GAMES FOR HEALTH JOURNAL: Research, Development, and Clinical Applications
Volume 7, Number 2, 2018

DOI: 10.1089/g4h.2017.0102

Virtual Sprouts: A Virtual Gardening Pilot Intervention Increases Self-Efficacy to Cook and Eat Fruits and Vegetables in Minority Youth

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Abstract

Objective: To examine the effect of the *Virtual Sprouts* intervention, an interactive multiplatform mobile gardening game, on dietary intake and psychosocial determinants of dietary behavior in minority youth.
Materials and Methods: In this quasi-experimental pilot intervention, 180 third-, fourth-, and fifth-grade students in Los Angeles Unified School District participated in a 3-week program that included three *Virtual Sprouts* gaming sessions, three in-school lessons, and three in-home activities, using a nutrition- and gardening-focused curriculum. Pre- and postintervention questionnaires were used to assess psychosocial determinants of dietary behavior, including knowledge about and self-efficacy to eat fruits and vegetables (FV). Data were collected on FV, whole grains, fiber, total sugar, added sugar, and energy from sugary beverages through the Block Kids Food Screener (''last week'' version) for Ages 2–17. Repeated measures analysis of covariance models was used for continuous outcomes, controlling for age, sex, ethnicity, school, and free school lunch.
Results: After the intervention, the intervention group ($n=116$) compared with the control group ($n=64$) had a significantly improved self-efficacy to eat FV score (+1.6% vs. −10.3%, $P=0.01$), and an improved self-efficacy to cook FV score (+2.9% vs. −5.0%, $P=0.05$). There were no significant differences in dietary intake or self-efficacy to garden scores between intervention and control groups.
Conclusion: The results from this 3-week pilot study suggest that an interactive mobile game with a nutrition- and gardening-focused curriculum can improve psychosocial determinants of dietary behavior in minority youth.

Keywords: Mobile gardening game, Augmented reality, Pedagogical agent, Human computer interaction, Nutrition, Self-efficacy

Introduction

According to recent estimates, the prevalence of childhood overweight and obesity has reached 33.4% in the United States.[1] Furthermore, the prevalence of childhood obesity among non-Hispanic Black (19.5%) and Hispanic (21.9%) youth surpasses the national rate (17.0%).[2] Children who are overweight and obese are at an increased risk of remaining overweight into adulthood[3] and of adult morbidity.[4] The association between childhood obesity and major health risks in childhood as well as adulthood highlights the urgent need for interventions that target children's dietary behaviors.

There is evidence that fruit[5] and vegetable[6] intake are inversely associated with body weight and obesity.[7] However, it is estimated that 93% of children (1–18 years of age) do not consume the recommended amount of vegetables set by the U.S. Department of Agriculture, and 60% do not

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consume the recommended amount of fruit.[8] School gardening programs have been shown to increase preference of and improve attitudes toward fruits and vegetables.[9,10] However, there are some challenges to implementing school gardens, such as restrictive costs and long-term sustainability.[11] Because children have access to and are familiar with games and technology,[12] a cost-effective and rapidly deployable solution might be to implement an interactive, mobile gardening game that instills comparable garden and nutritional science curriculum to a school garden.

This article introduces *Virtual Sprouts*, a tablet-based educational game that builds on a previous successful school gardening project.[10,13–16] *Virtual Sprouts* was developed to teach nutrition and gardening knowledge to minority and underserved third through fifth graders in Los Angeles, California. The game was grounded in behavior change theory, specifically Self Determination Theory,[17] which differentiates types of motivation, and Social Cognitive Theory,[18] which emphasizes the relationships among person, environment, and behavior. The intervention was designed specifically to target the hypothesized psychosocial determinants of dietary behavior. The aim of this study was to examine the effect of the *Virtual Sprouts* intervention on dietary intake and psychosocial determinants of dietary behavior. The hypotheses are that students who participate in the *Virtual Sprouts* pilot intervention compared with control participants will have greater improvements in gardening knowledge; preference for and motivation to eat fruits and vegetables; self-efficacy to cook and eat fruits and vegetables; and dietary intake of fruits and vegetables.

Materials and Methods

This study was registered on clinicaltrials.gov (Identifier # NCT02017158).

Participants

A convenience sample of 180 predominantly minority and underserved third-, fourth-, and fifth-grade students at two public elementary schools from Los Angeles Charter Schools was included in this quasi-experimental intervention study (Fig. 1). At both schools, two classrooms for each grade (third to fifth) were recruited, one received the intervention and one was in the control condition, for a total of 12 classrooms (six per school). Students in the intervention classrooms participated in the *Virtual Sprouts* intervention for 3 weeks ($n = 116$). Students in the control classrooms were invited to participate as control participants ($n = 64$) and participated in the pretest and posttest measurement only. This study was approved by the Institutional Review Board of the University of Southern California and review boards of participating Charter Schools. Informed written consent from parents and assent from children were obtained. The reporting of the *Virtual Sprouts* study adheres to the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) guidelines.[19]

Description of the intervention

Participants played *Virtual Sprouts* on tablets for one classroom hour a week, and received special *Virtual Sprouts* curriculum for 1 hour a week. There was one family home activity per week for 3 weeks, each typically spanning over the course of 3 days. All lesson and activity materials were provided to teachers and families. Control participants did not participate in any gameplay or receive *Virtual Sprouts* curriculum between pre- and post-measurements.

Description of the Virtual Sprouts game. The *Virtual Sprouts* game includes a series of cooking and gardening

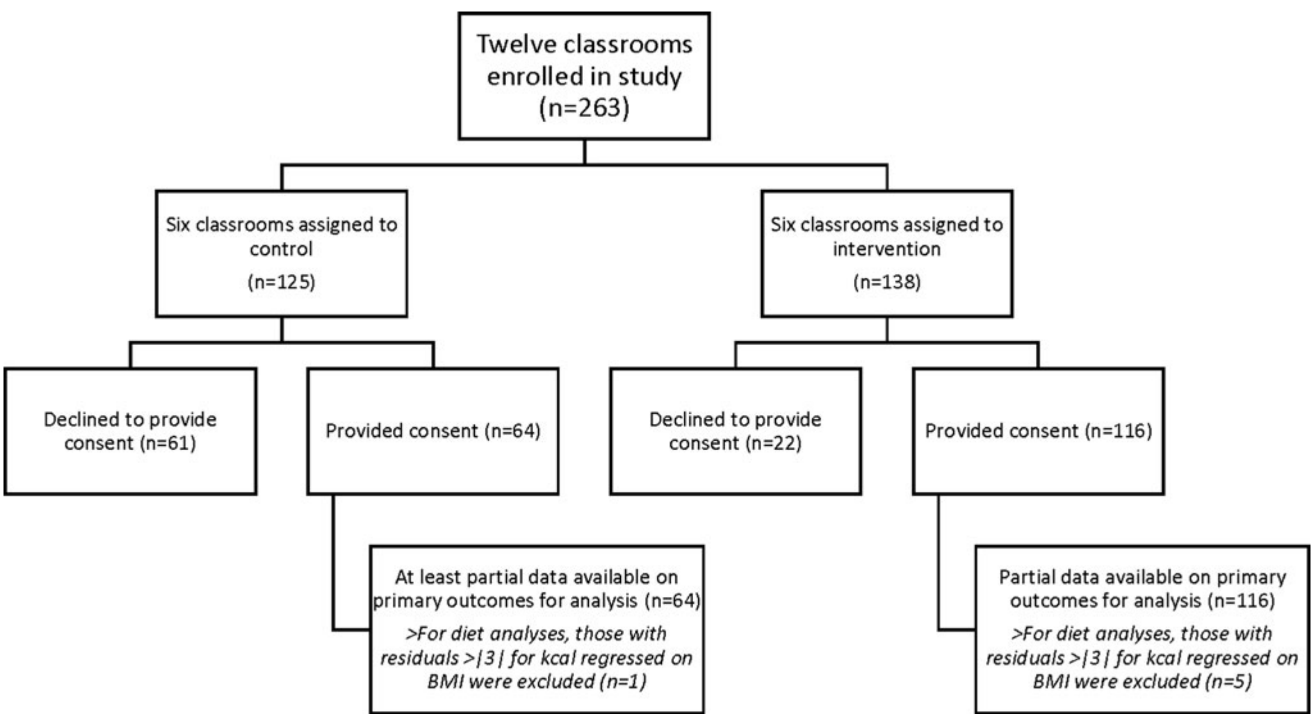

FIG. 1. Flow of participants through the Virtual Sprouts study.

Table 1. Characteristics of a Videogame for Health: *Virtual Sprouts*

Health topic: Childhood obesity
Targeted age group: age 9–12
Other targeted group characteristics: none

Short description of game idea: *Virtual Sprouts* is an educational game that invites players to explore gardening and cooking. In the game, players can grow fruits and vegetables in a virtual garden and prepare meals that meet the nutritional needs and cravings of Dotty, a virtual Ladybug. Suggestions and feedback are designed to promote learning and behavior change.

Target player(s): individual
Guiding knowledge or behavior change theories, models, or conceptual frameworks: Self-Determination Theory; Social Cognitive Theory
Intended health behavior changes: increase in psychosocial measures (self-efficacy to eat/cook/garden FV, intrinsic/extrinsic motivation); increase in fruit and vegetable intake
Knowledge elements to be learned: science and practice of gardening; procedures of healthy meal preparation; nutritional value of recipes and ingredients
Behavior change procedures (taken from Michie inventory) or therapeutic procedures employed: problem-solving, review of outcome goals, present instructive information, modeling, rehearsal and practice, adopt the perspective of a model, present feedback about performance, rewards dependent on success, and rewards dependent on effort or progress
Clinical or parental support needed?: no
Data shared with parent or clinician: no
Type of game: simulation; educational

Story

Synopsis (including story arc): the narrative premise of the game is that Dotty, an ambitious bug and master gardener and chef, was intercepted by weevils on her way to a competition and her prepared dish was destroyed. She enlists the player and the player's grandmother's cookbook in a quest to make a new dish in the magical garden and kitchen. The player must choose a recipe that meets Dotty's nutritional needs and preferences/cravings, plant and grow some of the ingredients required by the recipe, and prepare a meal for judging.

How the story relates to targeted behavior change: Dotty is designed to be a knowledgeable partner, to demonstrate a good attitude toward gardening and cooking, and to encourage participation. Furthermore, she is the game's primary conduit for important knowledge about the science of gardening and the nutritional value of the recipes.

Game components

Player's game goal/objectives: to select and complete a recipe that meets Dotty's nutritional needs and preferences/cravings, plant and grow some of the ingredients required by the recipe, and prepare a meal for judging

Rules: (1) meet the pedagogical agent's request for taste and nutrients; (2) grow a seed in season and match its sunlight and humidity requirements; (3) properly assemble the ingredients for the chosen recipe (scored for completeness, nutrition, and creativity); and (4) make good nutritional choices by reducing sugar and increasing fiber

Game mechanics: goal-based simulation environment (growing and tending to seeds and plants, assembling recipe ingredients)

Procedures to generalize or transfer what's learned in the game to outside the game: students received in-class and in-home training that expanded on the same topics introduced in the game (gardening and nutrition science).

Virtual environment

Setting: gardening occurs on a balcony in an urban setting; crops grown in pots with an umbrella to adjust sunlight and a nearby water source that can be moved closer or further away; cooking occurs in a small kitchen with access to a wide range of ingredients

Avatar

Characteristics: knowledgeable, positive, encouraging, patient, friendly, cute, energetic
Abilities: can fly, gives hints and suggestions, guides player through game
Game platform(s) needed to play the game: tablet (iOS, mac Mini)
Sensors used: camera/gyro for augmented reality rewards
Estimated play time: 1 hour

FV, fruits and vegetables.

activities. Our approach leverages narrative, touch-based mobile technologies, and Dotty, a ladybug and pedagogical agent whose job is to help the children learn and navigate the game. Players can choose from a selection of virtual recipes, plant seeds, cultivate fruit and vegetable plants, and use the resulting produce as ingredients while preparing meals (e.g., fruit smoothie, spinach salad) in the virtual kitchen. The player's effort is rewarded through augmented reality (AR) trophies that show up on-screen as a virtual trophy. Further details about the game and Dotty are given in Table 1.

In-class lesson materials. Classroom teachers received training before the intervention and taught the in-class lessons. Lessons were the length of one classroom session and consisted of cooking demonstrations, guided practice (with teacher assistance), independent practice (without teacher assistance), and student reflection on/evaluation of the lessons. The student learning objectives focused on information regarding: the life cycle and functions of plants (weeks 1 and 2) and the application of the USDA's recommended servings of various food groups (week 3).

At-home activity materials. The at-home sessions consisted of hands-on activities that were intended to be completed with the student's family members. The activity curriculum corresponded to the in-class student learning objectives. Activities included planting a mini garden at home (week 1), examining the internal structure of a celery plant (week 2), and designing recipes to incorporate into the family meal plan (week 3). Gardening materials and celery plants were provided to the families.

At the completion of all postintervention measures, the control group participants were given the opportunity to play the *Virtual Sprouts* game on the iPads during a classroom session.

Game development process

The field of human computer interaction (HCI) is highly fragmented and continually evolving its theoretical frameworks, which presents both a challenge and an opportunity for developing and validating theory-driven work.[20] This transdisciplinary research project combined theory and methodologies from several fields toward the design and evaluation of the game and pedagogical agent. Major disciplines represented in this project include psychology, nutrition, education, computer science, design, art, and public health. The theoretical framework underlying game design and pedagogical agent design principles were driven by an evidence-based consensus of the following tenets: (1) learning consists of more than cognitive outcomes, (2) design needs to tap into noncognitive outcomes, (3) games are cognitive-affective systems, and (4) behavior change could be attained through affective balance mediated by pedagogical agents.

The game was developed for the Apple iPad® mini with the Unity game engine and the Vuforia AR Software Development Kit (SDK). Dotty was built using LURE (Little Unity Rule Engine), a lightweight authoring tool for knowledge representation and control of agents in Unity3D developed by the authors.

The team developed an alpha version (feature-complete) digital prototype of the game through experience,[21] experiential,[22] and participatory[23] design principles at the formative research stage of the project.[24] Before game software development, activities included observation and immersion in cooking and gardening classes designed for children, conducting focus groups with stakeholders, surveying school and home technology penetration and behavior, paper prototyping and concept testing with stakeholders, and conducting observational studies with existing games.

Measurements

Data were collected before and after the intervention in the classroom through questionnaires, objectively measured height and weight, and a food recognition and taste test.

Demographics. Participants were asked to provide basic demographic information, including their age, sex, and race/ethnicity. The questionnaire included questions about the primary language spoken at home, mother's car ownership, and free/reduced lunch eligibility.

Anthropometrics. Height, weight, body fat percentage, and waist circumference were measured in all participants in a private section of a room, using a portable stadiometer and a research-grade Tanita scale (model TBF 300). Body mass index (BMI) and age- and sex-specific BMI percentiles were determined using the Centers for Disease Control and Prevention SAS program.[25]

Dietary intake. Intake of fruits and vegetables was measured in all participants by the Block Kids Food Screeners (''last week'' version) for Ages 2–17.[26,27] The screener contains 41 items that asks about food eaten the previous day, with outcomes measured in number of servings. The screener has been validated in metropolitan area youth.[28]

Preferences for, motivation, and self-efficacy to cook and eat fruits and vegetables. Measures to assess preferences for,[29] motivation,[30,31] and self-efficacy[32] to cook and eat fruits and vegetables were adapted from a range of developed and validated questionnaires. The questionnaires used in this study were previously developed for the LA Sprouts gardening intervention, described elsewhere in detail.[13] These measures were included in the pre- and posttest questionnaires.

Twenty-five questions asked about the level of overall preference for commonly eaten fruits and vegetables on a 4-point scale (where 1 = I like it a lot, 2 = I like it a little, 3 = I do not like it, and 4 = I do not know what it is). Seven questions assessed motivation relating to eating fruits and vegetables on a 4-point scale. Fourteen questions assessed self-efficacy to choose, cook, and eat fruits and vegetables on a 4-point scale.

Statistical analyses

For questionnaire scale measures (self-efficacy, motivation, fruit preferences, and vegetable preferences), Cronbach's alpha values were obtained and factor analyses were performed. Cronbach's alpha values were 0.80, 0.70, 0.59, and 0.89, respectively, for the aforementioned constructs. From factor analyses, self-efficacy and motivation did not factor into hypothesized subconstructs, so subconstructs were defined based on theory. Specifically, these were self-efficacy to eat fruits and vegetables, self-efficacy to cook FV, and self-efficacy to garden, autonomous motivation, and controlled motivation. For both fruit and vegetable preferences, one factor was acceptable from the factor analyses.

T-test and chi-squared test statistics were obtained to detect differences between groups at baseline. Repeated measures analysis of covariance was used with the following a priori covariates: age, sex, race/ethnicity, school, and free/reduced lunch eligible. Total energy (kcal/day) was used as a covariate in dietary models, and mixed models were used to account for energy intake at baseline and follow-up. For these analyses, energy intake was partitioned into two variables: mean energy intake per day for each participant; and deviation from the mean at each time point. Dietary models were also run with total energy (kcal/day) excluded as a covariate. Models were assessed to ensure that statistical assumptions were met. The number of missing observations varied by the measured item; hence, observations with missing data for certain measurements were disregarded in

Table 2. Baseline Characteristics of *Virtual Sprouts* Participants and Control Participants (N = 180)

Characteristic	Virtual Sprouts (n = 116)	Control participants (n = 64)	P[a]
	mean (SD)		
Age (years)	9.9 (0.9)	9.8 (0.9)	0.40
Anthropometrics[b]			
BMI z-score	0.5 (1.0)	0.7 (1.1)	0.25
BMI percentile	64.2 (27.5)	67.8 (29.4)	0.43
	n (%)		
≥85th percentile	32 (30.8)	23 (39.0)	0.29
≥95th percentile	12 (11.5)	13 (12.5)	0.18
Sex, male	60 (51.7)	24 (37.5)	0.07
Race/ethnicity[c]			0.64
Latino	11 (9.5)	7 (11.3)	
White	0 (0)	1 (1.6)	
Black	73 (63.0)	36 (58.1)	
Native American	1 (0.9)	0 (0)	
Mixed Race	30 (25.9)	18 (29.0)	
Other	1 (0.9)	0 (0)	
Mother has car, yes[d]	89 (82.4)	34 (77.3)	0.47
Language at home[e]			0.56
English	86 (77.5)	36 (80.0)	
English and another language	2 (1.8)	2 (4.4)	
Another language	23 (20.7)	7 (15.6)	
Eligible to receive free lunch, yes[f]	107 (92.2)	45 (72.6)	**<0.01**
	mean (SD)		
Attitude/perceptions			
Total self-efficacy[e,g]	3.3 (0.5)	3.3 (0.6)	0.40
Total motivation[e,g]	3.0 (0.6)	3.3 (0.6)	**<0.01**
Extrinsic motivation[g,h]	2.7 (0.7)	3.1 (0.6)	**<0.01**
Intrinsic motivation[e,g]	3.3 (0.8)	3.5 (0.8)	0.37
Fruit preferences[h,i]	1.3 (0.4)	1.2 (0.2)	0.44
Vegetable preferences[e,i]	1.8 (0.5)	1.9 (0.5)	0.56
Nutrient[j]			
Vegetables (cup equivalent, no potatoes/day)	1.4 (1.5)	1.0 (1.1)	0.06
Fruit (cup equivalent/day)	2.2 (1.6)	1.8 (1.4)	0.13
Whole grains (ounce/day)	1.0 (1.2)	0.8 (0.9)	0.19
Fiber (g/day)	21.6 (19.2)	16.0 (13.7)	**0.04**
Total sugar (g/day)	138.3 (104.3)	120.7 (91.8)	0.29
Added sugar (tsp/day)	15.6 (14.9)	14.1 (14.8)	0.55
Energy from sugary beverages (kcal/day)	87.1 (128.9)	103.1 (137.2)	0.46
Total energy (kcal/day)	2570.5 (2331.3)	1970.9 (1597.0)	0.06

[a]*P*-values were calculated using *t* tests and χ^2 tests (for continuous and categorical variables, respectively). Bold indicates $P < 0.05$.
[b]$n = 163$, [c]$n = 178$, [d]$n = 152$, [e]$n = 156$, [f]$n = 178$, [h]$n = 155$, [j]$n = 165$.
[g]Self-efficacy and motivation scores range from 1 to 4.
[i]Preference scores range from 1 to 3.
BMI, body mass index (calculated as kg/m^2).

analyses, including the measured item. Intention-to-treat analyses were performed on all data. All analyses were performed using the Statistical Analysis Software (Cary, NC, version 9.3) with an alpha value set at $P = 0.05$.

Results

Participant characteristics

One hundred sixteen of the 138 students (84%) from the intervention-designated classrooms agreed to participate in the *Virtual Sprouts* intervention, and 64 of the 125 students (51%) from the control-designated classrooms agreed to participate in the control group (Fig. 1). Compared with the control participants, *Virtual Sprouts* participants were somewhat more likely to be male (51.7% vs. 37.5%, $P = 0.07$) and were more likely to receive free/reduced lunches at school (92.2% vs. 70.3%, $P < 0.01$) (Table 2). *Virtual Sprouts* participants also had a higher baseline mean intake of dietary fiber (21.6 g/day vs. 16.0 g/day, $P = 0.04$). *Virtual Sprouts* participants had a lower mean total motivation to eat fruits and vegetables (FV)

Table 3. Change in Characteristics Between *Virtual Sprouts* Participants and Control Participants ($N=180$)

	Virtual Sprouts (n = 116)			Control (n = 64)			
	Pre	*Post*	*Mean change*	*Pre*	*Post*	*Mean change*	
Characteristic	*mean (SE)*			*mean (SE)*			P
Anthropometrics[a]							
BMI z-score	0.07 (0.34)	0.05 (0.35)	–0.02	0.35 (0.33)	0.31 (0.34)	–0.04	0.30
BMI percentile	52.26 (9.52)	52.07 (9.78)	–0.19	58.54 (9.24)	57.48 (9.49)	–1.06	0.32
Attitude/perceptions							
Total self-efficacy[b,c]	3.08 (0.17)	3.14 (0.17)	0.06	3.20 (0.17)	2.96 (0.17)	–0.24	**0.01**
Self-efficacy to eat FV[b,c]	3.07 (0.19)	3.12 (0.22)	0.05	3.19 (0.20)	2.86 (0.22)	–0.33	**0.01**
Self-efficacy to cook FV[b,d]	3.10 (0.19)	3.19 (0.19)	0.09	3.22 (0.19)	3.06 (0.19)	–0.16	**0.05**
Self-efficacy to garden[b,e]	3.07 (0.26)	3.13 (0.26)	0.06	3.20 (0.27)	3.05 (0.26)	–0.15	0.36
Total motivation[b,c]	2.92 (0.18)	2.71 (0.21)	–0.21	3.17 (0.19)	2.65 (0.22)	–0.52	**0.03**
Extrinsic motivation[b,f]	2.65 (0.21)	2.37 (0.25)	–0.28	3.02 (0.21)	2.37 (0.26)	–0.65	**0.02**
Intrinsic motivation[b,c]	3.26 (0.25)	3.20 (0.27)	–0.06	3.37 (0.25)	3.07 (0.27)	–0.30	0.21
Fruit preferences[g,h]	1.33 (0.11)	1.18 (0.10)	–0.15	1.29 (0.11)	1.26 (0.11)	–0.03	0.09
Vegetable preferences[c,g]	1.77 (0.14)	1.71 (0.15)	–0.06	1.81 (0.15)	1.73 (0.15)	–0.08	0.87
Nutrient[i]							
Vegetables (cups/day)	0.74 (0.44)	1.52 (0.41)	0.78	0.61 (0.43)	1.62 (0.40)	1.01	0.38
Fruit (cup equivalent/day)	2.02 (0.51)	3.19 (0.55)	1.17	1.65 (0.50)	3.12 (0.53)	1.47	0.41
Whole grains (ounce/day)	0.61 (0.34)	0.98 (0.37)	0.37	0.54 (0.33)	0.90 (0.36)	0.36	0.97
Fiber (g/day)	14.99 (5.63)	22.84 (5.09)	7.85	11.83 (5.49)	22.34 (4.96)	10.51	0.38
Total sugar (g/day)	121.16 (31.33)	163.89 (30.69)	42.73	111.18 (30.54)	158.04 (29.92)	46.86	0.83
Added sugar (tsp/day)	13.36 (4.62)	15.64 (4.38)	2.28	13.75 (4.51)	14.61 (4.27)	0.86	0.59
Energy from sugary beverages (kcal/day)	111.08 (42.69)	60.83 (36.11)	–50.25	127.15 (41.63)	66.96 (35.21)	–60.19	0.75

Repeated measures analysis of covariance were performed, adjusting for a priori covariates: age, sex, race/ethnicity, school, free lunch option. Dietary variables were also adjusted for energy. For diet data, those with residuals >|3| for kcal regressed on BMI were excluded ($n=6$). Bold indicates $P<0.05$.

[a] $n=141$; VS $n=91$; control $n=50$.

[b] Self-efficacy and motivation scores range from 1 to 4.

[c] $n=143$; VS $n=102$; control $n=41$.

[d] $n=141$; VS $n=100$; control $n=41$.

[e] $n=139$; VS $n=100$; control $n=39$.

[f] $n=142$; VS $n=102$; control $n=40$.

[g] Preference scores range from 1 to 3.

[h] $n=142$; VS $n=101$; control $n=41$.

[i] $n=135$; VS $n=89$; control $n=46$.

FV, fruits and vegetables; VS, *Virtual Sprouts*.

score (3.0 vs. 3.3, $P<0.01$) and a lower mean extrinsic motivation to eat FV score (2.7 vs. 3.1, $P<0.01$) at baseline. There were no significant differences between the intervention and control groups for the remaining baseline measures.

Main outcomes

After the 3-week intervention, *Virtual Sprouts* participants had improved aggregated self-efficacy to eat, cook, and garden FV compared with control participants (1.9% increase vs. 7.5% decrease, respectively; $P=0.01$). Their mean self-efficacy to eat fruits and vegetables score increased 1.6%, compared with a 10.3% decrease in the control group ($P=0.01$). They also had an improved self-efficacy to cook FV score (2.9% increase vs. 5.0% decrease, respectively; $P=0.05$). However, there was not a significant increase in the self-efficacy to garden factor scores for *Virtual Sprouts* participants (Table 3).

The intervention group had a significantly lower decrease in total motivation to eat FV as compared with the control group, (decrease by 7.2% and 16.4%, respectively; $P=0.03$) and a significantly lower decrease in extrinsic motivation as compared with the control group (decrease by 10.6% and 21.5%, respectively; $P=0.02$).

There were no significant differences observed between the intervention and control groups for any of the dietary intake measures (vegetables, fruit, whole grains, fiber, total sugar, added sugar, energy from sugary beverages) or FV preferences, nor for BMI z-scores or percentiles. Dietary models excluding total energy (kcal/day) as a covariate were also nonsignificant (data not shown). Body fat percentage and waist circumference were also measured with the Tanita scale at baseline and posttest, and no significant changes were observed.

There were no significant differences in age ($P=0.33$), sex ($P=0.64$), race/ethnicity ($P=0.96$), socioeconomic status indicators ($P=0.72$ for mother car ownership; $P=0.64$ for child free school lunch eligibility), or BMI z-scores ($P=0.29$) between students lost to follow-up and those who participated in the posttest, overall and by condition.

Discussion

Results from this study indicate that a 3-week virtual gardening game, with nutrition- and science-based educational components increased self-efficacy to cook and eat FV in predominately Hispanic and Black third- through fifth-grade elementary school students.

Longer school garden interventions (ranging from 3 to 5 months) have resulted in increased preferences for FV[10,33] and increased self-efficacy to eat FV.[34] These psychosocial variables have been shown to influence FV intake in adolescents,[35,36] and furthermore, there is evidence that self-efficacy contributes significantly to eating behavior.[37] This *Virtual Sprouts* intervention saw an increase in self-efficacy, which is a successful outcome for such a short pilot study. A recent review on school gardens by Davis, Spaniol, and Somerset[9] found that all three school garden studies that measured self-efficacy to prepare, cook, and/or garden FV resulted in improvements in self-efficacy and in dietary intake after the completion of the intervention.

Decreases in all self-efficacy measures in the control group were observed as well. Both prevention and intervention were taken into consideration during the design phase of this school-based study to target a wide range of weight statuses within the classroom ($\sim$33.4% of children are overweight or obese[1]). Longer follow-up of school-based interventions have shown successes in preventing an unfavorable increase in anthropometric[38] and BMI[39] outcomes in those receiving an intervention, whereas the control groups saw an increase in these outcomes. Similarly, the VS intervention was successful in not only maintaining, but also increasing the self-efficacy of students, whereas their control counterparts reported declines in self-efficacy.

The *Virtual Sprouts* intervention also significantly slowed observed decreases in total and extrinsic motivation to eat FV. While both groups had decreases in motivation to eat FV, the control group had steeper decreases compared with the intervention group (–16% vs. –7%; $P = 0.03$). There were similar decreases in both groups for extrinsic motivation score as well (–22% vs. –11%; $P = 0.02$). As reasoned above, the VS intervention prevented a significant decrease in students' motivation to eat FV, compared with the at-risk population of students whose motivation may have naturally decreased over time.

The 3-week *Virtual Sprouts* intervention did not significantly change dietary intake (of fruits, vegetables, whole grains, fiber, total and added sugar, and energy from sugar-sweetened beverages) or BMI. However, longer gardening interventions have shown significant changes in dietary, anthropometric, and metabolic variables.[15] A similar target population was evaluated in the LA Sprouts study,[13] a 12-week school gardening program in Los Angeles, CA. The overweight subsample of participants in the LA Sprouts intervention had significant reductions in BMI compared with the control group.[13] This subsample also had significantly different changes in dietary intake compared with the overweight controls (0% change vs. 29% decrease) by the end of the 12-week intervention.[13] The psychosocial and dietary measures developed for the LA Sprouts intervention were used for the *Virtual Sprouts* intervention, so it is possible that a 3-week period was not long enough to successfully change dietary intake or anthropometric variables.

Future directions

The *Virtual Sprouts* game showed significant promise. The game was developed to provide the framework for further development, such as the addition of more content (e.g., recipes, characters) and development to sustain a longer intervention interval. However, as commercial interactive multiplatform games have become more popular, accessible, and affordable; they have also become increasingly sophisticated. It is extremely costly to develop the kind of slick and sophisticated games to which most people have become accustomed. Public/private partnerships might be needed to develop and sustain interactive games that offer a full cast of characters, multitudes of recipes, and hours of engaging play. Such relationships could help the scalability of these projects into commercial releases. The success of these products also requires inclusion of a basic curriculum and teacher training that could be delivered online or during teacher professional development days. In addition, the game would require tablets and expansion into the Android platform, but tablet ownership is rapidly growing,[40] as are ''phablets,'' which are large smartphones, similar in size to the iPad mini.

Members of the *Virtual Sprouts* team have had a positive experience with an educational product (The Brain Architecture Game[41]) that was recently commercially released worldwide through a seed fund by a private foundation. Revenue from the game is reinvested into the project to sustain it. *Virtual Sprouts* was funded through a federal grant, which expects that a release of products be made freely available to the public, but this model is almost impossible to execute with entertainment products, unless there is continuous investment by an external sponsor. For projects to be discoverable and inspire confidence in their use, some investment has to be made in the production quality of the experience design of the product. This means some aspect of the product must generate revenue that can be reinvested back into maintaining the product, especially as it would have to keep up with software updates and hardware releases. While it is true that maintenance of *Virtual Sprouts* may be cheaper than a real garden, the cost is not zero. However, the possibility for scaling in terms of size and speed is faster with digital products.

Another possibility would be to use *Virtual Sprouts* as a strong complement or enhancement for existing garden programs. Such games might be able to bolster and/or maintain program effects. As an additional component to a traditional gardening program, *Virtual Sprouts* could be augmented in a future iteration and overcome some of the shortcomings of traditional hands-on gardening programs. Because full-length games can be hard to implement and sustain high adherence, the combination of a gardening program (e.g., LA Sprouts) and a mobile gardening game (e.g., *Virtual Sprouts*) could employ the advantageous features of each. Future research is needed to understand the interaction between these two types of programs.

Limitations

There are several limitations of the current study. First, while baseline characteristics were largely the same between the intervention and control group, this is a quasi-experimental design. The schools requested that students be consented after classes were selected, therefore, they were not blinded to condition at consent. This might have contributed to the difficulty in recruiting control samples, leading to an imbalance in sample size between the intervention and control groups ($n = 116$ vs. $n = 64$, respectively). Thus, there may not have been enough participants in the control group to detect significant BMI or dietary intake changes.

The loss to follow-up shown in Figure 1 (36% of control participants and 12% of intervention participants) might have been due to the timing of the posttest data collection. Posttest data collection occurred very close to summer vacation (late May) and there was a large classroom absence rate during this time. We were only able to collect posttest information in the classroom, so we were not able to collect the posttest information from those students who were absent on the day of collection. As mentioned earlier, there were no significant differences in age, sex, race/ethnicity, socioeconomic status indicators, or BMI z-scores between students lost to follow-up, and those who participated in the posttest.

Another limitation was the short length of the intervention. The *Virtual Sprouts* participants only played the *Virtual Sprouts* game once per week for 3 weeks (three times total), which may not have provided adequate exposure to the game. However, the fact that the *Virtual Sprouts* game was able to move the needle on important determinants of dietary intake in 3 weeks is extremely novel. Lastly, the sample was predominantly Black and Hispanic, so our results may not be generalizable to nonminority and nonurban youth populations.

Conclusions

The results from this 3-week pilot study of a mobile interactive educational game with a nutrition- and gardening-focused curriculum suggest that such an intervention can improve self-efficacy to cook and eat FV in minority youth. Changes in psychosocial determinants have been shown to lead to changes in diet and, consequently, obesity,[13] so the results from this brief intervention are promising. Public health researchers should consider a mobile educational game as a possible alternative or addition to school gardens for pediatric obesity interventions.

Acknowledgments

This research was funded by the National Institute of Health–Science Education Partnership Award (Grant No. 1R25RR032159-01). B.M.B. is funded by NSF Grant No. 1521722. The authors would also like to thank Apple™ for their generous loan of iPads and other equipment that made this work possible.

Author Disclosure Statement

M.G. receives financial compensation as a consultant from AppliedVR. No competing financial interests exist for the remaining authors.

References

1. Fryar CD, Carroll MD, Ogden CL. *Prevalence of Overweight and Obesity Among Children and Adolescents Aged 2–19 Years: United States, 1963–1965 Through 2013–2014*. Health E-Stats; 2016.
2. Ogden CL, Carroll MD, Fryar CD, Flegal KM. Prevalence of obesity among adults and youth: United States, 2011–2014. NCHS Data Brief 2015:1–8.
3. Singh AS, Mulder C, Twisk JW, et al. Tracking of childhood overweight into adulthood: A systematic review of the literature. Obes Rev 2008; 9:474–488.
4. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: Systematic review. Int J Obes (Lond) 2011; 35:891–898.
5. Alinia S, Hels O, Tetens I. The potential association between fruit intake and body weight—A review. Obes Rev 2009; 10:639–647.
6. Kepper M, Tseng TS, Volaufova J, et al. Pre-school obesity is inversely associated with vegetable intake, grocery stores and outdoor play. Pediatr Obes 2016; 11:e6–e8.
7. Ventura E, Davis J, Byrd-Williams C, et al. Reduction in risk factors for type 2 diabetes mellitus in response to a low-sugar, high-fiber dietary intervention in overweight Latino adolescents. Arch Pediatr Adolesc Med 2009; 163:320–327.
8. National Cancer Institute. Usual dietary intakes: Food intakes, U.S. population, 2007–10. 2015. http://epi.grants.cancer.gov/diet/usualintakes/pop/2007-10/ (accessed April 28, 2017).
9. Davis JN, Spaniol MR, Somerset S. Sustenance and sustainability: Maximizing the impact of school gardens on health outcomes. Public Health Nutr 2015; 18:2358–2367.
10. Gatto NM, Ventura EE, Cook LT, et al. LA Sprouts: A garden-based nutrition intervention pilot program influences motivation and preferences for fruits and vegetables in Latino youth. J Acad Nutr Diet 2012; 112:913–920.
11. Ozer EJ. The effects of school gardens on students and schools: Conceptualization and considerations for maximizing healthy development. Health Educ Behav 2007; 34: 846–863.
12. American Speech-Language-Hearing Association; http://www.asha.org/About/news/Press-Releases/2015/New-ASHA-Survey-of-US-Parents-Significant-Percentages-Report-That-Very-Young-Children-Are-Using-Technology/ (accessed April 28, 2017).
13. Davis JN, Ventura EE, Cook LT, et al. LA Sprouts: A gardening, nutrition, and cooking intervention for Latino youth improves diet and reduces obesity. J Am Diet Assoc 2011; 111:1224–1230.
14. Davis JN, Martinez LC, Spruijt-Metz D, Gatto NM. LA Sprouts: A 12-week gardening, nutrition, and cooking randomized control trial improves determinants of dietary behaviors. J Nutr Educ Behav 2016; 48:2–11.e11.
15. Gatto NM, Martinez LC, Spruijt-Metz D, Davis JN. LA sprouts randomized controlled nutrition, cooking and gardening programme reduces obesity and metabolic risk in Hispanic/Latino youth. Pediatr Obes 2017; 12:28–37.
16. Martinez LC, Gatto NM, Spruijt-Metz D, Davis JN. Design and methodology of the LA Sprouts nutrition, cooking and gardening program for Latino youth: A randomized controlled intervention. Contemp Clin Trials 2015; 42:219–227.
17. Deci EL, Ryan RM. *Intrinsic Motivation and Self-Determination in Human Behavior*, 1 ed. New York, NY: Plenum Press; 1985.
18. Bandura A. *Social Foundations of Thought and Action: A Social Cognitive Theory.* Englewood Cliffs, N.J.: Prentice-Hall; 1986.
19. Des Jarlais DC, Lyles C, Crepaz N. Improving the reporting quality of nonrandomized evaluations of behavioral and

public health interventions: The TREND statement. Am J Public Health 2004; 94:361–366.
20. Hekler EB, Klasnja P, Froehlich JE, Buman MP. Mind the theoretical gap: Interpreting, using, and developing behavioral theory in HCI research. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). ACM, New York, NY, USA.
21. Blythe M, Wright P, McCarthy J, Bertelsen O. Theory and method for experience centered design. In: CHI '06 Extended Abstracts on Human Factors in Computing Systems. ACM, New York, NY, USA.
22. Ryong W. A holistic experiential approach to design innovation. J Korean Soc Des Sci 2008; 21:167–180.
23. Muller M, Kuhn S. Participatory design. Commun ACM 1993; 36:24–28.
24. Wen CK, Auerbach D, Turpin D, et al. User-centered design of Virtual Sprouts: A mobile device-based gardening and cooking game for promoting dietary behavior change among minority school children. In: Proceedings of the Wireless Health 2014 on National Institutes of Health. ACM, New York, NY, USA.
25. CDC Division of Nutrition Physical Activity and Obesity. A SAS Program for the 2000 CDC Growth Charts (ages 0 to <20 years). 2016; www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm (accessed June 13, 2017).
26. Garcia-Dominic O, Treviño RP, Echon RM, et al. Improving quality of Food Frequency Questionnaire response in low-income Mexican American children. Health Promot Pract 2012; 13:763–771.
27. Nutrition Quest. Block food screeners for ages 2–17 2007. www.nutritionquest.com/assessment/list-of-questionnaires-and-screeners/ (accessed April 28, 2017).
28. Hunsberger M, O'Malley J, Block T, Norris JC. Relative validation of Block Kids Food Screener for dietary assessment in children and adolescents. Matern Child Nutr 2015; 11:260–270.
29. Domel SB, Baranowski T, Davis H, et al. Measuring fruit and vegetable preferences among 4th- and 5th-grade students. Prev Med 1993; 22:866–879.
30. Ryan RM, Connell JP. Perceived locus of causality and internalization: Examining reasons for acting in two domains. J Pers Soc Psychol 1989; 57:749–761.
31. Williams GC, Grow VM, Freedman ZR, et al. Motivational predictors of weight loss and weight-loss maintenance. J Pers Soc Psychol 1996; 70:115–126.
32. Baranowski T, Davis M, Resnicow K, et al. Gimme 5 fruit, juice, and vegetables for fun and health: Outcome evaluation. Health Educ Behav 2000; 27:96–111.
33. Ratcliffe MM, Merrigan KA, Rogers BL, Goldberg JP. The effects of school garden experiences on middle school-aged students' knowledge, attitudes, and behaviors associated with vegetable consumption. Health Promot Pract 2011; 12:36–43.
34. Evans A, Ranjit N, Rutledge R, et al. Exposure to multiple components of a garden-based intervention for middle school students increases fruit and vegetable consumption. Health Promot Pract 2012; 13:608–616.
35. Larson N, Laska MN, Story M, Neumark-Sztainer D. Predictors of fruit and vegetable intake in young adulthood. J Acad Nutr Diet 2012; 112:1216–1222.
36. Franko DL, Cousineau TM, Rodgers RF, et al. Social-cognitive correlates of fruit and vegetable consumption in minority and non-minority youth. J Nutr Educ Behav 2013; 45:96–101.
37. Shannon B, Bagby R, Wang MQ, Trenkner L. Self-efficacy: A contributor to the explanation of eating behavior. Health Educ Res 1990; 5:395–407.
38. Singh AS, Chin APMJ, Brug J, van Mechelen W. Dutch obesity intervention in teenagers: Effectiveness of a school-based program on body composition and behavior. Arch Pediatr Adolesc Med 2009; 163:309–317.
39. Taylor RW, McAuley KA, Barbezat W, et al. Two-year follow-up of an obesity prevention initiative in children: The APPLE project. Am J Clin Nutr 2008; 88:1371–1377.
40. Smith A. Record shares of Americans now own smartphones, have home broadband. Pew Internet & American Life Project 2017. www.pewresearch.org/fact-tank/2017/01/12/evolution-of-technology/ (accessed October 16, 2017).
41. The Brain Architecture Game. https://dev.thebrainarchitecturegame.com/ (accessed October 16, 2017).

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