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Original Articles

Incorporating Behavioral Techniques into a Serious Videogame for Children

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Abstract

Introduction: Little is known about how to design serious videogames for children. The purpose of this article is to describe how behavior change techniques promoting self-regulation were incorporated into a serious videogame to help children consume more fruits and vegetables (FVs) and the extent to which these techniques were used by players. A secondary goal is to contribute to the body of scientific knowledge regarding how to design effective serious videogames for children.
Materials and Methods: This research examines the gameplay data from an effective 10-episode online serious videogame promoting FV consumption to preadolescent children in the United States (roughly 9–11-year-olds).
Results: Children participated in the self-regulation components. Modifications to reduce potential cognitive overload and inform future game design were identified.
Conclusion: This research provided suggestive evidence that behavior change techniques promoting self-regulation can be successfully integrated into a serious videogame for children without detracting from game appeal. It also emphasizes the importance of formative research to the design of an appealing game where children understand and can successfully perform the behavior change procedures.

Keywords: Videos, Nutrition, Behavioral health, Self-regulation

Introduction

Many children[1,2] do not meet federal guidelines for fruit and vegetable (FV) consumption,[3] placing them at risk for cardiovascular disease, type 2 diabetes, and certain cancers.[4–6] Although interventions encouraging children to consume FVs have shown some promise,[7,8] work is still needed to increase the likelihood of sustained change. Serious videogames, that is, engaging videogames that balance entertainment with behavior change,[9,10] are emerging as a potentially important behavior change method.[11,12]

Although there is some evidence about how to design serious videogames to promote dietary behavior change, it remains a challenge. The literature suggests that theory-informed games that integrate behavior change procedures (e.g., goal setting, self-monitoring) into the entertainment components (e.g., story, challenge) may be an effective method for creating appealing games that change behavior, particularly when the game is developed in conjunction with the target audience.[9,10,13,14] This suggests that thoughtful design is important, where a conceptual framework is first developed based on the game purpose, which is then used to inform game design decisions.[15] When operationalizing the conceptual framework, formative research (e.g., interviews, alpha and beta testing) is an important consideration to ensure that designers are aware of players' needs, interests, expectations, comprehension, and how they experience the game (e.g., boring, fun).[13,14,16–18] A recent meta-analysis examining the role of participatory design (i.e., player involvement) in game effectiveness concluded that involving players as testers or informants in the development of key game components (e.g., challenges, levels) was more likely to have a positive impact on game effectiveness than involving them in the more superficial aspects of design (e.g., aesthetics) or as codesigners (e.g., equal partners with game designers).[19]

Regardless of the design approach used, behavior change is the ultimate goal of a serious game for health. Self-regulation, also called self-control or self-directed behavior, is a key concept in behavior change.[20,21] Fundamental behavior change techniques derived from the self-regulation literature include goal setting, self-monitoring, goal review (i.e., reporting), and feedback.[22,23] Planning may also be an important behavior change technique that facilitates goal attainment.[24] Adoption and use of these techniques work together to promote behavior change in both children[25] and

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adults.[22,26] It is likely they facilitate change by enhancing self-efficacy (e.g., confidence in the ability to successfully perform a behavior)[27] and autonomous motivation (self-directed motivation),[28] which have been shown to be key mediators of behavior change in children.[29–33]

Self-efficacy is enhanced through mastery experiences (i.e., experiences of success) as well as through observational learning (i.e., watching respected others successfully accomplish a particular task), feedback (i.e., performance appraisal), verbal persuasion (e.g., encouragement), and emotional arousal (e.g., positive feelings associated with success, such as public recognition of an accomplishment).[27] Autonomous motivation is facilitated by the satisfaction of basic psychological needs: autonomy (i.e., choice, control); competence (i.e., knowledge, skills); and relatedness (i.e., connection to self and important others).[28]

Identifying compelling ways to incorporate behavioral techniques into serious games for children may offer important insights into how to create effective serious games. The purpose of this article is to (1) describe how behavioral techniques promoting self-regulation were incorporated into a serious game promoting dietary behavior change to children, (2) report the degree to which children engaged with these components, and (3) discuss implications of this research for the design of serious games for children.

Materials and Methods

Participants

Fourth and fifth-grade children (roughly 9–11-year-olds) and a parent were recruited from a large city in the southwestern United States for the randomized controlled trial that examined intervention effects on child FV consumption.[34] The sample size ($n = 400$ parent/child dyads) was calculated based on the number of children needed to detect a half serving increase in child FV consumption.

Game description

''S*quire's Quest! II: Saving the Kingdom of Fivealot* (SQ2)'' was a 10-episode action adventure videogame played online. Since the game has been described in greater detail elsewhere,[13,34] it is only briefly described here. A figure of the game components and pathways the player could take through the game has been previously published.[13]

Children were randomized to one of four groups after both parent and child completed baseline data collection. Groups varied only on whether children created an implementation intention as part of goal setting (Action, Coping, Action+Coping, Control). The Action group created an action plan after setting an FV consumption goal, while the Coping group created an if/then plan to overcome barriers that may hinder goal attainment (i.e., coping plan). The children assigned to the Action+Coping group created an action plan, followed by a coping plan, while children assigned to the Control group set an FV consumption goal, but did not create an action or coping plan. FV consumption challenges (i.e., goals) varied by episode and gradually increased in difficulty to increase the likelihood of success (i.e., a mastery experience), thus leading to enhanced self-efficacy.

The goal of SQ2 was to encourage increased FV consumption among players. Children began the game as Squires who were attempting to become Knights in the Kingdom of Fivealot. To demonstrate their worthiness to become Knights in the Kingdom, the Squires (i.e., players) received two challenges each episode (i.e., goals) that had to be met in the real world—one to eat more FVs and one to make a FV recipe demonstrated in the game. FV consumption challenges were issued by the Wizard who served as a mentor for the young Squires as they attempted to gain the coveted knowledge and skill required of Knights in the Kingdom of Fivealot.

The game was grounded in behavior change techniques operationalized within a framework informed by social cognitive[27] and self-determination theories (Table 1).[28] These techniques, goal setting, planning, self-monitoring, goal review, and feedback, were supported by fundamental knowledge (e.g., portion size, eating FV away from home), heuristics (e.g., shortcuts to help remember steps to performing key skills), schemas (e.g., patterns identifying different ways to consume five servings of FVs a day), and virtual recipe demonstrations. These techniques were specifically integrated in the game into a manner designed to promote self-efficacy and autonomous motivation, key mediators of child behavior change.[29–33]

Parents of children enrolled in the game received electronic newsletters and access to a study-only website. Newsletters and website installments complemented game sessions so that parents were aware of what their children were learning each episode and were prepared to support and encourage FV goal attainment. Parent use of these materials has been reported elsewhere.[34]

Goal setting

Goals represent behavioral intention.[24] They provide direction and focus, strengthen motivation, and encourage persistence over time.[35,36] Specific, proximal, and appropriate (i.e., realistic) goals[36] that promote optimal challenge[28] are more likely to be effective than nonspecific, general, or distant goals that are too easy or hard. Therefore, children were encouraged to set highly specific time-sensitive goals (e.g., eat strawberries with my breakfast tomorrow) that gradually increased in difficulty to increase the likelihood of mastery (i.e., successful goal attainment).

Tailoring has been shown to enhance behavior change.[37] Therefore, to facilitate tailoring, in the initial episode, the Wizard asked the player to identify their top 10 preferred Fs; top 10 preferred Vs; three personal values[18]; and ways in which eating FVs showed that value was important to them (i.e., reason statements). For example, if the value, Being Successful, was selected, the player was presented with three reason statements and asked to select one that demonstrated a reason to meet the challenge in that episode (Table 2). An algorithm tailored the game by presenting the player with their preselected choices (F, V, reason statements) at appropriate times during gameplay to enhance autonomous motivation through fulfillment of two of the basic psychological needs: autonomy (offering choice) and relatedness (enhancing sense of connection to self by linking behavioral attainment to personal values).

The Wizard issued general FV consumption challenges (i.e., goals) each episode. Following the Wizard's pronouncement, the player was shown the three reason statements selected in the first episode. The Wizard then asked the

Table 1. Game Components and Corresponding Theoretical Constructs

Behavioral technique	*Game components*	*Social cognitive theory constructs*	*Self-determination theory constructs*
Goal setting	FV goals—gradual increases	Self-efficacy (mastery)	
	FV choices		Autonomous motivation (autonomy)
	Value/reason choices		Autonomous motivation (autonomy, relatedness)
	Tailored challenges		Autonomous motivation (autonomy, relatedness)
Planning	Implementation intentions	Self-efficacy (mastery)	Autonomous motivation (autonomy)
Self-monitoring	Tracking sheets	Self-efficacy (feedback)	Autonomous motivation (autonomy, competence)
Goal review	Goal reporting	Self-efficacy (feedback)	Autonomous motivation (competence)
Feedback	Problem solving	Self-efficacy (feedback)	Autonomous motivation (autonomy, competence)
	Guidance tailored to level of goal attainment	Self-efficacy (feedback)	Autonomous motivation (autonomy)
	Badges, public display	Self-efficacy (verbal persuasion, emotional arousal)	Autonomous motivation (autonomy, relatedness)
Support	Fundamental knowledge		
	Heuristics/skills	Self-efficacy (observational learning, mastery)	
	Schemas	Self-efficacy (observational learning, mastery)	
	Recipe preparation	Self-efficacy (mastery)	Autonomous motivation (autonomy, competence, relatedness)

FV, fruit and vegetable.

player to pick a reason to meet the episode challenge (Fig. 1). The player then selected which of their 10 favorite Fs and/or Vs they would eat to meet the challenge. These steps were incorporated to enhance goal commitment and autonomous motivation by emphasizing the basic psychological needs of autonomy (choice, control) and relatedness (connection to self through personal values).

Implementation intentions (planning)

Creating implementation intentions represents a specific type of planning that is closely connected to goals.[24,38] The two types of implementation intentions are action plans and coping plans. Action plans represent the ''how'' of goal attainment (i.e., who, what, when, where), while coping plans take the form of if/then statements and specify a particular course of action under a variety of circumstances.[24,39–41] Implementation intentions have been effective at encouraging adults to engage in a variety of behaviors[38] and there is some evidence they may be effective at promoting dietary behavior change in children.[42]

After setting a goal, children in three of the groups (Action, Coping, Action+Coping) created an implementation intention to facilitate goal attainment. This step was designed to enhance self-efficacy by increasing the likelihood of goal attainment (personal mastery) and autonomous motivation by promoting autonomy (choice, control).

Table 2. Example of Value–Reason Statements

Value	*Reason statements for eating FV*
Being successful	Shows I can meet my challenges
	Shows I can make hard decisions
	Shows I work hard for what I want

FV, fruit and vegetable.

Because motivation or intention to plan has been found to be a key factor in the actual creation of an implementation intention in adults,[43] the process of creating an implementation intention was simplified and guided players through the steps to encourage them to create a plan. For example, to create an action plan, children sequentially identified who they could ask to help them meet their goal (e.g., ''Mom'') and what they (the child) could ask them to do (''to buy the F that I need''), as well as what they could do to help meet their goal (''I can write my challenge on the family calendar'') and when (''when I finish playing SQ2''). After completing the sequence of steps, players were presented with their plan and they could choose to accept it or start over. Creating coping plans consisted of selecting from a list of potential barriers that could hinder goal attainment (e.g., ''It is hard to find fruit on fast food menus''). Once the barrier was identified, players were presented with a list of barrier-specific solutions and asked to select one to try if that barrier was encountered (e.g., ''Eat the fruit I chose **before** I eat at a fast food restaurant''). Children were then presented with their coping plan at which time they could accept it or choose to create a different one.

Self-monitoring and goal review

Self-monitoring provides immediate feedback and promotes awareness of both goal progress and deviations.[44] Reporting goal attainment has been associated with greater

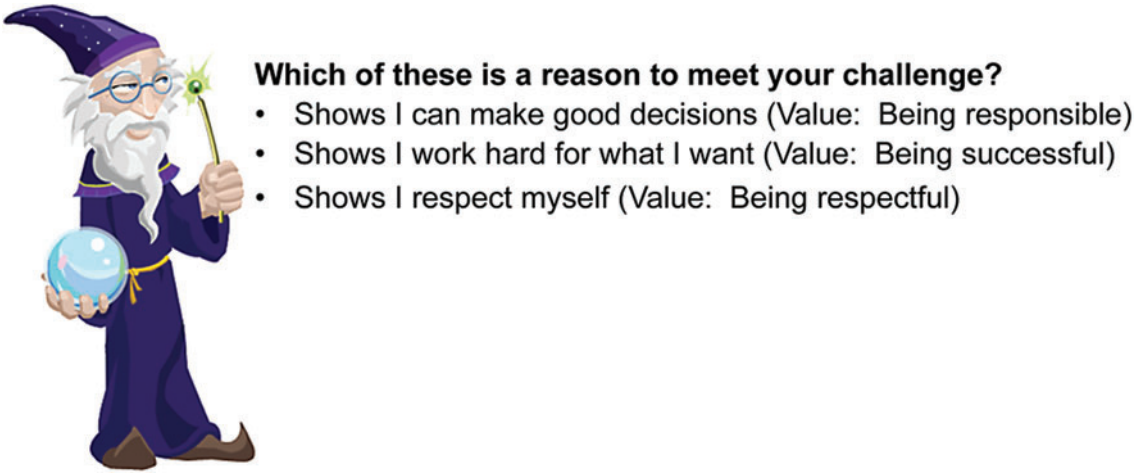

FIG. 1. Example of value–reason statements supporting goal attainment

goal attainment[22] and provides an opportunity to deliver tailored feedback that encourages and supports continued change.[45] Players were encouraged to record real-world FV consumption and recipe goal attainment on their SQ2 challenge sheet and use it to help them report whether they met their challenges at the appropriate times in the virtual game world (i.e., during goal review). Self-monitoring was included to enhance self-efficacy through immediate feedback; it also enhanced autonomous motivation by subtly emphasizing the importance of personal choice; it also boosted competence by providing an opportunity for players to adjust behavior to meet the goals. Goal review was included to provide the foundation for tailored feedback.

Tailored feedback

At the beginning of episodes 2–10, players reported goal attainment and whether self-regulatory skills (i.e., heuristics) were used to help meet their real-world challenges (i.e., FV consumption and recipe goals). If players created an implementation intention, they also reported whether it was used to meet their challenge.

Several forms of tailored feedback were utilized: (1) guided problem solving; (2) verbal tailored feedback delivered by one of the game characters; and (3) virtual badges awarded by the Wizard. If one or more goals were not attained, players participated in a brief, guided problem-solving module where they identified the problem that inhibited goal attainment and selected a solution they could enact next time that problem occurred. Verbal feedback was tailored to the player's goal attainment and skill use (e.g., ''Great job! Using skills helped you meet your challenges!''). This was followed by awarding of virtual badges for each goal the players reported they attained. One FV consumption and one recipe badge could be attained each episode. Badges were adhered to the player's virtual shield and displayed in the castle foyer for viewing by the inhabitants of Fivealot. Taken together, these actions promoted self-efficacy through feedback, verbal persuasion, and emotional arousal, as well as autonomous motivation, by emphasizing the effect of personal choice and control over goal attainment (autonomy), enhanced skill (competence), and connection to characters providing recognition and support (relatedness).

Support components

Knowledge. Behavior change was supported indirectly by conveying fundamental knowledge (i.e., real FVs vs. FV imposters, portion sizes, finding FVs when eating out). This knowledge provided the foundation for behavior change by imparting essential information needed to enhance FV consumption.

Heuristics/skills. Game characters taught key behavioral self-management skills as part of the game, including self-monitoring, asking/negotiation, and problem solving. Heuristics[46] (i.e., shortcuts) were included to make it easier to remember the steps to successfully perform these key skills. Self-monitoring was referred to by the heuristic—Keeping Track. In the game, characters encouraged the players to keep track of their FV consumption and recipe goal attainment on their challenge sheet. There were no separate steps for this simple heuristic as the name was designed to remind the players to monitor goal attainment. The heuristic for asking/negotiation was PART, and the heuristic for problem solving was TALK (Table 3). Using dialog and graphics,

Table 3. Heuristics for Behavioral Skills Taught in the Game

Self-monitoring heuristic—Keeping Track
No separate steps
Asking/negotiating heuristic—PART
Be **P**olite
Ask with confidence
Be **R**easonable
Good **T**iming
Tag line: Be **PART** of the solution!
Problem-solving heuristic—TALK
Think. Identify the problem and think of solutions
Ask. Ask others for ideas
Look. Look at all the solutions
Keep. Keep and try the best

characters modeled problems they had in the past when attempting to eat more FVs and how these skills helped them meet their FV consumption challenges. This segment promoted self-efficacy through observational learning and increased likelihood of successful goal attainment (mastery experience). Heuristics were gradually introduced over three episodes (one per episode).

Schemas. In episode 5, schemas (i.e., patterns for FV consumption) were introduced.[47] Schemas were operationalized as approaches the characters used to help players eat at least five servings of FVs each day. Five schemas were presented (Wizard, King, Queen, Knight Julie, and Knight Alex); each schema varied on number of FVs consumed at meals/snacks throughout the day. For example, Knight Julie ate 1 FV at breakfast, lunch, and dinner and 2 at snack, while the Wizard ate 1 FV for breakfast, lunch, and snack and 2 at dinner. Starting with episode 8, players were offered an opportunity to select a schema to help them to meet their challenge to eat five servings of FVs a day.[13] This segment encouraged self-efficacy through observational learning and increased likelihood of personal mastery.

Heuristics and schemas were introduced to minimize the cognitive load or the amount of information the child needed to have available in working memory to successfully use the skill and/or meet their goal.[48] For example, when the need for problem solving arose, the child simply had to remember TALK versus a complex series of steps to overcome the problem and meet their goal.

Recipe preparation. Players were also taught how to make simple FV recipes in a popular component entitled ''Virtual Kitchen.'' Recipes were tested before inclusion in the game to ensure they were child-friendly, tasted good, and looked attractive. New recipes were introduced in each episode and were connected to the focus of each episode (i.e., F, V, or both FV). Each recipe included a brief video clip demonstrating how to prepare it. During an episode, players viewed one or more of the video clips and then set a goal to make one at home with a parent or responsible adult (i.e., recipe goal). Recipe preparation skills and parent involvement were included to increase self-efficacy by increasing the likelihood of successful goal attainment (e.g., mastery experience) and autonomous motivation through choice (autonomy), skill development (competence), and parent involvement (relatedness).

Data sources

This article uses child gameplay and qualitative data to draw implications for the design of serious games for children; no parent data are reported. Game actions, i.e., gameplay data, were automatically recorded as players navigated the game each session. As part of post 1 data collection, children were asked to participate in a brief telephone interview. The purpose of the interview was to understand children's game-related thoughts, reactions, and experiences.

Statistical analysis

Responses were tallied for each quantitative variable. Descriptive statistics were calculated. Analysis of variance was used to examine group differences in FV consumption and recipe goal attainment.

Qualitative data were analyzed by two coders independently using deductive thematic analysis, a flexible qualitative analytic approach that identifies themes and patterns in the data in relation to the research question.[49] Codes were compared throughout analysis; differences were discussed and resolved. Because all groups received the same self-regulatory components with the exception of implementation intentions, group differences were not expected in children's reactions to the game. Therefore, the qualitative data were not analyzed by group.

Results

Although primary outcome results have been previously reported,[34] they will be briefly summarized here. Four hundred fourth and fifth-grade children (typically 9–11-years-old in the U.S.) and their parents ($n = 400$ parent/child dyads) were successfully recruited from a large area in the southwestern United States. The sample of children was multiethnic (26.2% African American, 27.0% Hispanic, 36.0% white), from well-educated households (38.7% had parents with postgraduate education), with incomes of >$61,000 (38.7%), and 53.6% were female. Participating parents were married (78.2%) and race/ethnicity was similar to that of the participating children. Ninety-one percent of children played all 10 episodes of the game. However, only the children who created action plans increased FVs at both the conclusion of game-play and maintained it for 3 months after the game ended (0.72 servings, 0.68 servings, respectively).[34] The Action group also reported favorable changes in energy density and key nutrients.[50]

Children selected a variety of Fs and Vs as their favorites (Tables 4 and 5). The most frequently selected Fs and Vs

Table 4. Preferred Fruits

	n	%
Strawberries	336	84.0
Grapes	327	81.8
Apples	317	79.3
Oranges	298	74.5
Watermelon	290	72.5
Bananas	273	68.3
Pineapple	229	57.3
Peaches	224	56.0
Cherries	201	50.3
Pears	162	40.5
Blueberries	160	40.0
Applesauce	153	38.3
Mango	145	36.3
Plums	137	34.3
Cantaloupe	133	33.3
Blackberries	112	28.0
Fruit salad/cocktail	110	27.5
Raisins	94	23.5
Raspberries	89	22.3
Grapefruit	87	21.8
Dried fruit	39	9.8
Honeydew	38	9.5
Papaya	16	4.0

Table 5. Preferred Vegetables

	n	%
Corn	368	92.0
Carrots	312	78.0
Broccoli	265	66.3
Green beans	261	65.3
Baked potato	254	63.5
Lettuce	252	63.0
Salsa	204	51.0
Tomatoes	181	45.3
Sweet potatoes	177	44.3
Celery	175	43.8
Cucumbers	170	42.5
Spinach	157	39.3
Garden salad	150	37.5
Peas	143	35.8
Pinto beans	132	33.0
Cabbage	113	28.3
Okra	93	23.3
Black beans	92	23.0
Black-eyed peas	82	20.5
Cauliflower	82	20.5
Red potatoes	66	16.5
Red beans	64	16.0
Asparagus	51	12.8
Collard greens	44	11.0
Squash	39	9.8
Turnip salad	19	4.8
Egg plant	18	4.5
Kale	6	1.5

were strawberries (84.0%) and corn (92.0%); the least favorite were papaya (4.0%) and kale (1.5%).

The most frequently selected values were getting good grades (49.0%), being healthy and fit (17.0%), and being a good person (7.0%). The most common reason statement for each of these values was getting good grades—''may give me energy to pay attention in school'' (83.7%), being healthy and fit—''may help me be a healthy weight'' (47.1%), and being a good person—''may give me energy to help others'' (35.7%). Values selected by the fewest number of children included being respected by my friends (1.8%), being respected by my teachers (1.3%), and being respectful (1.3%) (Table 6).

In episodes 2–10, children in the Action, Coping, and Action+Coping groups reported whether they used their action and/or coping plans to help meet their goals. Overall, reported plan use was high, regardless of type. Of children enrolled in the study, 85.3% in the Action group reported using their action plan to meet their FV goal, while 84.6% in the Action+Coping group reported using their action plan. Furthermore, 82.9% of children in the Coping group and 84.7% in the Action+Coping group reported using their coping plan to meet their FV consumption goal (Tables 7 and 8).

In general, children reported frequent use of heuristics to meet their FV consumption goals, regardless of type. The most commonly used heuristic was Keeping Track (86.1%), while PART was used slightly less often (80.9%) than the other heuristics (Table 9).

Beginning in episode 8, children could use a schema to meet their FV consumption goal. On average, the most frequently selected schemas were Wizard (26.1%) and Knight Julie (23.8%), while King Brocwell's schema was the least often selected (11.7%) (Table 10).

In each episode, children were offered 1–3 recipes from which to select for home preparation. In general, when offered a choice between an F recipe and a V recipe, children were more likely to select the F recipe (Table 11).

Children reported goal attainment in episodes 2–10. Therefore, the highest level of goal attainment possible in the 10-episode game was 9 FV consumption goals and 9 recipe goals. Mean goal attainment was high (8.7 FV consumption goals, 8.2 recipe goals). Most children (79.3%) attained all 9 FV consumption goals, and 65.5% attained all 9 recipe goals; furthermore, 57.5% attained all 18 goals (9 FV consumption and 9 recipe). There were no statistically significant group differences in either FV consumption ($P = 0.259$) or recipe ($P = 0.513$) goal attainment.

Children could also earn a total of 18 badges if they played all 10 episodes of the game and met both goals each episode (9 FV consumption, 9 recipe). Total badge attainment ranged from 0 to 18. All 18 badges were earned by 52.0% of children enrolled in the study, while 8.5% earned no badges (i.e., met none of the challenges). Overall, badge attainment was high, with children earning an average of 15.3 total badges.

Program satisfaction was also high (13.28 ± 3.28, of a possible 16 points). This was supported by the qualitative findings. When asked to grade the game, 92% graded it an A or B. Children reported the game was fun and entertaining, and most liked the game components, such as learning about healthy behaviors and making recipes. As two children said:

Because it encourages me to eat more fruits and vegetables now. I eat more than what I used to eat before.
Because I learned how to cook a lot of healthy recipes.

When asked what or who helped them meet their challenges, most children reported Mom (86%), making recipes (68%), and using skills, particularly reminders (95%) and planning ahead (92%). As the children said:

My mom reminded me, bought stuff for me and helped me make it.
I set goals, put a reminder on my phone, and told my Mom what to buy.
I used TALK [problem solving heuristic] and PART [asking heuristic]—they helped me set my goals.

And finally,

I learned eating healthier is worth it; it gives you energy and helps you in school.

Discussion

These results demonstrated that children used the behavior change techniques embedded in a serious videogame and reported a high level of program satisfaction. This provides some of the first evidence that a serious videogame heavily grounded in behavioral techniques promoting self-regulation and behavior change can be designed to appeal to preadolescent children. This should reduce concerns expressed by others regarding serious videogames and player acceptability.[51–53] These findings may be due to the extensive formative work conducted during development to ensure children

Table 6. Values and Corresponding Reason Statements Selected by Participants

	n	%	% within category
Getting good grades	196	49.0	
May give me energy to pay attention in school.	164		83.7
May give me energy to do my homework.	32		16.3
Being healthy and fit	68	17.0	
May help me be a healthy weight.	32		47.1
May give me energy to take care of myself.	15		22.1
May help my digestive system work right.	7		10.3
May give me energy to exercise.	14		20.6
Being a good person	28	7.0	
Shows I make good decisions.	6		21.4
Shows I make hard decisions and stick to them.	3		10.7
May give me energy to help others.	10		35.7
Helps me take care of myself so I can help others.	9		32.1
Pleasing my family	21	5.3	
May make my family happy.	9		42.9
Shows my family I care about being healthy.	6		28.6
Shows my family I am responsible.	1		4.8
Shows I can make good decisions on my own so my family doesn't have to remind me.	5		23.8
Being athletic	18	4.5	
Helps keep me healthy so I can work hard at being athletic.	15		83.3
May give me energy to work harder.	2		11.1
Is a good choice for people who are active.	1		5.6
Being proud of myself	14	3.5	
Shows I take care of myself to help me stay healthy.	13		92.9
Shows I can make hard decisions and stick to them.	1		7.1
Shows I work hard to meet my challenges.	0		0.0
Being successful	11	2.8	
Shows I can meet my challenges.	6		54.5
Shows I work hard for what I want.	5		45.5
Shows I can make hard decisions and stick to them.	0		0.0
Being good at something	9	2.3	
Shows I am good at making healthy choices.	3		33.3
Shows I am good at making smart choices.	6		66.7
Shows I work hard to be good at things that are important to me	0		0.0
Being responsible	8	2.0	
Shows I can make good decisions.	3		37.5
Shows I want to take care of my body.	3		37.5
Shows I can make hard decisions and stick to them.	1		12.5
Shows I can take care of myself.	1		12.5
Being respected by my friends	7	1.8	
Shows my friends I make hard decisions and stick to them.	4		57.1
Shows my friends I am responsible.	3		42.9
Helps my friends look up to me.	0		0.0
Being respected by my teachers	5	1.3	
Shows my teachers I make good decisions.	4		80.0
Shows my teachers I make hard decisions and stick to them.	1		20.0
Shows my teachers I am responsible.	0		0.0
Being respectful	5	1.3	
Shows I respect my family's wishes for me to be healthy.	3		60.0
Shows I respect myself	2		40.0

Table 7. Action Plan Use by Episode

Group	*Ep 2*	*Ep 3*	*Ep 4*	*Ep 5*	*Ep 6*	*Ep 7*	*Ep 8*	*Ep 9*	*Ep 10*	*%*
Action group	85	82	85	89	87	85	86	84	85	85.3
Action+Coping group	86	85	86	84	86	85	83	84	82	84.6

Ep, episode.

Table 8. Coping Plan Use by Episode

	Ep 2	*Ep 3*	*Ep 4*	*Ep 5*	*Ep 6*	*Ep 7*	*Ep 8*	*Ep 9*	*Ep 10*	*%*
Coping group	79	82	85	83	84	82	85	84	82	82.9
Action+Coping group	89	87	91	84	86	80	79	84	82	84.7

Ep, episode.

understood the behavioral procedures and could complete them (e.g., interviews, alpha testing, beta testing).[13] The participation of children in shaping the components likely contributed to the development of a game that appealed to this age group on many levels, including an entertainment level. It may also be that their early involvement contributed to a game that was consistent with their developmental level, resulting in an appropriate cognitive load.[48] This is consistent with the literature on formative work that emphasizes the importance of working with the target audience to help create appealing developmentally appropriate games.[17] It is also consistent with the instructional design literature.[48]

A key component in the game was goal setting. Few youth-focused dietary change studies have specifically examined the effect of goal setting on behavior change,[54] and the results have been mixed. In a previous study, achieving FV recipe goals in a videogame promoting FVs to children increased consumption, but this appeared to occur mostly in children who had high baseline consumption.[55] Although differences were observed, attaining FV goals was generally associated with higher consumption.[56] In a study with Boy Scouts, FV goal attainment was not associated with low-fat V consumption, but was associated with fruit juice intake; however, this relationship was only seen with high home availability of FVs.[57] Finally, a study with middle school youth revealed that when given a choice of goals (breakfast, lunch, dinner, after-school snack), children set goals to eat common Fs (e.g., apples, bananas, grapes) and Vs (e.g., carrots, corn, broccoli) for their afternoon snack.[58] This may be due to children feeling they have more control over their intake at snacks than other times of the day when meals have to take others' preferences into consideration.[59]

Even though children reported attaining their goals, only the group that created action plans increased and maintained a higher FV intake.[34] This is puzzling and could have been due to several factors. First, it could be that the FV consumption goals were too easy. In an effort to promote mastery experiences, the FV consumption goals gradually increased in difficulty. Perhaps the goals should have been more challenging or progressed to promoting at least five servings of FVs a day more quickly. Second, children may not have been truthful when reporting goal attainment in their desire to attain the badges awarded by the Wizard for goal attainment or to avoid participating in the problem-solving component. Finally, consistent with the literature on dietary data collection in children,[60–63] depending on when the tracking sheet was completed, it may be that children had a difficult time accurately remembering what they consumed, therefore compromising reporting accuracy. This suggests that more objective methods of assessing dietary intake, such as the e-button,[64] are an important aspect of accurately assessing the effect of serious games promoting dietary change to children. Pairing this with real-time reporting of goal attainment (e.g., app, text message) is an important area of investigation for games research.

Research is also needed to investigate the relationships between goal setting, goal attainment, FV consumption, and their mechanism of effect in a game environment, particularly with children. Understanding these relationships and mechanisms, particularly in a game environment, would contribute to the science of game design and, ultimately, to the design of more effective, targeted serious games.

Children reported using the action and/or coping plans (i.e., implementation intentions) to help them meet their goals. Implementation intentions may facilitate goal attainment and behavior change in preadolescent children by providing direction and focus and early identification of deviations so that corrective action can be taken.[24,38,65] While implementation intentions have demonstrated success with a variety of behaviors, much of the work has been conducted with adults.[38] The results of this study contribute to the limited body of knowledge on the effect of implementation intentions on dietary behavior change in healthy children.[42] Furthermore, it extends this research by providing suggestive evidence that action plans may be particularly effective with this age group, in that only the children in the action group increased and maintained FV consumption. More research is needed to understand the mechanism(s) of effect and possible interactions with the other behavioral strategies in the game, thus providing key information with which to design more effective serious videogames.

Implications for game design and future research

This research emphasizes the importance of having an integrated team, comprised of researchers, content experts, and entertainment professionals such as game designers, to

Table 9. Heuristic Use by Episode

	Ep 2	*Ep 3*	*Ep 4*	*Ep 5*	*Ep 6*	*Ep 7*	*Ep 8*	*Ep 9*	*Ep 10*	*%*
''Keeping Track''	352	366	354	343	336	339	335	331	na	86.1
''PART''	na	361	333	327	312	308	314	310	na	80.9
''TALK''	na	na	330	332	324	324	320	320	na	81.3

Ep, episode; na, not applicable.

Table 10. Schema Use Each Episode

	Ep 2	*Ep 3*	*Ep 4*	*Ep 5*	*Ep 6*	*Ep 7*	*Ep 8*	*Ep 9*	*Ep 10*	*%*
Wizard	na	na	na	na	na	na	97	105	111	26.1
Knight Julie	na	na	na	na	na	na	99	91	95	23.8
Queen Nutritia	na	na	na	na	na	na	64	77	49	15.8
Knight Alex	na	na	na	na	na	na	65	48	53	13.8
King Brocwell	na	na	na	na	na	na	43	43	54	11.7

Ep, episode; na, not applicable.

create serious games for children that entertain and promote behavior change. It also suggests that extensive formative research is essential to the design of a serious game that appeals to children and promotes behavior change. This is consistent with other research reported in the literature.[13,14,16–18] Children participated in the development of SQ2 as testers (alpha, beta) and informants (interviews), rather than as codesigners. Recent research suggests that this is an important distinction in the design of effective serious games.[19] Future research is needed to investigate the best ways to efficiently integrate the target audience into game design and when and how their input would be most useful.

Cognitive load is an important consideration, particularly in children.[48] The results suggest that certain components offered in the game, such as FV selections, values, reason statements, and schemas, could be reduced. For example, ''papaya'' (F), ''kale'' (V), ''being respected by my teachers'' (value), and ''shows my teacher I am respectful'' (reason statement) were selected by very few participants. However, choices made by the participants in this sample may have been specific to this group of preadolescent children. Other samples may make different selections. Therefore, research is needed to identify specific ways to offer options as well as options most likely to have the broadest appeal to diverse groups. It may be that qualitative research is needed with the target audience to refine the choices offered or that a more extensive algorithm be developed to finely tailor the options offered at specific points in the game.

Research is also needed to identify ways to more objectively assess food consumption and goal attainment,

Table 11. Recipe Selections Each Episode

Episode no.	*Recipe name*	*Brief description*	*Focus*	n	*%*
1 Recipe 1 ($n=389$)	Razzle Dazzle Juicy Delight	Fruit juice mixed with frozen fruit juice ice cubes	100% fruit juice	389	100.0
2 Recipe 2 ($n=384$)	On-the-Run Trail Mix	Trail mix with dried fruit, cereal, and pretzels	Fruit	94	24.5
	Fantastic Fruit and Chocolate	Chocolate-dipped fruit	Fruit	290	75.5
3 Recipe 3 ($n=380$)	Fiery's Black Bean Burrito	Bean-filled burrito with corn, cheese, and salsa	Vegetable	219	57.6
	M.I.C.H.A.E.L.'S Veggie Wrap	Vegetable-filled tortilla wrap	Vegetable	161	42.4
4 Recipe 4 ($n=378$)	Fivealot's Famous Fruit Salad	Apple, banana, orange, and raisin salad	Fruit	225	59.5
	King Brocwell's Stuffed Potatoes	Vegetable-stuffed potato	Vegetable	153	40.5
5 Recipe 5 ($n=374$)	Fiery's Bean Dip	Bean and salsa dip	Vegetable	193	51.6
	Knight Julie's Veggie Snack	Raw vegetables with low-fat salad dressing	Vegetable	181	48.4
6 Recipe 6 ($n=373$)	Royal Smoothie	Fruit smoothie with strawberries and banana	Fruit	249	66.8
	Squire's Strawberry Split	Yogurt with strawberries, bananas, and almonds	Fruit	124	33.2
7 Recipe 7 ($n=368$)	Power Pudding Dip	Pudding dip served with fruit	Fruit	238	64.7
	Wizard's Magic Pocket	Vegetable-filled pita pocket	Vegetable	130	35.3
8 Recipe 8 ($n=368$)	Celebration Sundae	Fruit dessert with yogurt and granola	Fruit	285	77.5
	Chef Supremo's Cinnamon Carrots	Carrots with a cinnamon sauce	Vegetable	83	22.6
9 Recipe 9 ($n=365$)	Queen Nutritia's Dip	Fruit and peanut butter dip	Fruit	247	67.7
	Platinum Sweet Potatoes	Sweet potato and marshmallow mixture	Vegetable	118	32.3
10 Recipe 10 ($n=362$)	Moledred's Ice Pops	Frozen fruit juice popsicles	100% fruit juice	237	65.5
	Knight Alex's Banana Pops	Frozen banana popsicle	Fruit	90	24.9
	Golden Knight Burrito	Vegetable-filled burrito	Vegetable	35	9.7

particularly in children, so that a more accurate assessment of game effectiveness and mechanism(s) of effect can be identified. It also suggests that additional research is needed regarding children's goal setting and goal attainment in an online serious videogame; for example, perhaps goals should be broken into smaller segments, such as daily, to facilitate real-time reporting of attainment.

Finally, this research points to the importance of the team when creating a serious videogame for children. The goal of a serious videogame is to both entertain and change behavior. That speaks to the need to convene a team that includes researchers and content experts, as well as entertainment professionals (e.g., artists, writers, animators, and programmers), who understand the business of entertainment. This is not a matter of simply having these positions represented on the team. It means creating an environment where everyone truly functions as a team and contributes to the process—their thoughts, ideas, and suggestions help shape the game. Serious game design is typically not an easy process and it is often time-consuming, but oh what an exciting and rewarding journey it is, particularly when behavior change is attained and children engage with and enjoy the game!

Strengths/limitations. Strengths of this study included a large sample size with complete data on most participants as well as collection of the data needed to quantify the use of the behavioral strategies promoting self-regulation. Limitations were reliance on self-report data and the limited geographical region, which could potentially impact generalizability.

In conclusion, this research suggests that behavioral techniques promoting self-regulation can be successfully integrated into a serious game, promoting behavior change to children.

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Author Disclosure Statement

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