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"Alien Health Game": An Embodied Exergame to Instruct in Nutrition and *MyPlate*

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Abstract

Objective: A feasibility study was run on an immersive, embodied exergame ("Alien Health Game") designed to teach 4th–12th-grade students about nutrition and several U.S. Department of Agriculture *MyPlate* guidelines. This study assessed acceptability and limited efficacy. Students learned about the amount of nutrients and optimizers in common food items and practiced making rapid food choices while engaging in short cardiovascular activities.
Subjects and Methods: Nineteen 4th graders played a "mixed reality" game that included both digital components (projected graphics on the floor) and tangible, physical components (hand-held motion-tracking wands). Players made food choices and experienced immediate feedback on how each item affected the Alien avatar's alertness/health state. One member of the playing dyad had to run short distances to make the game work. The final level included a digital projection of the *MyPlate* icon, and each food item filled the appropriate quadrant dynamically.
Results: All students remained engaged with the game after approximately 1 hour of play. Significant learning gains were seen on a pretest and posttest that assessed nutrition knowledge (paired $t_{18} = 4.13$, $P < 0.001$). In addition, significant learning gains were also seen in knowledge regarding *MyPlate* (paired $t_{18} = 3.29$, $P < 0.004$).
Conclusions: Results suggest preliminary feasibility via demonstrated acceptability and improved within-group content knowledge. Future research should explore improved measures of knowledge gains, alternative mechanisms for supporting the game mechanics to increase the scalability of the system (i.e., via Kinect® [Microsoft®, Redmond, WA] sensors), and the formal evaluation of the system via a randomized controlled trial.

Introduction

Unhealthful eating and physical inactivity are highly prevalent suboptimal health behaviors among U.S. school children. In 2010, more than one-third of U.S. children and adolescents were considered overweight or obese.[1] One potential mechanism for promoting improved healthful eating and physical activity could be via videogames. In particular, "exergames" are a class of videogames that require active physical engagement to play and may provide new opportunities for both physical activity and healthful eating education. Videogames allow for a variety of behavior change mechanisms such as goal setting, modeling, and skill development activities into a meaningful, entertaining, and immersive game environment.[2] Although school-based interventions to change diet and body composition have been only marginally effective,[3] we believe well-designed exergames that incorporate engaging educational content about diet and foster learning via physical, embodied activities may provide powerful mechanisms for combating obesity. Such games can be played in school environments, in informal learning spaces, or at home via intergenerational play.

We are also interested in exploring how knowledge changes and choices can be affected by learning in a more embodied manner. A large and diverse body of previous research suggests that human cognition is embodied cognition. Specifically, cognitive processes are deeply rooted and come from the body's interactions with its physical environment.[4] Multiple research areas now support the tenet that embodiment is an underpinning of cognition and the various domains include (but are not limited to) neuroscience,[5] cognitive psychology,[6–8] math,[9] gesture,[10] expert acting,[11] and dance.[12] To foster embodied cognition and by extension learning, the player's gesture (e.g., in the "Alien Health

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Game" reaching to choose the food and placing it in the Alien's mouth) must map to the learning in a manner that is *congruent* to the content to be learned. Gestural congruency is an important component in embodied learning, and the first author has recently published a taxonomy on its use in education games.[13]

Developing an age-appropriate game-based intervention, particularly one that takes full advantage of embodied cognition for learning, requires "substantial formative research (e.g., focus group discussions, intensive interviews, observations) with the targeted demographic group on story and character concept, story arc, personality and visual representation, and alpha testing on fun and functionality of the interactive components."[2] We present here a feasibility study that addressed acceptability and limited-efficacy testing. We wanted to know if the game would be engaging for an entire class of young students and to get a sense of the magnitude of the effect sizes that would be associated with immediate knowledge gains. The "Alien Health Game" was created for a "mixed reality" platform,; this means the game uses both *digital* components (projected graphics on the floor) as well as *tangible, physical* components (students manipulate three-dimensional printed motion-capture wands to move digital objects).[14]

We wanted know if students could learn dietary information during physically active and collaborative gameplay. In addition, we postulated that physically engaging in the process of choosing the foods in a comparative manner and placing the choices in the Alien's mouth would foster improved memory for the information taught. The game was designed for an entire class to cycle through during one period (approximately 45 minutes worth of play), and we also needed to know if it would hold the interest of the students for that long.

Subjects and Methods

Participants

All procedures were approved by the authors' home institutions' Institutional Review Board. Nineteen 4th graders were recruited from a K–8 school in an urban city. The class was 80 percent white, 10 percent African American, and 10 percent Hispanic. There were 10 girls and 9 boys. Although it was the end of the school year, they had not yet received a unit on health and nutrition.

Apparatus/platform

SMALLab (Situated Multimedia Arts Learning Lab) is a mixed-reality educational platform that uses 12 infrared OptiTrack (NaturalPoint, Inc., Corvallis, OR) motion-tracking cameras mounted in a ceiling or on a trussing system. Figure 1 gives a schematic. The cameras record where in three-dimensional space a student is holding a rigid-body trackable object (the three-dimensional printed wand). The floor space is 15×15 feet, and the tracked space extends approximately 8 feet high; wands are tracked with x,y,z coordinates with up to 1 mm in precision. The wand functions similarly to a cursor in this three-dimensional, interactive space. For example, when the wand is dipped below a certain level, a virtual object projected on the floor can be "grabbed" by the wand and moved to another location (like a drag-and-drop interaction).

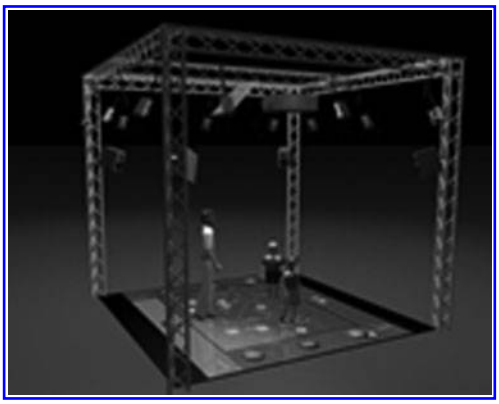

FIG. 1. Schematic for the SMALLab platform.

Students who are on the perimeter of the SMALLab active space are encouraged to collaborate via discussion and whiteboard activities, while the two students utilizing the tracking technology are interacting with the system. The lab at Arizona State University has researched the effectiveness of this platform in several content domains, including language arts,[15] science, technology, engineering, and mathematics and physics,[16,17] geology,[18] and disease transmission.[13]

Game design

The background story was that the student had awoken to find an Alien under the bed. The Alien is hungry and tired but cannot communicate. Students were told that the Alien had a "body like a human's." Via trial and error, the students were asked to discover the foods that made the Alien healthier (perk up) or sleepier and more tired (functional outcome of poor health). This was accomplished through a series of forced choice food decisions. The first author led the

FIG. 2. Screenshot of the floor projection for "Alien Health Game" with interactive *My Plate* icon.

gameplay session. Student pairs were randomly chosen from the group of 19, although when possible mixed-gender pairs were created. Each pair played approximately 6–8 minutes and engaged in both roles of the game: "selector" and "transporter."

The pair stood in the middle of the projection, and one was chosen to be the selector. The selector dips down with the wand, almost touching the floor, and "grabs" the virtual item. The selector then verbally checks with the transporter for agreement on the choice. We always try to design discourse into our games and make them collaborative. Figure 2 shows an example of the floor projection. An example of a forced choice food pair is shown in the top right corner. When the selector hovers the wand over a food item (i.e., holds the wand above the item without lowering it down close to the ground to "grab" it), the top left of the space displays the nutrients and optimizers present in that item. The Nutrition Test in the Appendix gives an example of the types of pairs in the game (9 of the 20 listed were present in the game). Placement of food (left side versus right) and items themselves were randomized across play session. When the better choice was picked (e.g., the bowl of blueberries versus the pie), the Alien stayed green and smiling.

Poorer food choices made the Alien more fatigued. In the final state of fatigue, the Alien is a sallow yellow with drooping antennae, closed eyes, and no smile. Figure 3 shows the Alien in a midlevel state.

After the selector provides the food to the Alien, the transporter player then "grabs" the glowing nutrients at the top of the play space and physically runs them down to the Alien tissue at the bottom of the space.

FIG. 3. Partial shot of the Alien after being fed an item with less nutritional value, looking fatigued.

Nutrient selection

Our overall goal was to balance the desire for a comprehensive lesson about food nutritional value and a desire to keep it simple enough for the students to be able to easily remember the information when confronted with food choices in a real-world context. Two subject matter experts (i.e., a registered dietitian and a nutrition expert at Arizona State University) were consulted extensively during the design of the game. Early on, the group decided that a focus on food quality as opposed to quantity would be more appropriate. Specifically, it appeared that children were not particularly mindful of calories when making food choices, but that they did have some awareness of food quality when making food choice decisions in a their normal context (e.g., cafeteria line). It was determined that a focus on food quality decisions could implicitly influence food choices that could be beneficial to counter obesity while not explicitly incorporating issues of overweight/obesity into the game mechanics to avoid any potential stigmatizing stimuli (e.g., the Alien does not get fatter). Our goal was to get children to think about foods that satiate and were "more" nutritious in a comparative manner. We were giving them physical practice choosing healthier foods in the belief that these decisions might become reified over time.

Based on preliminary usability testing and the literature from cognitive psychology, it was determined that a maximum of five nutritional factors could be included and comprehended by the students to support improved food decisions. The nutrients and optimizers—protein, carbohydrates, fatty acids, fiber, and vitamins/minerals—represent broad nutritional domains important for understanding food quality. For each factor, four levels of magnitude were included to represent varying concentrations of each within each food choice. More information on this and gameplay can be found on the first author's Web site at http://egl.lsi.asu.edu/

Levels and nonfoods

There were six levels total in the game. The purpose and specific game mechanics for each level were:

1. Practice: Mechanics for selector—One food item shows up, discuss how nutrients light up
2. Practice: Mechanics for transporter—Two items force choice with transporter transporting the nutrients from their source to the Alien tissue
3. Play: Forced choice with two food items—Randomized display of the 22 food pairs
4. Play: *MyPlate* with forced choice—*MyPlate* icon fills dynamically as students place each item on the plate.
5. Practice: Nonfoods—Forced choice with mystery food tubes only, five pairs, children forced to decide based on nutrient content only
6. Play: Forced choice with nonfoods—Food tubes interspersed with real food pairs

Only the first several student pairs completed the first two practice sessions; later pairs started at Level 3 and spent approximately 6 minutes in the game. In Level 4, the *MyPlate* icon was introduced to further generalize the nutritional knowledge from the gameplay to a real-world icon with

which the students would likely interact in the future. The experimenter went over the names of the food groups and kept instruction brief, saying, "In general, you should try to eat more fruits and vegetables and fewer grains and proteins." The circle for dairy was not included because the dairy requirement is considered by some to be controversial, and we only wanted to focus on foods. When the selector chose a food, the appropriate quadrant of the *MyPlate* icon would begin to fill. The item mapped to one serving, or a portion that a 12-year-old boy would eat for a lunch (e.g., the grilled fish was deemed one serving, and it filled up one-third of the protein section of the *MyPlate* template). An apple would fill one-fourth of the fruit section. Figure 2 shows the partially icon filled.

Nonfoods level

By 4th grade, children are savvy about what they *should* choose in a test situation. When the forced choice pair of ice cream versus low fat frozen yogurt shows up, they know the yogurt is better for them, but they may not know *why*. The use of known foods in the forced choice conditions may lead children to not attend to the nutrient profile. Given the pull of social desirability[19] and good guessing, even the worst eater could get many of the choices correct. Thus, we included a level in the game that forced the children to attend to the nutrient profile and ensure they would not use simple visual cues with associated histories of known foods to make a decision. We called these nonfoods or "food tubes" (Fig. 4). The backstory was that these were found in the Alien's backpack, and you needed to figure out which would make him feel better.

Table 1 gives an example of the magnitude of nutrients in some of the nonfoods. Of these two foods, the best choice (the one that would make the Alien more alert) would be *Horch*, the bolded item.

FIG. 4. Screen capture of nonfoods. These are labeled tubes "found in the Alien's backpack."

Table 1. Food Tubes with Nonword Names and Nutrition Values

Food tube name	*Protein*	*Carbohydrate*	*Fat*	*Fiber*	*Vitamins and minerals*
Horch	**3**	**1**	**1**	**2**	**2**
Chupacab	3	2	1	1	2

The best food choice is given in bold type.

This level of the game was modeled from a construct used in the classic nonword reading task,[20] which is the gold standard for assessing dyslexia. In that task participants are asked to read nonwords so they cannot rely on sight reading or memory for the words. To decode the word and read it out loud, the children must use their phonological awareness skills. Similarly, the children in the food tube task must make their choice based on the comparative values in the nutrients.

Procedure

One week before students came to the University, two experimenters went to the school to administer pretests. The following week, the students arrived and played the game at the same time of day (before lunch). Immediately upon finishing their turn, the active pair of students was taken into another room to complete the posttest (approximately 10 minutes). They were then escorted back into the main play area of SMALLab to observe their peers in the game; thus they either played or observed for a total of 45 minutes each. Each pair was assigned an ordinal pair number. The hypothesis was that the more time a student had to observe the gameplay (i.e., the higher the pair number), the greater his or her gains would be by posttest.

Measure: Nutrition and food choice test. This test contained a mixture of forced choice and open-ended items (see Appendix). Although we did find several potential measures to use related to nutrition knowledge,[21,22] we could not find a measure that was in line with the educational content specifically focused on in the game and for this age group. This experimenter-designed measure was piloted with a small focus group before the study. It includes 31 items and a blank *MyPlate* template that students were asked to fill in. The maximum score on the test was 100, which was never reached (the highest score achieved was 95). Because the *MyPlate* image was in grayscale, it did not matter if students placed the correct label on the correct color, but to receive the full 4 points on a quadrant the two larger sections had to be labeled either "fruits" or "vegetables." A common error was when students wrote "meat" in one of the smaller sections. This was awarded 3 points instead of 4 because it is a type of protein.

SPSS version 20 software (IBM Corp., Armonk, NY) was used for the analyses. The first analysis used a paired *t* test to assess within gains from pretest to posttest.

Results

The descriptives statistics and effect sizes (Cohen's *d*) for the nutrition test are listed in Table 2.

Table 2. Descriptives for Alien Health—SMALLab

Test	Mean (standard deviation) Pretest	Posttest	Difference	Effect size
Nutrition test				
Total test	70.87 (11.32)	77.95 (13.66)	7.08	0.57
My Plate subitems	7.74 (4.48)	11.17 (5.01)	3.43	0.72

Significant learning gains were seen on the nutrition knowledge total test (paired $t_{18} = 4.13$, $P < 0.001$). Significant gains were also seen on the *MyPlate* subtask (maximum score, 16) (paired $t_{18} = 3.29$, $P < 0.004$). The effect sizes were gathered by subtracting the pretest score from the posttest score and using the average of the two standard deviations as the denominator (Cohen's *d*). The students came up over a half standard deviation in nutrition knowledge.

Order effects

Each student was ordinally coded for time of play. A Spearman's rank order correlation was used to determine whether there were any effects for pair number or rank and posttest gain scores. We chose the nonparametric Spearman's correlation because we assumed the function was monotonic but not necessarily linear. Results generally did not support the hypothesis that using the system later in the game play impacted nutrition overall—on the entire test. However, there was a trend for posttest scores on the *MyPlate* template [$r_{s(16)} = 0.47$, $P = 0.067$, $d = 0.72$], suggesting that the longer the students watched their peers work with the *MyPlate* icon, the better they recalled the *MyPlate* categories.

Discussion

The results indicate that playing and observing a mixed-reality game for approximately 45 minutes can have positive and significant impacts on knowledge about nutrition. Statistically significant gains were seen in explicit knowledge regarding food choices on a nutrition test. There is evidence of transfer of knowledge of general principles related to nutrition because over half of the items on the nutrition test were new items that students had not seen in the game. In addition, students learned about *MyPlate* categories and proportions by playing the game; on this subtask they displayed a large effect size in learning of 0.72 by the end of play. This is interesting because students received only cursory instruction on *My Plate*, suggesting that exposure to and short interactions with the icon during play may be instructive and result in significant knowledge change, although additional research is required to fully delineate the active mechanism of knowledge transfer. Interviews were conducted with a random subsample, and students reported they "…found it really fun" and "want to play it again."

Implications

Overall, results suggest that there is great promise for using a mixed-reality environment for nutrition education. Active whole class participation is difficult to achieve with more traditional multimedia designs when each child is viewing an individual screen. Via these outcomes and enthusiastic teacher reports, we believe we have achieved acceptability and feasibility for the collaborative "Alien Health" exergame to be incorporated into schools. Furthermore, we see this as an exciting "stealth" strategy for promoting both nutritional knowledge and physical activity without explicitly emphasizing either point (e.g., see Hekler et al.[23]).

Limitations

There were several limitations. First, we were unable to get a control condition at the small school. We can, however, make comparisons with other studies' effect sizes. Our effect sizes are similar to those seen in the experimental condition in a controlled study done by Lieberman.[24] We do not have reliability statistics yet on the experimenter-created nutrition knowledge test. We do, however, recognize the importance of using validated measures and plan to explore the following options for our future work: (a) continue to iterate on our measures with a nutritionist and more participants to further determine the reliability and validity of the measure; (b) further explore the literature to find more appropriate measures; (c) gather body mass index and other biometrics on our future samples; and (d) explore how the game affects plate waste measures in an experimental kitchen.

We recognize that the pedagogy may have been an oversimplification for some situations. For example, we did not distinguish between "bad fat" such as saturated fats or trans fats and "good fat" such as olive oil and other related unsaturated fats. In future work, we plan to explore other nutrition education models for youth[21,22] and to explore other strategies for providing empirically sound education related to nutrition that also is appropriately cognitively calibrated for this age group. We are currently using the Microsoft® (Redmond, WA) Kinect® sensor as the input device. We also believe the Kinect may prove to be a "game changer" in the exergames domain[25] as well as for teaching embodied educational games.[13]

Conclusions

Overall, results suggest that the use of a mixed reality game for fostering improved nutritional knowledge is feasible for 4th-grade children. Future research should explore the system using randomized controlled trial procedures. Additional research should further explore the potential active ingredients, or causal effects, in the intervention (e.g., factors related to embodied cognition). These results provide further preliminary support for the tenet that exergames can be used to improve children's understanding of healthful eating behaviors.

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Author Disclosure Statement

M.C.J.-G. was a co-founder of the company SMALLab Learning, LLC. E.B.H. declares no competing financial interests exist.

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(*Appendix follows* →)

Appendix

Nutrition test

Alien Health Test

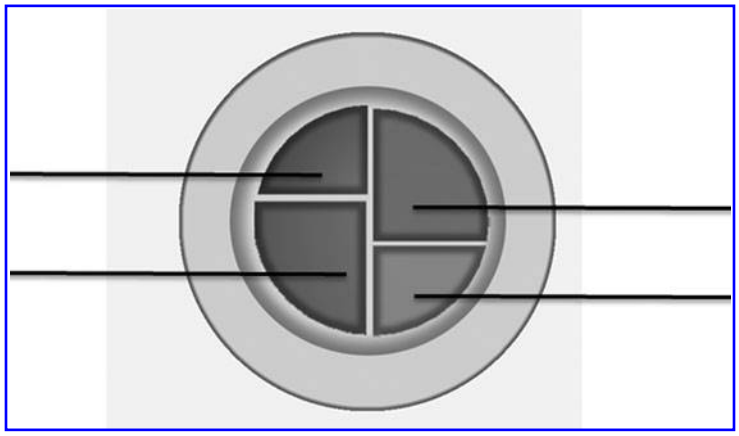
Name: Class: Date: Pretest Posttest

1. A well-balanced lunch should have which types of foods?
2. There are different kinds of **fats** in food.

On each line on the table below, is a pair of foods. **Circle the food that you think would be BEST** for you.

Olive oil or	Butter
Potato with sour cream or	Potato with parmesan cheese
Rice cake with peanut butter or	Pancake with whipped cream

3. In food science, a **carbohydrate or (carb) refers to a food rich in starch or sugars**. Please list three foods high in carbohydrates.
4. Circle the one in the pair below that has the most **fiber?**
   a. Fresh carrots or glass of carrot juice
   b. Brown rice or white rice
5. Which might be the healthier choice? Circle and **write why beneath**?
   a. Pork burrito Veggie burrito
   Why?
   b. Cheese and olive pizza Cheese and pepperoni pizza
   Why?
   c. Grilled asparagus Grilled corn
   Why?
6. When you eat a major meal you should make sure it is "balanced," what does that mean?



The picture on the left is called MY PLATE. You will learn more about it next week.

Take your best guesses at which types of foods might go in the four areas. Write your answers on the lines.

Using the list below, circle the food in the pair that you think would be best for you to eat.

Blueberries	Blueberry pie
Cupcake	Carrot muffin
Corn tortilla	White bread
Avocado	Sour cream
Celery Baked white potato	Apple Baked sweet potato
Apple	Applesauce
Bagel with cream cheese	Whole wheat toast with peanut butter

Hot oatmeal	Oatmeal snack bar
An orange	A glass of orange juice
White milk	Chocolate milk
Fresh carrots	Frozen carrots
A can of soda pop	Chocolate milk
Low fat frozen yogurt	Ice cream
Poptart	Whole wheat toast with jam
Vanilla ice cream with sprinkles	Vanilla ice cream with strawberries
Candy bar	Strawberries in dark chocolate
Potato chips	Baked potato
Fresh peas	Frozen peas
Nuts and chocolate chips	Nuts and dried fruit

Gameplay details

One important fact about SMALLab is that the entire class can sit around the perimeter and partake in the lesson via observational learning and open discourse. To see videos of SMALLab please visit the Web site (www.smallablearning.com). Before a food item was selected, information was displayed about the nutrient profile (e.g., protein, carbohydrates, and fatty acids and the two "optimizers"—fiber and vitamins/minerals). After discussing the choice with the transporter, the selector grabbed the item and brought it to the Alien's mouth, where a chewing animation followed. Feedback was shown regarding the quality of the choice by the Alien's alert state.

There are four nutrient magnitude glow levels attached to each item. The graphic metric is as follows: None/negligible = outline, small amount = glowed dim, moderate amount = glowed brightly, and large amount = bright and spinning. When the better choice was picked (in Fig. 2, that would be the bowl of blueberries with less fat and more fiber), the Alien would stay green and smiling; had the piece of blueberry pie been chosen, the Alien would display the beginning of five stages of decline into a reduced state of alertness.

During transportation, the "transporter" would bring that is run down the molecule to the tissue at the end of the side of the 15-foot space. A new item would not appear until all nutrients were transported; thus the transporter was motivated to "hustle." The students on the sidelines vociferously encouraged classmates to bring the nutrients down rapidly so they could see the next game choice.