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Make Your Garden Grow: Designing a Physical Activity Estimation Improvement Game

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***Abstract*—We present a novel game and virtual world based application that is aimed at improving the physical activity estimation skills of parents. It has been well established that lack of proper estimation of preschool children's activity levels may be one of the main causes for childhood obesity. Childhood obesity has several long term health effects ranging from cardio-vascular disease to type II diabetes and obese preschool children are at risk for later life. We have developed an application that caters to both the parent and the child and uses a virtual garden as a fledgling ecosystem controlled both by the parent and the child. By using a low-cost activity monitoring device and combining the data collected from the device with the estimation inputs from the parent the ecosystem manifests into real life-like visualizations that are updated on a daily basis. The goal of the design is to promote a two way intervention: 1)provide parents with a tool to daily estimate and monitor their child's activity levels and 2)motivate the child to achieve built in goals and keep the ecosystem lively and flourishing. We believe that our design will lead to improved outcomes in physical activity levels as well as long term retention and reuse by the parents. In this paper we are providing the design of the system and in future plan to present the results of a pilot trial.**

I. Introduction

Young preschool children, once thought to be very active, have become more sedentary over time, which has contributed to the high prevalence of overweight/obesity of preschoolers [1]–[4]. Regular physical activity (PA) in youth has been associated with decreased abdominal circumference [5], lower blood pressure [6], reduced mental health issues [7]–[9], improved sleep, cardiovascular health and aerobic fitness [6], increased lean muscle mass, and bone strength [10]. Sedentary behavior and PA of youth have been found to track at a moderate level from early childhood into adolescence/adulthood and to predict adolescent adiposity [11], [12], evidence also suggests that the body mass index (BMI) of early school-aged children can be significantly predicted by modifiable behaviors (e.g., TV viewing, PA) of preschoolers [13], [14]. Furthermore, PA is associated with low levels of later-life overweight and obesity [6], [15], and regular PA results in a decreased adult risk of metabolic syndrome [16], [17], heart disease, hypertension, type 2 diabetes and osteoporosis [18] and plays a significant role in health promotion. Therefore, identifying strategies to increase PA and decrease sedentariness of preschool children is an important approach to preventing childhood obesity.

A systematic review of obesity prevention programs with children, 0-5 years, identified 11 studies that focused on increasing child PA and decreasing sedentariness [19]; 7 measured PA by subjective parent report, 6 of which reported positive changes. PA was objectively measured using accelerometry/pedometry, in 4 studies that were conducted in preschool/childcare settings and demonstrated limited effectiveness on PA (frequent sedentary behavior and low PA levels) [2], [19], [20]. This may be due to limited parental involvement, which is essential in effective healthy lifestyle interventions with preschool children [20] due to the vital role parents play in facilitating sustainable behavior changes in children [19], particularly in regards to PA [21], [22]. Because the lack of parental involvement may have greatly limited the success of previous programs, a home-based intervention focused on family involvement that includes objectively measured PA may be one of the most effective PA promotion intervention strategies with young children [23], [24]. The game "Make Your Garden Grow (MYGG)" targets parent-child interaction and focuses family conversation on healthy PA in a fun way through the use of biobehavioral feedback and parental building of PA estimation skills. The major contribution of this paper is the design of a parent and child intervention delivered via an interactive game based virtual world that tackles several topics such as virtual environments, game based learning and exercise and activity promotion.

II. Related Work

PA in preschool-aged children also has been found to significantly predict change in body mass index (BMI) of 6-8-year-old children [1] and improves mental health outcomes [9]. Identifying methods to increase regular child PA in preschool children is, therefore, critical in altering a childs behavioral health risk profile [15], [25]. Targeting diet and PA in an intervention makes it difficult to identify their individual contribution to outcomes [26], [27]. Previous research suggests that programs focused on either diet or PA showed a small, positive impact on child BMI, but combined approaches did not result in significant BMI change. By testing innovative interventions separately, researchers can better understand their independent contributions to outcomes before conducting a multifaceted intervention trial [20]. Some investigators have found that children, 4-5 years old, had significantly more sedentary time and fewer minutes in light and moderate-to-vigorous physical activity (MVPA) than children who are less than 4 years [28]. Other researchers, however, have found that 1-4-year-old children had significantly less time in MVPA than 4-6-year-old children [29], [30]. With these findings in mind, the design of MYGG has been targeted towards children aged 4-5.

Several game based approaches to promote physical activity and reducing sedentary time have been proposed. In [31] a commercially popular game Dance Dance Revolution (DDR) is used in participant's homes to improve MVPA numbers and [32] compared the use of active video games such as DDR and Wii sports to treadmill walking and found 2-3 fold increases in energy expenditure with active games. In [33] it was found that even though exergaming can reduce screen time and promote activity, it fades in comparison to activity by playing real sports or activities. In essence the real application of games would be to motivate and encourage real world activity and be the drivers of this change. Such motivational interventions that apply game based applications have been successful in promoting healthy eating habits as shown in [34] and [35]. Behavior change and how games can promote it to improve health outcomes has been presented in [36]. Avatars that provide meaning and inspire change in behavior has been explored by many researchers [37]–[39] and representing step count as avatars has been presented in [40]. In [41] the relation between self-presence in the virtual world and actions in the real world are presented. However very little has been done to improve the effectiveness of the parent in estimating the child's PA levels. Avatars and virtual worlds offer a playground for both the parent and child to facilitate discussion and achieve a common goal. This research combines behavior change using avatars with parent child facilitation and goal setting to provide a platform to improve the MPVA levels for children aged 4-5.

III. Significance

Physical activity and sedentariness are important contributing behaviors associated with obesity and thus should be targeted for intervention efforts. There is a wealth of empirical evidence which suggests that obesity treatment interventions have demonstrated limited effects to date and that emphasis might be better placed on prevention interventions [42]. Furthermore, it has been noted that interventions that are implemented with young children and their parents may occur prior to the development of deleterious health habits [43]. Preschool children are greatly influenced by their home environment. Research that has been conducted in childcare settings support this perspective as they have demonstrated limited positive prevention effects to date. The primary aim of this group study is to test the overall feasibility and acceptability of a novel parent skill-building intervention, designed to increase activity levels of 48 non-obese (less than 95th BMI percentile) preschool-aged children (4-5 years) and a parent/legal guardian. The secondary aims are to (a) test the immediate and intermediate (6 months following intervention) effects of this theoretically-based, prevention intervention strategy on parental knowledge, motivation, skill development and PA as they relate to the physical health outcomes of preschool children, (b) obtain information to refine this intervention strategy for use in home settings, and (c) evaluate potential study limitations and alternative strategies to inform and estimate effect size to power a large-scale randomized controlled trial (RCT) in a rigorous efficacy test comparing this activity encouraging

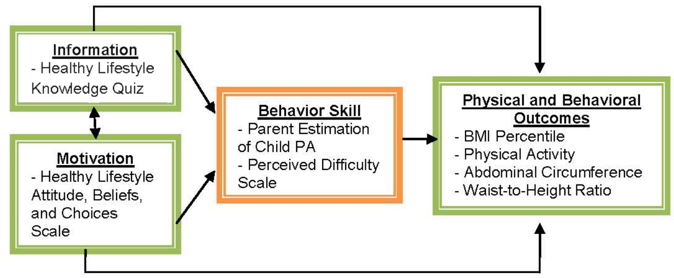

Fig. 1. Diagram depicting the design flow in the IMB model

strategy with other available technologies designed to encourage activity in preschool-aged children. This paper presents the first phase of this research, the design of MYGG that would be installed in the home via a touch screen computer. MYGG includes a computer generated depiction (i.e., an animation) of a child's physical activity level and a skills-building program for parents, which will result in a parent's ability to more accurately assess how active their child is and work with their child to become more active. Increased physical activity in preschool children is associated with many positive health benefits. Emphasis on regular physical activity at an early age may affect healthy habit development, enhance a child's general health, and potentially alter later life weight gain.

IV. Design Methodology

The design of MYGG builds on complementary theories and ideas from behavioral science, avatars, game design and goal-setting. Developed by Fisher and Fisher [44] the information, motivation, and behavior skills (IMB) model, serves as the theoretical foundation for this design (Figure 1). It is an empirically supported, partially mediating model in which information (e.g., for skills building) and motivation (e.g., supported intentions to make healthy choices) result in behavioral skills (e.g., parental skills to estimate and monitor child's PA) for initiating and maintaining preventive health-related behaviors (e.g., increased child PA). MYGG satisfies the following design principles originating from the IMB model:

- ***Modeling:*** The true essence in deriving a successful model, is the the ability of the model to be able to relate to both the child and the parent in ways that demonstrates ideal behaviors that can be easily emulated. We have specifically chosen a garden as the modeling construct to represent the four levels of PA inspired from prior work in estimating PA by tempo and intensity [45]. **a)** Inactive or no activity beyond baseline activities of daily living. **b)** Low activity or activity beyond baseline but fewer than 150 minutes (2 hours and 30 minutes) of moderate-intensity physical activity a week or the equivalent amount (75 minutes, or 1 hour and 15 minutes) of vigorous-intensity activity. **c)** Medium activity or 150 minutes to 300 (5 hours) minutes of moderate-intensity activity a week (or 75 to 150 minutes of vigorous-intensity physical activity a week). **d)** High activity or more than the equivalent of 300 minutes of moderate-intensity physical activity a week. The garden consists of two plants that are central to the ecosystem of flowers,

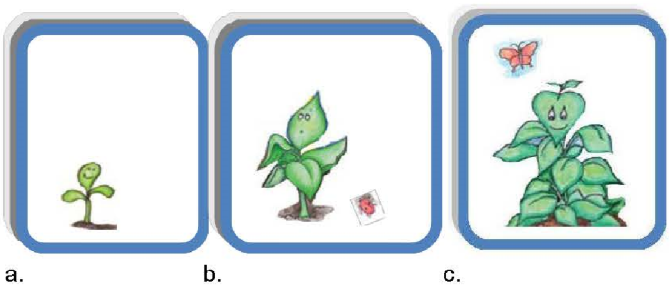

Fig. 2. Accumulated minutes of MVPA a. 15 minutes b. 30 minutes and c. 80 minutes

Fig. 3. The Fitbit accelerometer

bees, insects, birds and if you are extremely active a bear can be sighted as well. One plant represents the estimated levels entered by the parent and the other plant captures the real activity numbers coming from a low-cost pedometer worn by the child. The plant uses a procedural height/branch/leaf generator based on a activity scale generated from the four PA levels. Equation 1 shows the calculation of $scale$ based on the weekly percentages of lightly active, moderately active and highly active levels represented by b,c, and d. The equaltion is reposible for building the proper visual representation for PA and was finalized after several iterations with an obesity expert.

$$scale = (b * 0.3) + (c * 0.3) + (d * 0.4) \quad (1)$$

- ***Positive Reinforcement:*** A key aspect of several games involves rewarding the player when ideal behavior is enacted, MYGG provides an ecosystem that represents built in motivations for the child and parent to keep it flourishing. These are **a)** Environment changes (changes the look and feel of the surroundings, from gloomy over cast clouds, intermittent rain and snow to sunny bright colorful worlds), **b)** Plant posture and growth (changes from leafy, green and flowering to dry and wilting), **c)** Garden ecosystem (results in the number of bees, insects, bugs, birds and other animals that have flocked around the garden)
- ***Social support and skills building:*** The design is heavily dependent on daily communication between the parent and the child and provides an interface to discuss strategies daily before dinner. Parents have the opportunity to set or revise the PA goals, set or revise the PA estimates and launch the game. The length of the game can also be customized to weekly intervals. Over continued use of the game we predict that parents would be able to become accurate estimators of their child's PA and also be able to set effective goals that are achievable over set periods of time.

V. Implementation

In MYGG an animated representation of a plant will depict the regularity and intensity of a childs PA (Figure 2). This virtual garden scene will be visible for parents and children on a touchscreen computer monitor provided to the families. The software will differentiate between the intensities of PA; if a child spends more time in sedentary-light PA, the plant will not grow as rapidly as if he/she spends more time in MVPA. Regularity of the PA will be interpreted by a change in the virtual weather on the display (i.e., sunny, cloudy). Because young children do not carry cell phones, we have designed MYGG so that children wear a small Fitbit accelerometer (Figure 3), which transmits the PA data to the provided computer screen. In MYGG's garden scene, the plant will flourish when the game interprets the accelerometer data (Figure 2). In addition to the plant representing the childs actual activity level, there will be a plant to represent the parents estimate of the childs activity. Each days garden scene will build on the previously saved scene to display an accumulated version of the two plants. The display representing the childs PA will be automatically updated when the child is within 30 feet of the computer. To improve skill-building, parents are instructed on what to observe and discuss daily about the changes in the computerized display. As the parents become more aware of the childs current PA level and the recommendations, they become encouraged to add attainable virtual goals for their child.
The perception parents have of their childs PA has been found to be significantly different from reality. With the two levels of display (actual and parental perception) appearing daily on the computer screen, a parent may more appropriately align his or her estimation of PA with the actual level and the age-specific recommended PA level [46]. Aligning parent estimates of child PA with the actual level may be key in strengthening a parents ability to identify low levels of PA and effectively intervene.

A. Technology

The game was developed using the Microsoft XNA framework [47] and C++ programming language. The software development followed the Agile/Scrum [48] development process. Python was used start and continuously run an application script that would manage any power outages or shut down of the game on the touchscreen. The game communicates with the Fitbit using the OAuth authentication [49] via wi-fi as direct access to the data on the Fitbit is not available. The Fitbit was recently validated as a reliable device to measure step counts in young adults [50]. All four PA levels are tracked by the Fitbit as distance units and step counts. We convert these values and use Equation 1. to estimate the scale value used to animate and grow the plant. Check-in by the child is performed on a 24 hour cycle before dinner time. A transition based animation system is used to animate the plant and the environment as new data gets pushed to the game on a daily basis. Table 1. shows the

Object	State	Condition
weather	stormy	0 check-ins per week
weather	gloomy	1-3 check-ins per week
weather	normal	4-6 check-ins per week
weather	sunny	7 check-ins per week
worm	idle	0 - 150 MVPA minutes per week
worm	moving	greater than 150 MVPA minutes per week
ladybug	idle	150 - 200 MVPA minutes per week
ladybug	moving	greater than 200 MVPA minutes per week
carrot	sprouting	200 - 250 MVPA minutes per week
carrot	harvest	greater than 200 MVPA minutes per week
bird	flying	250 - 300 MVPA minutes per week
bird	nesting	greater than 300 MVPA minutes per week
bear	idle	300 - 350 MVPA minutes per week
bear	moving	greater than 350 MVPA minutes per week

Fig. 4. MYGG complete ecosystem

objects and their states based on goals achieved and check-in frequency. Check-in frequency influences the weather and climate and other environment conditions of the game, it doesnt not effect the garden's growth. The MVPA numbers influence the garden growth and the growth progression and the subsequent ecosystem changes are depicted in Table 1. Parent can then compare their environment and ecosystem progress with those populated by the accelerometer data. Over continued use of the application it is expected that parents would become better estimators.

B. Results

We have successfully completed the implementation of our design and have tested it with 5 students and 2 obesity researchers. Figure 4. shows the complete ecosystem at ideal MVPA numbers. The game always starts showing the several possibilities and then transitions into the current state to motivate and remind the child of the various goals and achievements that are possible. Figure 5. shows the side by side comparison of the two plants at the beginning of the game and Figure 6. shows a simple goal-setting interface that the parents use to estimate PA values before starting the game.

VI. Conclusion and Future Work

In this paper, we have presented the design for a game that helps parents with improving their PA estimation skills and over continued use of the game, achieve several long

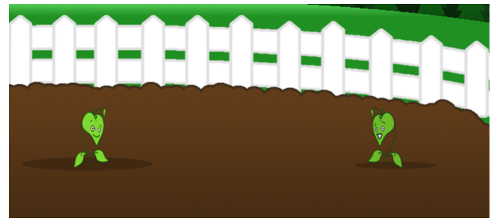

Fig. 5. Parent estimated and actual child's PA being represented by two plants

Fig. 6. Goal setting interface

term childhood obesity prevention goals. In future, we will be conducting real world testing with parents and children in small focus groups and refine the intervention based on usability and other performance improvement metrics. Specifically we will be measuring the baseline demographics, nutrition information, motivation to be healthy, behavior improvement and progress towards daily, weekly and monthly goals as well as Body Mass Index (BMI), waist circumference and waist-to-height ratio at several stages of the intervention. We believe that regular meetings with the parents and educating them with the use of the interface and looking at the above metrics will provide additional motivation and knowledge needed to achieve their goals. MYGG will be further enhanced to have an administrator panel, that will provide researchers access to all the needed data sets and analysis and build those into the application. Furthermore, we will concurrently be conducting a validation study of the Fitbit using the previously validated Actigraph accelerometer to establish the psychometrics of the Fitbit for future use with young children.

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