recommended before running a RCT [32]. Considering that we used an innovative approach, running an intervention through an app, to be recommended by health professionals at healthcare centers, it is important to assess adherence. Therefore, we analyzed the enrollment of health professionals at the healthcare center, their recruitment of participants and the participant's retention rates during a four-week intervention period (both for an intervention and control group). We also tested the intervention group's engagement with the app through a monitoring website.

II. Related Work

The solution developed was inspired in the OB CITY prototype [33]. This was designed for children 9–12 years old with OB and for their parents. It consisted of an app with two modes—one for the parent and other for the child—connected to each other. Parents had six modules in the app, with knowledge related to their child's diet, exercise, and emotions. Additionally, they were invited to monitor the child's use of the app, to exchange messages with other parents and with their child, and to define goals for the child's lifestyle. The system helped parents develop goals in a progressive way, adapting the difficulty as the child completed each defined goal. This strategy of prompting intention formation by motivating the goal setting, and providing information about behavior, by giving feedback on action and reinforcing it, was shown to be one of the most effective combinations of health behavior change techniques and is increasingly used in e-health programs [34]. The child had to choose an avatar and play with it in a virtual city and had a pet that should feed and exercise appropriately. The child had access to the goals defined by parents and could connect with other users "living" in the OB CITY. Both parent and child earned points and medals by completing each task. An important distinction from our study, beyond being directed to younger children, was that we simultaneously considered intervention work on parents' healthful skills and practices (namely those related to the management of food environment and child's intake) beyond merely helping them set goals [12]. A game more related to that purpose was *Mommio*, a prototype developed specifically to help parents deal with the rejection of vegetables, from their preschool child [35], [36]. This role-play game simulated a mother's interaction with her child (*Kiddio*) that hated vegetables. The game happened in a 3-D scenario that was a house with different distractions (such as television), in which the user played during interactions at mealtime. Parents were invited to choose a vegetable recipe to offer at each meal and the child refused it. For each refusal, parents could improve the environment (e.g., turning OFF the television) and interact with the child with different food parenting practices. This meant that they could decide how to answer, selecting from a choice of statements, and selecting their voice tone and facial expression. Parents won points every time their child tasted vegetables. During the intervention, parents received

automatic motivational messages and a plan with strategies to use at home designed to increase children's intake of vegetables. This information was tailored based on parent's initial answers to a questionnaire, where they reported a parenting value that is important for them (such as "having a healthy child") [37].

At preschool ages, children learn better through "make believe" [38]. Previous work of Birch *et al*. [7], [39] implemented a six-week program of individual and group activities to help children improving their ability to self-regulate. This study suggested that self-regulation in eating can be promoted by helping children focus on their physiologic signals of hunger and satiety, thereby indicating a need for new tools that encourage and help parents training this capacity in children in the home setting. The program included play states where the children used a physical doll to reflect the state of their own stomach (empty, half-full, or full). An alternative that has been seen in other studies for this age group focuses on educational games using virtual-pet or cartoon characters (even if not evidence-based designs) [40]. Virtual-pet games engage children in their animism, thereby creating an emotional connection with the device that is known today as the *Tamagotchi Effect* [41]. Thus, these types of games have the potential to drive children to caring behaviors that can be mirrored in themselves and thus explored to elicit health improvement behaviors [41]. An example is to raise a dog and improve its health through increased physical activity time and fruit and vegetables intake [42], [43]. In my virtual tooth—virtual pet, children had a toothbrush timer to help them brush for three whole minutes [44]. In those games, individual behavior in real life is measured and/or reported and will determine the health or growth of the virtual pet or character. There are also virtual pet games designed to teach children how to manage their own conditions or disease. Wizdy Pets teaches children from 5 to 11 years old how to manage their own asthma, while caring for a dragon who has asthma [45]. To earn points, kids must give their pet dragon a maintenance inhaler twice a day, recognize and clean up potential asthma triggers at home, and identify and act on asthma symptoms. The diabetic dog game helps 8–9 years old diabetic children to learn how to manage the disease, taking care of a diabetic dog and learning out how much insulin to feed him [46]. A recent systematic review found few studies on serious games specifically designed for childhood OB control and testing its impacts and none devoted to the preschool age [47].

As strengths of the presented studies, we identified the fact that the app can targeted both parents and children (OB CITY), work with parents on their skills and practices, rather than only helping them set goals (*Mommio*) and work with children in the management of their own health condition through a virtual-pet (Wizdy Pets for asthma). However, few studies on serious games were designed for the prevention and treatment of OB in young children. This development is important because lifestyle interventions to treat children with OW/OB had the largest effect on the reduction of the excessive weight in children 2–5 years old [48]. The majority of the games were also directed to the treatment of diseases and not to the improvement of lifestyles in order to contribute to disease prevention. Serious games may have the potential to influence the risk behaviors preventing the expression of the noncommunicable disease (such as OB and diabetes) [41]. It would also be important to understand how the app can be recommended to their users in a real-world setting and to test those procedures. We identified healthcare centers as a great setting to detect deviations in weight in children and to promote changes in children's lifestyle to revert those deviations [2].

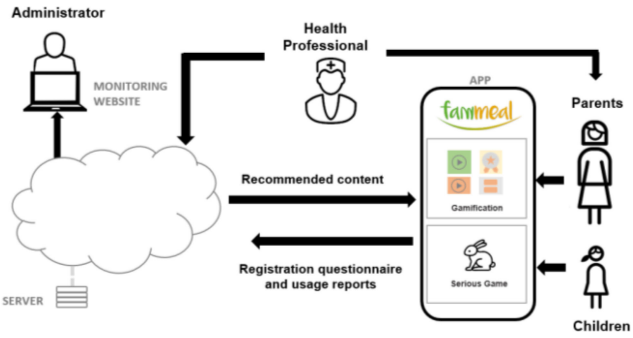

Fig. 1. *Fammeal* workflow diagram.

III. Methods

We capitalized on the strengths identified in related work and considered the existing limitations to develop the current solution. The supporting platform—entitled *Fammeal*—was developed with close collaboration among behavioral scientists, public health practitioners, and software developers, as recommended [24]. It was directed at both parents and their children ages 3–6 years old, and was designed to be promoted in healthcare centers by health professionals (see Fig. 1).

This solution was designed to be recommended by medical doctors or nurses after detecting a significant deviation in a child's weight trajectory. That is, this can also be a preventative solution directed to children with OW, in order to promote a better lifestyle and prevent OB. It included a prototype of the *Fammeal* app that was available for Android devices. It also included a monitoring website that can be accessed by the administrator/health professional, to monitor recruitment and the app usage.

The process is initiated by the enrollment of health professionals that recruit parents to participate. Parents installed the *Fammeal* app and introduced an assigned ID, as the first step of the registration process. That ID was created to protect the user's personal data: it identified the health professional, the healthcare center, and the participant. The participants then answered the registration questionnaire to generate tailored recommendations. Those answers could be consulted in the monitoring website by an administrator. The app had two modes: one for parents (opened by default) and another for children (by clicking in the button "child mode," locked by password) (see Fig. 2).

The mode for parents focused on setting improved lifestyle goals for their children, sharing knowledge about guidelines for age, and promoting positive food parenting practices aimed at improving their skills (those related to the management of

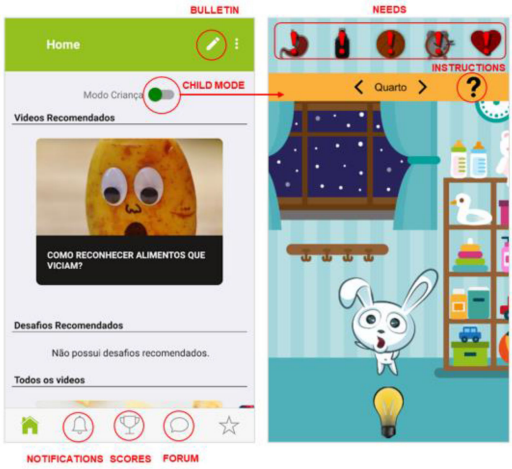

Fig. 2. App screenshots—home and serious game for children.

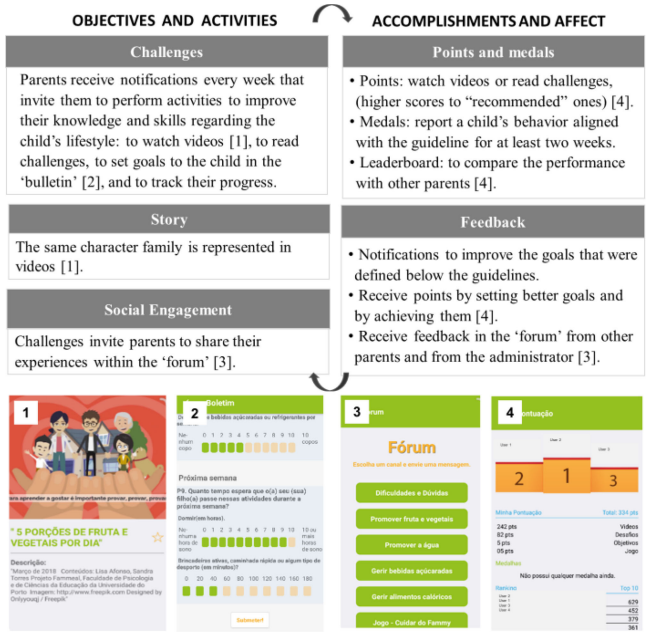

Fig. 3. Gamification mechanics included in the app.

food environment and child's intake) and relation with children. Parents received tailored recommendations and gamification strategies to motivate them.

For children, we created a serious game, namely a virtual-pet cartoon—a rabbit called *Fammy*—for them to care for. Parents were instructed to explain the game to children and invite them to play three times each week. Children's use of the app and interactions with *Fammy* were both monitored and facilitated by their parents. Recognizing that sedentary behaviors and distractions while eating should be reduced for children with excessive weight [48], parents were invited to promote the game in substitution of other games/screen time, outside of meal times, and for 5 min maximum per play session. To help parents understand the game, we created two types of instructions, related to the children's game: child-centered, general instructions to explain the game to their child, and caregiver-focused contextual instructions (one for each screen) to clarify the virtual-pet's needs.

In this section, we detail the parent and child modes of the app, as well as the monitoring website.

A. *Fammeal App and Monitoring Website*

1) Parents' Mode of the Fammeal App: When parents registered in the app, they completed a short questionnaire, which was used to tailor recommendations and define whether the content appeared as "recommended." The content included 15 short, educational videos that were stored online and opened in the app, via the internet [49]. Parents were recommended to watch 8–10 videos. These videos included recommendations designed to counteract pediatric OB, selected according to the international guidelines for the key lifestyle factors: healthy eating, drinking, sleeping, and moving habits [2]. Suggestions to improve food environment and implement positive food parenting practices were made based on a recent compilation of Vaughn *et al.* [50], based on Self-Determination Theory. We organized the recommendations according to select dimensions of the Theory of Planned Behavior, namely, behavioral beliefs, attitudes, and perceived behavioral control [51]. The automatic recommendation system is detailed in [52].

Parents were invited to watch content, provide regular updates on their child's behaviors, and exchange messages with other users. These tasks were encouraged by gamification mechanics as detailed in Fig. 3, organized according to Miller *et al.*'s [21] design principles and reflecting the user engagement process, following the objectives, activities, accomplishments, and affect framework [53].

The app included a reward system available in the "Scores" screen (see Fig. 2). Additionally, parents were invited to set goals related to their child's lifestyle (water, fruit, and vegetables intake per day; energy-dense foods and sugar-sweetened beverages intake per week; and sleeping and physical activity time per day) and track their progress in the "Bulletin" screen.

Parent-centered challenges were also presented during the intervention. These were short texts with suggestions of activities related to the provided videos (e.g., inviting parents to introduce children to a variety of fruit and vegetables ready to eat, at home). They were invited to share those experiences with other parents and with the administrator, via messages within the app's "Forum" screen. Parents received automatic notifications from the system, which could be consulted in the "Notifications" screen.

2) Children's Mode of the Fammeal App: For children, a serious game appropriate for chronological ages 3–6 years was previously designed [54]. Children were invited to take care of *Fammy* on the key lifestyle topics of water, food intake, sleeping, and physical activity; topics in which parents were instructed to promote in themselves as well. Although the child may not necessarily mirror behaviors in *Fammy*, we expected to raise children's awareness about those topics, as they play out in the virtual-pet. For that purpose, the game tasks were to feed *Fammy*

Fig. 4. Serious game spaces.

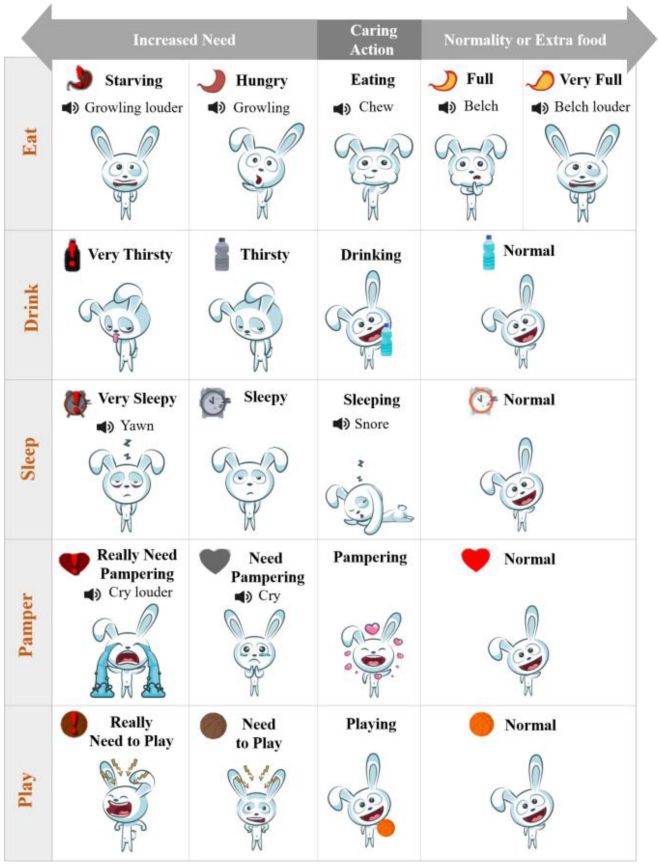

Fig. 5. *Fammy* states (icons and sounds associated), related to each task.

with fruit and vegetables, give it water, pamper and play with it, and get it to sleep. For each task, there was a need icon, with a load indicator, which loses color as the need increases and that gets a red exclamation mark to signal the extreme need. We created three game spaces, where *Fammy* can perform different game tasks (see Fig. 4).

In the bedroom, it goes to sleep by touching the lamp, which dims the light. In the kitchen, it can eat and drink (fundamental game tasks, specified below). Finally, in the yard, it can drink and play by jumping, moving the phone with the hand, or playing mini-games to collect food. *Fammy* could be pampered in every screen by touching its image with the child's finger.

To feed *Fammy*, children had to monitor its needs load indicators and give him food if needed. While instructed that they should only give food to *Fammy* if it was hungry, they could give more food than needed, and the stomach icon distended. A "full" image popped up when the stomach was full, to make it clear to children. To feed *Fammy*, the child could touch the plate icon in the kitchen to access the food. The child could then fill the plate with the desired portions. For *Fammy* to chew the food, the child would touch the plate. The child decided the eating rate: touching the plate with the finger faster lead to faster chewing and, consequently, *Fammy* would eat more food per sitting. A higher eating rate lead to higher amount eaten. For *Fammy* to drink, the child touched the bottle icon in the kitchen or the yard. When presenting the app, parents were invited to explain to their children how to care for *Fammy,* introducing these rules and why these lifestyle components were so important, for *Fammy* and for themselves. To give feedback to children about how they were caring for the rabbit, different states of *Fammy* were created (see Fig. 5). Some states were reinforced with sound (e.g., cry sound in the "needs pampering" state or stomach growling in the "hungry" state).To give a long-term feedback and encourage planning, there were also three developmental stages (baby, young, and adult) and it could be underweight, normal weight, or OW, depending on how much food the child gave.

The serious game also included three mini-games. Mini-games were comprised of age-appropriate color and shape games with fruits and vegetables, and a running game, in which the child tapped the screen to jump over trees to collect carrots, water, and beans. While playing the running game, children's interest in eating foods by their nutritional attributes was promoted with carrots and water to improve the vision of *Fammy*, and with beans to give it strength to pass by trees without jumping. These messages were also suggested to parents in the videos/challenges (e.g., parents were recommended to explain to their children that carrots improve vision).

The serious game only included positive messages about food promotion (i.e., earn points while finding a vegetable). In previous studies, promoting the exposure to a variety of fruits and vegetables while educating about their benefits improved intake [55]. We avoided inclusion of energy-dense foods and sugar-sweetened beverages, or negative messages associated (e.g., lose points while finding a cake), to avoid giving undue attention to those foods or adding negative associations, which previous studies have associated with increased interest in and disruption to healthy eating behaviors, in real-life [3].

3) Interface Between Parents' and Childrens' Modes: Two processes were designed to create the interface between the parent's mode and the child's serious game. First, the child's lifestyle behaviors reported by parents in the questionnaire affected the virtual-pet's needs. Among other questions from the registration questionnaire, parents were asked about child's usual intake of water per day usual minutes per day of active play, speed walking or any sport, and hours of sleep. If the child was below recommended levels for water intake, physical

activity, or sleeping, then *Fammy* exhibited a 25% greater need for water, playing, and sleeping, respectively. Conversely, the way the child cared for the virtual-pet generated recommendations for the parents. Parents received recommendations to watch videos related to child's need for water, physical activity, and sleep if their child had more than three games per week without giving water, or without playing or getting *Fammy* to sleep when needed. The way the child fed the virtual-pet also generated recommendations for parents, related to children's self-regulation in eating. If, for one week, the child has *Fammy* chewing food too quickly more than 40% of the time, a video about eating rate is recommended. In addition, if the child feeds too much food to *Fammy* more than 25% time, a video about hunger and satiety is recommended. Parents also received points every time the child played with *Fammy*.

4) Monitoring Website: We created a monitoring website where the administrator do the following.

1) Managed recruitment by adding healthcare centers and health professional profiles and by managing their recruitment over time.
2) Added or deleted topics in the forum.
3) Monitored usage data: questionnaire answers, videos watched, and challenges read (recommended/not recommended), goals set, achievements per week, logins to the app, and points earned per day.

In this prototype of the app, the child's mode was not linked to the monitoring website.

B. Solution Testing

To test the solution, we performed an acceptance test and a pilot study within a healthcare center in Porto, Portugal. We ran a session in the healthcare center to explain the protocol of the study to medical doctors and nurses, as they recruited parents to use and evaluate the app. Parents were invited during a well-child care visit and if they accepted the invitation, a meeting with the project technician was scheduled to install the app (not all invitees attended). They were invited to bring the device they prefer, to be used by them and by the child. The app was then installed in the phone or tablet selected by parents.

1) Participants: Participants were parents of children aged 3–6 years. They were invited to participate by family doctors after considering anthropometric data collected at the last well-child care visit. The eligibility criteria were: parents involved in child feeding management ($\geq$ 5 of involvement on a 0–10 scale from "not at all" to "extremely involved"), owning an Android device and internet connection, and willing to participate in the research study [56]. For the pilot study, an additional criterion was considered: only children identified with OW/OB (according to World Health Organization criteria [57]) were invited. For both studies, we excluded children with any medical conditions that affected growth, food intake, physical activity, or who received any professional dietary advice in the last six months.

Written informed consent was obtained from all participants. This study complied with the Ethical Principles of the Declaration of Helsinki [58] and was approved by the Ethics Committee of the Faculty of Psychology and Educational Sciences of the University of Porto (reference: 2017/10-4).

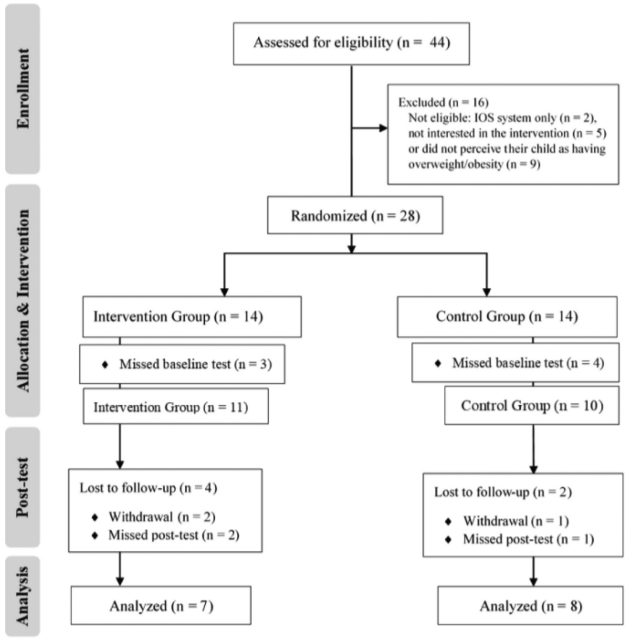

Fig. 6. Flowchart of progression through the phases of the pilot study.

2) Acceptance Test: For the acceptance test, medical doctors and nurses invited 32 parents to participate and all accepted. However, only 13 attended the interview and installed the app to be used for three weeks. During the three weeks, the administrator monitored the use, evaluated, and resolved any technical problems. At the end, parents were invited to evaluate the app by completing an online questionnaire composed of statements and a five-point Likert scale (from "strongly disagree" to "strongly agree"). They also classified the usefulness of the app on a ten-point Likert-type scale (from "not useful at all" to "extremely useful") and reported their ideal duration of intervention.

Based on these results, we expected to perform some minor improvements to the system.

3) Pilot Study: We tested the procedures of a RCT but with a smaller sample, in order to test its feasibility, by addressing participants' enrollment, engagement, and retention in the study.

For the pilot study, medical doctors and nurses invited 44 parents to participate. The flowchart of progression through the phases of the pilot study for intervention and control groups is presented in Fig. 6.

Those enrolled were assessed for eligibility and 28 met the inclusion criteria and consented to participate. The major reason for parents' refusal to participate was parental denial of their children's OW/OB status (20.5% of eligible parents). The 28 consenting parents were assigned randomly to either the control or intervention group (1:1), using the random number generator of Excel. They were blinded to the group to which they were allocated, by offering a delayed access to the app to the control group (after posttest). Only 21 parents attended and completed the baseline test, answering questionnaires that evaluated sociodemographic and outcome measures (see Table I). Parents

TABLE I
CHARACTERISTICS OF PARTICIPANTS

	Acceptance Test (n = 13)	Pilot Test (n = 21)
Parents		
- Mothers, *n* (%)	12 (92.3)	15 (71.4)
- Age (years), mean (SD)	36.4 (5.5)	37.3 (3.6)
- With university degree, *n* (%)	6 (46.2)	14 (66.7)
Children		
- Girls (%)	7 (53.9)	12 (57.1)
- Age (years), mean (SD)	4.8 (1.1)	5.0 (1.2)
Children's Weight Status		
- Normal weight, *n* (%)	4 (30.8)	0 (0.0)
- Overweight, *n* (%)	5 (38.4)	9 (42.9)
- Obesity, *n* (%)	4 (30.8)	12 (57.1)
Frequency of others apps usage		
- Never, *n* (%)	0 (0.0)	0 (0.0)
- Rarely, *n* (%)	0 (0.0)	0 (0.0)
- Sometimes, *n* (%)	4 (30.8)	2 (9.5)
- Often, *n* (%)	9 (69.2)	19(90.5)

in the control group received treatment as usual. Parents in the intervention group installed the app and were invited to use it for at least four complete weeks (and up to 30 d maximum). A four week parameter was selected based on parent-reported feedback from the acceptance test performed previously. In this test, some parents reported that they could use the app for more than three weeks. During the four-week period, the administrator monitored whether parents were using the app. Both groups performed a posttest in the healthcare center. The final dataset included 15 parents due to exclusions caused by withdrawal and missing posttest data.

A detailed description of procedures and measures is given in the trial registration [56]. To test the feasibility of the study we analyzed several indicators. From the app usage reports, we examined participants' engagement during the four-week intervention period. We consulted the monitoring website to analyze the number of logins, videos watched, points and medals earned, answers to bulletins, and total weeks of usage. Within the app's forum we also confirmed the number of shares per participant. In this prototype of the app, we had the connection from the app to the game (e.g., we can make *Fammy* thirstier) but we did not have the connection in the reverse direction (from the game to the service), due to service and time constraints. Therefore, serious game analytics could not be evaluated in the pilot iteration. Thus, we asked parents to report the child's game usage, by number of play sessions during the four weeks. We identified and grouped parents *à posteriori* in different profiles based on data usage, namely: the number of points earned (this reflects parents' usage of different features of the app), weeks of usage, and "bulletin"/"forum" usage.

IV. RESULTS

In this section, we present results related to the acceptance and the pilot test of the *Fammeal* solution. The medical doctors and nurses who were invited accepted participation in the recruitment of participants.

TABLE II
PARTICIPANT'S ACCEPTANCE ASSESSMENT ($N = 6$)

How much do you agree with the following statements about the *Fammeal* app?	Agree (%)[a]	Median (range)[b]
'It is visually appealing'	50	3.5 (3-4)
' It is easy to use'	100	4.5 (4-5)
'I learned watching the videos'	100	4.5 (4-5)
'The recommended videos interested me'	100	4.5 (4-5)
'My child liked the game'	67	4.0 (2-5)
'My child asked me to play the game'	50	3.5 (2-5)
'I was interested in comparing my score with other participants.'	17	1.5 (1-4)
'I was interested in answer to the weekly report'	17	2.0 (1-4)
'I was interested in the parents' forum'	0	2.0 (1-3)
'I'm interested in continuing to use the app'	50	3.5 (2-4)

[a] Users who agree with the statement. Includes both "Agree" and "Totally agree."
[b] Likert scale ranging from 1 ("Totally disagree") to 5 ("Totally agree").

A. Participants

Participants' characteristics at baseline are presented in Table I.

B. Acceptance Test

During the three-week study period, nine of the 13 parents used the app (69.0%). Of the four parents that did not use the app, three reported using another app(s) sporadically, and mentioned difficulties remembering the registration password and/or username. Six parents (66.7% of active users) completed the questionnaire (see Table II).

The median acceptance ranking attributed to the app was seven (ranging from 7–8 on the ten-point Likert scale) and they considered three weeks (median value, ranging from 2–4) as the ideal time to watch all contents. After the acceptance test, we performed the following minor improvements.

1) We simplified the password criteria and gave parents a card if they want to take note of username and password.
2) We improved notifications that were failing.

C. Pilot Study

Retention rate was 71.4%, which was similar between the intervention and control groups (70.0% and 72.3%, respectively). All participants of the intervention group ($n = 9$, after attrition) used the app. The mean points earned per day are depicted in Fig. 7.

All parents watched all the recommended videos, seven (77.7%) also watched additional videos that were not recommended, and two (22.2%) watched all the videos available in the app. The majority of parents read the recommended challenges ($n = 7$; 77.7%). Points earned by participant, per day, are presented in the Supplemental Material. Parents earned the majority of their points during the first week of intervention (70.5%). Based on data usage and defined criteria, we grouped parents in four different profiles of usage (see Table III), which represent different levels of engagement.

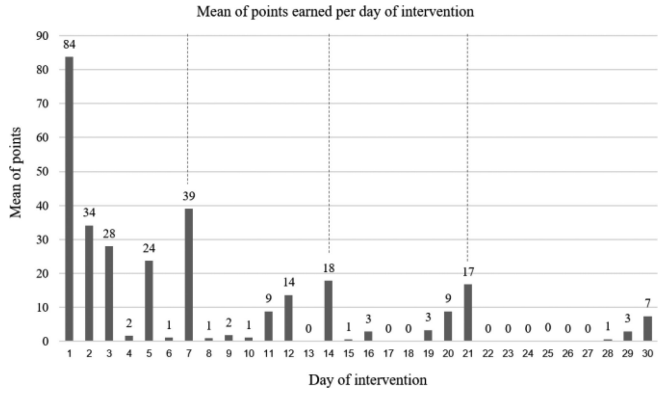

Fig. 7. Report of mean daily usage (by points earned) ($n = 9$). Dashed lines indicate the system notifications, inviting parents to watch contents in the app.

TABLE III
APP ENGAGEMENT PATTERNS AND METRICS ($N = 9$)

App Engagement	Type 1	Type 2	Type 3	Type 4
Users	1	1	3	4
Logins	310	36	24-34	10-30
Weeks of usage	**4**	**4**	**3-4**	**1-2**
Videos watched	17	16	9-14	8-12
Points earned	**612**	**442**	**246-272**	**159-269**
Medals earned	1	0	0	0
Serious game usage	30	7	6-25	2- 30
Answer to bulletins	**3**	**1**	**0**	**0**
Shares in forum	**6**	**1**	**0**	**0**

Note: Bold indicates the criteria to define the profiles of usage.

V. DISCUSSION

This study aimed to present and test a solution for parents of children identified in healthcare centers as having OW/OB. The solution included an app, which tailored recommendations and included gaming strategies with the intent to motivate participants. Additionally, we present the engagement metrics, from data gathered on a monitoring website that was developed to facilitate intervention management.

In the first study to determine the acceptance of the app, parents classified the app positively. Data from that study suggested that the main factor that contributed to some app abandonment was difficulty in remembering the username and/or password. The topics with weak ranking were the forum, the score, and the bulletin. However, it should be noted that some related notifications failed in the first study and, thus, missed the opportunity to reinforce attention to those topics. We improved the registration and notification systems and, in the pilot test, the participant rate increased and we had two parents using the forum and answering to bulletins. However, uptake of these components remained less than expected. This leads us to consider how we could further improve these components. In the weekly bulletin, we invited parents to set goals and report behaviors related to all the lifestyle behaviors under study, which could be time consuming. To improve this, we should perhaps focus on select or reduced behaviors that children should change, and not all of them. Some factors may be the basis of reduced participation in the forum. First, a greater number of users may be necessary to create a social network effect. We only had five parents using the app continuously during the four-week study period. Second, studies indicate that it may be difficult to promote program-specific discussion boards or chat rooms due to their artificial nature compared with mainstream social media platforms already frequented by participants [59]. Furthermore, we acknowledge that we created a forum that lacks in media richness because it is only text-based, allowing only the simple exchange of messages.

The healthcare professionals invited to participate accepted and recruited participants. We explored the feasibility of running a RCT, by analyzing participant enrollment, engagement, and retention within the pilot study. Regarding enrollment, we found that the most frequent reason to participation refusal was parents' denial of their children's excessive weight, even after the medical doctor's recommendation. Further strategies testing are needed to engage those parents in future interventions. Despite this, the recruitment rate was acceptable but can be improved, namely when the users can install the app alone, without the need of scheduling an extra meeting with the technician in the health center. All parents in the intervention group showed engagement with the app, watching all of the recommended contents. Four caregivers used the app for only two weeks, and half of those ($n = 2$) used the app for only one day. To those parents, other features of the app may not be needed to motivate them to watch the contents. This also suggests that we may need to expand the content to differentiate the user's engagement and motivate their use of the app for a longer period. There were 15 one-minute videos that can all be watched in one sitting, which may have reduced parents' motivation to access the app at later dates. Our final retention rate was 71.4% and similar between the intervention and control groups, showing that it is feasible to consider randomization. This retention rate was between the ranges identified in other eHealth and parent-focused interventions to treat or prevent childhood OB (70%–93%) [60].

This study has some limitations and strengths that deserve attention. Due to the method by which participants were recruited, we were unable to follow a more user-centered design approach before testing the solution. This could be improved in a future iteration, using the information gathered in the study as basis. It would also be useful to conduct a usability test, by analyzing participants' interactions performing each of the app tasks and errors analysis. Additionally, we ended up with six parents in the acceptance test of the app and a minimum of 11 parents would be necessary to detect $\geq$80% of the app problems [61]. However, in the pilot test, there was no difficulty in accessing the app or any reported technical difficulty by the parents, which may indicate that the major technical problems were resolved. As strengths, this solution was evidence-based and developed in collaboration across scientific fields, resulting in a comprehensive multitarget platform. Furthermore, the solution was tested in a real context, being recommended by medical doctors and nurses within health care centers. Additionally, we had a control group, which enabled the testing of the procedure of randomization and of the retention rate for this group.

VI. Conclusion

In this article, we present a solution to support the prevention and treatment of childhood OB at healthcare centers. This solution is based on a platform that is innovative when compared with those existing because: 1) it is directed to both parents and young children and involves them through tailoring and gaming strategies; 2) it is designed to prevent or support the treatment of OB by promoting parents' skills to change the family lifestyle; and 3) it is designed to be used at health care centers. We tested it in a healthcare center, involving the health professionals, parents, and preschool children with OW/OB. This article showed that health professionals accepted this innovative approach and parents accepted the app. We were not able to evaluate the acceptance by children, as the access was controlled by their parents. Parents reported no rejection of the app by children, but further study on this is necessary. Moreover, the platform will benefit from some improvements identified in this study, before running the RCT. We may simplify the "Bulletin," inviting parents to set goals only on topics that children should change. We need to reconsider the social component, perhaps by including the use of a social media platforms already used by participants. Pilot study results suggest the need to develop more content to differentiate the user's engagement and to motivate their use of the app for a longer period. Additionally, we need to connect the serious game to the monitoring website, in order to evaluate the game analytics in a future iteration. After those improvements, we aim to run the RCT with a larger sample, in a multicenter study, to test the impacts of its use on children's behavior and weight status. We may contribute to the development of an effective tool to support the treatment of pediatric OB, in the primary health care setting.

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References

[1] L. Webber *et al.*, "Eating behaviour and weight in children," *Int. J. Obes.*, vol. 33, no. 1, pp. 21–28, 2009.
[2] D. M. Styne *et al.*, "Pediatric obesity-assessment, treatment, and prevention: An endocrine society clinical practice guideline," *J. Clin. Endocrinol. Metab.*, vol. 102, no. 3, pp. 709–757, 2017.
[3] P. DeCosta *et al.*, "Changing children's eating behaviour - A review of experimental research," *Appetite*, vol. 113, pp. 327–357, 2017.
[4] L. L. Birch and M. Deysher, Caloric compensation and sensory specific satiety: Evidence for self regulation of food intake by young children," *Appetite*, vol. 7, no. 4, pp. 323–331, 1986.
[5] M. K. Fox *et al.*, "Relationship between portion size and energy intake among infants and toddlers: Evidence of self-regulation," *J. Amer. Diet Assoc.*, vol. 106, no. 1 Suppl 1, pp. S77–S83, 2006.
[6] S. O. Hughes and A.C. Frazier-Wood, "Satiety and the self-regulation of food take in children: A potential role for gene-environment interplay," *Curr. Obes. Rep.*, vol. 5, no. 1, pp. 81–87, 2016.
[7] L. L. Birch *et al.*, "Clean up your plate: Effects of child feeding practices on the conditioning of meal size," *Learning Motivation*, vol. 18, no. 3, pp. 301–317, 1987.
[8] S. A. French *et al.*, "Eating behavior dimensions. Associations with energy intake and body weight. A review," *Appetite*, vol. 59, no. 2, pp. 541–549, 2012.
[9] M. Rietmeijer-Mentink *et al.*, "Difference between parental perception and actual weight status of children: A systematic review," *Maternal Child Nutr.*, vol. 9, no. 1, pp. 3–22, 2013.
[10] A. Lundahl, K. M. Kidwell, and T. D. Nelson, "Parental underestimates of child weight: A meta-analysis," *Pediatrics*, vol. 133, no. 3, pp. e689–e703, 2014.
[11] P. B. Juliusson *et al.*, "Parental perception of overweight and underweight in children and adolescents," *Acta Paediatr.*, vol. 100, no. 2, pp. 260–265, 2011.
[12] O. G. Jenni, "Starting the debate: Rethinking well-child care in Europe," *J. Pediatr.*, vol. 179, pp. 276–277, 2016.
[13] S. M. Gerards *et al.*, "Parental perception of child's weight status and subsequent BMIz change: The KOALA birth cohort study," *BMC Public Health*, vol. 14, pp. 291, 2014.
[14] A. Perez and G. D. Ball, "Beyond oblivobesity: Seven myths about parental misperception of children's weight," *Child Obes.*, vol. 11, no. 6, pp. 735–737, 2015.
[15] M. Frenn *et al.*, "Authoritative feeding behaviors to reduce child BMI through online interventions," *J. Spec. Pediatr. Nurs.*, vol. 18, no. 1, pp. 65–77, 2013
[16] S. K. Myung *et al.*, "Effects of web- and computer-based smoking cessation programs: Meta-analysis of randomized controlled trials," *Arch. Intern. Med.*, vol. 169, no. 10, pp. 929–937, 2009.
[17] A. O'Brien, "Web-based weight management programs for children and adolescents: A systematic review of randomized controlled trial studies," *ANS Adv. Nurs. Sci.*, vol. 33, no. 1, p. 2, 2010.
[18] S. L. Saperstein, N. L. Atkinson, and R. S. Gold, "The impact of Internet use for weight loss," *Obes. Rev.*, vol. 8, no. 5, pp. 459–465, 2007.
[19] K. Broekhuizen *et al.*, "A systematic review of randomized controlled trials on the effectiveness of computer-tailored physical activity and dietary behavior promotion programs: an update," *Ann. Behav. Med.*, vol. 44, no. 2, pp. 259–286, 2012.
[20] J. Looyestyn *et al.*, "Does gamification increase engagement with online programs? A systematic review," *Plos One*, vol. 12, no. 3, 2017, Art. no. e0173403.
[21] A. S. Miller, J. A. Cafazzo, and E. Seto, "A game plan: Gamification design principles in mHealth applications for chronic disease management," *Health Informat. J.*, vol. 22, no. 2, pp. 184–193, 2016.
[22] D. A. DeWalt and A. Hink, "Health literacy and child health outcomes: A systematic review of the literature," *Pediatrics*, vol. 124, no. Suppl 3, pp. S265–S274, 2009.
[23] S. McCallum, "Gamification and serious games for personalized health," *Stud. Health Technol. Informat.*, vol. 177, pp. 85–96, 2012.
[24] E. A. Edwards *et al.*, "Gamification for health promotion: Systematic review of behaviour change techniques in smartphone apps," *BMJ Open*, vol. 6, no. 10, 2016, Art. no. e012447.
[25] T. Burrows *et al.*, "Nutrition interventions for prevention and management of childhood obesity: What do parents want from an eHealth program?" *Nutrients*, vol. 7, no. 12, pp. 10469–10479, 2015.
[26] J. D. Dias *et al.*, "Serious game development as a strategy for health promotion and tackling childhood obesity," *Revista Latino-Americana de Enfermagem*, vol. 24, 2016, Art. no. e2759.
[27] A. DeSmet *et al.*, "A meta-analysis of serious digital games for healthy lifestyle promotion," *Prev. Med.*, vol. 69, pp. 95–107, 2014.
[28] J. S. Li *et al.*, "Approaches to the prevention and management of childhood obesity: The role of social networks and the use of social media and related electronic technologies: A scientific statement from the American Heart Association," *Circulation*, vol. 127, no. 2, pp. 260–267, 2013.
[29] T. L. Webb *et al.*, "Using the Internet to promote health behavior change: A systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy," *J. Med. Internet Res.*, vol. 12, no. 1, 2010, Art. no. e4.
[30] D. W. Davis *et al.*, "Parent education is changing: A review of smartphone apps," *MCN Amer. J. Maternal Child Nurs.*, vol. 42, no. 5, pp. 248–256, 2017.
[31] D. E. Schoffman *et al.*, "Mobile apps for pediatric obesity prevention and treatment, healthy eating, and physical activity promotion: Just fun and games?" *Transl. Behav. Med.*, vol. 3, no. 3, pp. 320–325, 2013.

[32] N. Feeley *et al.*, "The importance of piloting an RCT intervention," *Can. J. Nurs. Res.*, vol. 41, no. 2, pp. 85–99, 2009.
[33] R. Hu *et al.*, "OB CITY-definition of a family-based intervention for childhood obesity supported by information and communication technologies," *IEEE J. Transl. Eng. Health Med.*, vol. 4, Feb. 2016, Art. no. 2200114.
[34] E. Dusseldorp *et al.*, "Combinations of techniques that effectively change health behavior: Evidence from meta-CART analysis," *Health Psychol.*, vol. 33, no. 12, pp. 1530–1540, 2014.
[35] L. Brand *et al.*, "Training vegetable parenting practices through a mobile game: Iterative qualitative alpha test," *JMIR Serious Games*, vol. 3, no. 2, 2015, Art. no. e6.
[36] A. Beltran *et al.*, "Alpha test of a videogame to increase children's vegetable consumption," *Games Health J.*, vol. 1, no. 3, pp. 219–222, 2012.
[37] A. Beltran *et al.*, "Identifying and clarifying values and reason statements that promote effective food parenting practices, using intensive interviews," *J. Nutrition Educ. Behav.*, vol. 43, no. 6, pp. 531–535, 2011.
[38] D. Thompson, "What serious video games can offer child obesity prevention," *JMIR Serious Games*, 2014. vol. 2, no. 2, 2014, Art. no. e8.
[39] S. L. Johnson, "Improving preschoolers' self-regulation of energy intake," *Pediatrics*, vol. 106, no. 6, pp. 1429–1435, 2000.
[40] H. K. Kabali *et al.*, "Exposure and use of mobile media devices by young children," *Pediatrics*, vol. 136, no. 6, pp. 1044, 2015.
[41] L. Lawton, "Taken by the Tamagotchi: How a toy changed the perspective on mobile technology," *Journal*, vol. 2, no. 2, pp. 1–8, 2017.
[42] S. J. Ahn *et al.*, "Using virtual pets to increase fruit and vegetable consumption in children: A technology-assisted social cognitive theory approach," *Cyberpsychol. Behav. Soc. Netw.*, vol. 19, no. 2, pp. 86–92, 2016.
[43] S. J. Ahn *et al.*, "Using virtual pets to promote physical activity in children: An application of the youth physical activity promotion model," *J. Health Commun.*, vol. 20, no. 7, pp. 807–815, 2015.
[44] PEAKSEL D.O.O. NIŠ, My Virtual Tooth - Virtual Pet. 2016.
[45] Wizdy, Wizdy Pets - Asthma Game, version 30305. 2017.
[46] Nobel Prize, The Diabetic Dog Game. 2009.
[47] J. D. Dias *et al.*, "Serious games as an educational strategy to control childhood obesity: A systematic literature review1," *Revista latino-americana de enfermagem*, vol. 26, pp. e3036–e3036, 2018.
[48] L. J. Ells *et al.*, "Interventions for treating children and adolescents with overweight and obesity: An overview of Cochrane reviews," *Int. J. Obes.*, vol. 42, no. 11, pp. 1823–1833, 2018.
[49] University of Porto. Fammeal Project Website. 2018 11 June 2020]. [Online]. Available: https://fammeal.up.pt
[50] A. E Vaughn, D. S. Ward, and J. O. Fisher, "Fundamental constructs in food parenting practices: A content map to guide future research," *Nutr. Rev.*, vol. 74, pp. 98–117, 2016.
[51] G. Godin and G. Kok, "The theory of planned behavior: A review of its applications to health-related behaviors," *Amer. J. Health Promot.*, vol. 11, no. 2, pp. 87–98, 1996
[52] L. Afonso *et al.*, "A mobile-based tailored recommendation system for parents of children with overweight or obesity: A new tool for health care centers," *Eur. J. Investig. Health, Psychol. Educ.*, vol. 10, no. 3, pp. 779–794, 2020.
[53] H. Schoenau-Fog, "The player engagement process - An exploration of continuation desire in digital games," in *Proc. DiGRA Conf., Think Design Play*, 2011, pp. 1–18.
[54] L. Afonso *et al.*, "Development and usability test of a virtual-pet game to prevent childhood obesity," to be published.
[55] S. E. Benjamin Neelon and M. E. Briley, "Position of the American Dietetic Association: Benchmarks for nutrition in child care," *J. Amer. Diet Assoc.*, vol. 111, no. 4, pp. 607–615, 2011.
[56] ClinicalTrials.gov, "The System Fammeal With Tailored Recommendations and Gamification for Parents to Counteract Childhood Obesity (Fammeal). in March 19, 2019, ClinicalTrials.gov Identifier: NCT03881280 2019. [Online]. Available: https://clinicaltrials.gov/ct2/show/NCT03881280
[57] WHO Multicentre Growth Reference Study Group, *WHO Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development*, ed. World Health Organization. 2006, Geneva.
[58] World Medical Association, "World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects," *JAMA*, vol. 310, no. 20, pp. 2191–2204, 2013.
[59] T. Chang *et al.*, "The role of social media in online weight management: Systematic review," *J. Med. Internet Res.*, vol. 15, no. 11, Art. no. e262, 2013.
[60] M. L. Hammersley, R. A. Jones, and A. D. Okely, "Parent-focused childhood and adolescent overweight and obesity eHealth interventions: A systematic review and meta-analysis," *J. Med. Internet Res.*, vol. 18, no. 7, 2016, Art. no. e203.
[61] W. Hwang and G. Salvendy, "Number of people required for usability evaluation: The 10+-2 rule. *Commun*," *ACM*, vol. 53, no. 5, pp. 130–133, 2010.