Research Article

Psychological Science
24(8) 1541–1553
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DOI: 10.1177/0956797612474827
pss.sagepub.com

Teaching Young Children a Theory of Nutrition: Conceptual Change and the Potential for Increased Vegetable Consumption

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Abstract

In two experiments, we used a novel approach to educating young children about nutrition. Instead of teaching simple facts, we provided a rich conceptual framework that helped children understand the need to eat a variety of healthy foods. Using the insight that children's knowledge can be organized into coherent belief systems, or intuitive theories, we (a) analyzed the incipient knowledge that guides young children's reasoning about the food-body relationship, (b) identified the prerequisites that children need to conceptualize food as a source of nutrition, and (c) devised a strategy for teaching young children a coherent theory of food as a source of diverse nutrients. In these two experiments, we showed that children can learn and generalize this conceptual framework. Moreover, this learning led children to eat more vegetables at snack time. Our findings demonstrate that young children can benefit from an intervention that capitalizes on their developing intuitive theories about nutrition.

Keywords

cognitive development, science education, health, intervention

Received 7/23/12; Revision accepted 12/19/12

In this article, we present the first nutrition-education program for young children that, instead of teaching simple facts, provides children with a rich conceptual framework to understand the need to eat a variety of healthy foods. Throughout development, children construct coherent belief systems, or intuitive theories, to understand, predict, and explain the world (Au, Romo, & DeWitt, 1999; Carey, 1987, 2009; R. Gelman, Brenneman, Macdonald, & Roman, 2009; S. A. Gelman, 2003; Gopnik & Wellman, 1994; Murphy & Medin, 1985). Although individuals construct and use lay theories throughout their lives, few health interventions have capitalized on these conceptual systems. In fact, the idea that disseminating knowledge could lead to positive behavioral changes has been widely discredited in health-intervention research (Baranowski, Cullen, Nicklas, Thompson, & Baranowski, 2003; Contento et al., 1995; Helweg-Larsen & Collins, 1997; Robinson, 2010; Wansink, 2010; Wartella, Lichtenstein, Yaktine, & Nathan, 2011). Skepticism about knowledge-based nutrition-intervention programs is particularly strong in the case of preschool and early elementary school children, who are thought to be concrete and perceptually driven thinkers and therefore unlikely to benefit from explanations of abstract concepts, such as nutrients and digestion (Contento, 2007; Contento et al., 1995). We believe it is premature to discount children's ability to learn such concepts if educational materials are tailored to children's developing theories and address gaps or misconceptions that may constitute obstacles to understanding the new concepts.

One notable example is that teaching that germs are living, biological entities helped children learn, generalize, and utilize strategies for avoiding infection (Au et al., 2008; Zamora, Romo, & Au, 2006). Another example is that teaching students to understand academic effort as a vehicle for creating neural connections, rather than as a sign of low intelligence, led to increased motivation and

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even improved grades (Blackwell, Trzesniewski, & Dweck, 2007). Thus, the very few interventions that built on participants' intuitive theories have been promising.

In the present study, we aimed to (a) analyze the incipient knowledge that guides young children's reasoning about the food-body relationship, (b) identify conceptual prerequisites for understanding food as a source of nutrition, and (c) teach young children a new theory of food as a source of diverse nutrients. The importance of eating a variety of healthy foods was the central message of our intervention. We refrained from teaching about portion control, calories, or avoiding "unhealthy" foods because we thought it unreasonable to expect young children to regulate their food intake in this way and could even backfire (Johnson & Birch, 1994). It is caretakers' responsibility to provide children with appropriate food choices. But children must also be willing to accept healthy foods offered to them (Birch & Fisher, 1998). We therefore constructed an explanatory framework for teaching children that because different foods have different nutritional profiles, people need to eat many different kinds of food. This explanation rests on several concepts, some likely to be readily understandable by preschoolers and others opaque.

Preschool children will at first find the existence of invisible, heterogeneous nutrients inside homogeneous-looking food puzzling. Young children expect substances to be continuous, not particulate; for example, no matter how many times clay is divided, the resulting pieces are still fundamentally clay (Au, 1994). To convey the discrete nature of nutrients, we capitalized on the insight that young children do understand mixtures: They recognize, for example, that water still contains sugar after the sugar dissolves and disappears (Au, Sidle, & Rollins, 1993; Rosen & Rozin, 1993). We explained nutrients by analogy with mixtures: Nutrients in food are like sugar dissolved in water. You cannot see nutrients just like you cannot see the sugar, but they are there.

Young children understand what happens to food inside the body only crudely, in terms of their lay mechanical knowledge. Most preschoolers recognize that food enters the stomach and eventually exits the body, but they have little knowledge of intermediate processes (Teixeira, 2000). Young children therefore lack a plausible mechanism for explaining how the body could use nutrients. To provide such a mechanism, we taught children that after food enters the body, the stomach breaks it into smaller pieces and extracts the nutrients, and then blood carries the nutrients throughout the body. This explanation was intelligible in terms of an elaborated mechanical theory—we thought it unnecessary to teach young children biochemical mechanisms for how the body extracts nutrients.

Next, understanding the importance of variety assumes knowledge of different food kinds. However, the principal U.S. Department of Agriculture (USDA) food categories are not transparent. The protein group, for example, contains members as diverse as eggs, beans, and steak. To help with this, we built on research establishing the power of labels to unite perceptually distinct exemplars and to convince children that category members share important internal properties (e.g., S. A. Gelman, 2003; S. A. Gelman & Markman, 1986). We provided felicitous labels for each food group, emphasizing that foods within categories share similar but not identical nutrients. We did not expect children to identify food groups on their own.

Finally, taking into account young children's belief that food provides the unspecified "vital force" that allows living things to carry out biological processes (Inagaki & Hatano, 1996, 2004; Wellman & Johnson, 1982), we taught that different bodily processes require different nutrients. We did not ask 4- to 5-year-olds to memorize specific nutrient-function mappings. Rather, we emphasized that the body has many functions and that each function requires different combinations of nutrients.

In sum, although children have some knowledge of nutrition, their understanding is based on causal relationships with vague or nonexistent mechanisms (see also Slaughter & Ting, 2010). We taught children a new theory of nutrition that is more coherent and elaborated than what is available through children's untutored incipient knowledge; however, children could still fully comprehend this new theory in terms of mechanical principles without transitioning to a biochemical theory of nutrition.

Experiment 1

Method

Participants. Participants were 59 4- to 5-year-old children at a preschool affiliated with Stanford University. Each of four classrooms was randomly assigned to an intervention condition (n = 30 children; 16 girls, 14 boys; mean age = 4.8 years, SD = 0.36) or a no-treatment control condition (n = 29 children; 15 girls, 14 boys; mean age = 4.6 years, SD = 0.36).

Intervention materials. The conceptual framework for understanding nutrition was presented in five storybooks that featured child-friendly language, color photographs of food and people, and interactive questions (e.g., "after we stir the sugar, what do you think will happen?"). Each book emphasized one of five key concepts: (a) dietary variety—just one kind of food is not enough (but people do not need lots of any single food to get the nutrients they need); (b) digestion—the stomach breaks food into tiny pieces and extracts nutrients, and then blood carries the nutrients throughout the body; (c) food categories—even though category members look different, categories such as protein-rich food share similar nutrients; (d) microscopic nutrients—nutrients are there, even though they cannot be seen; and (e) nutrients and biological functions—there are a wide variety of biological functions that require a variety of nutrients. Although each book focused on a specific concept, all books mentioned each of the five key concepts in order to bolster this coherent view of nutrition.

Intervention procedure. In the intervention condition, books were read to children zero to two times per week for approximately 10 to 12 weeks. Book sessions were integrated into the school's routine of reading to small groups of children during snack time. After children had heard each of the five books at least once, an experimenter conducted a 15-min structured interview to assess children's grasp of each component of the intervention. This interview included questions about food variety, nutrients, the dependence of biological processes on nutrients, and digestion. Tables 1 through 4 provide detailed descriptions of the questions. Most interviews were conducted by experimenters unaware of the intervention.

Snack observation procedure. Forty of the 59 children were observed at snack time before and after the intervention. The observation procedure followed the school's snack-time routine, in which small groups of children are served fruit, cheese, and crackers by teachers and invited to select as much as they want. We built on this routine by offering both new and typical selections of fruits, vegetables, crackers, and cheese. The number of pieces children ate of each food were recorded in person by an experimenter, who usually was unaware of the intervention. We computed three indexes of children's willingness to accept a variety of healthy foods:

1. Total unique foods—the number of combined typical and new foods (0–8) of which children ate at least one piece
2. Unique new foods—new foods (0–4) of which children ate one piece
3. Total vegetables—Total pieces of vegetables (0+) that children ate during snack time

Because some children were observed more than once, an average pretest and posttest score for each of these three indexes was created for each child. Further methodological details are provided in the Supplemental Material available online.

Results

Tables 1 through 4 present detailed results for each task.

Knowledge in the control group. In addition to providing a comparison with the intervention group, the control group provided evidence of young children's untutored knowledge of nutrition.

Children in the control group showed some understanding that variety is desirable. First, across four items in which children were asked to choose a second food for a puppet who already had one food on its plate, children selected a different food at a rate above or nearly above chance when given both two alternative food choices, $M = 66\%$ correct, $t(28) = 2.20$, $p = .04$, and three alternative food choices, $M = 43\%$ correct, $t(28) = 1.81$, $p = .08$. Second, across three items, when asked whether eating just one kind of healthy food is healthy, children said "no" at a nearly above-chance rate, $M = 63\%$ correct, $t(28) = 2.0$, $p = .06$. When children were asked to explain why just one kind of food would not be healthy, 40% explicitly mentioned needing different foods. However, only 8% mentioned some missing nutrient (e.g., "he needs protein"). Instead, children said that the food itself was unhealthy (32% of children) and that too much of the food would result in sickness (16% of children).

Children in the control group showed little knowledge of nutrients. Across four items, when asked whether four different foods have anything inside too small to see, children said "yes" at chance, $M = 42\%$ correct, $t(27) = -1.47$, $p = .15$. When they did answer "yes," only 15% ever said nutrients (e.g., vitamins, protein, or "nutrients") were inside.

When given a definition of nutrients and asked whether they are needed for six bodily functions, children in the control group answered "yes" at a rate overwhelmingly above chance, $M = 90\%$ correct, $t(27) = 12.77$, $p < .00001$. This finding replicates consistent research indicating that young children do recognize a link between food and many biological processes (Inagaki & Hatano, 1996; Nguyen, 2007; Wellman & Johnson, 1982).

Finally, consistent with Teixeira (2000) and Rowlands (2004), results revealed that children had only a coarse understanding of digestion. When asked open-ended questions about food inside the body (e.g., "what happens to food after you swallow it?"), 54% of children described food entering the throat, stomach, or body, and 29% mentioned it exiting the body. However, only 11% mentioned the stomach breaking food into pieces, 14% (across all digestion questions) mentioned blood carrying food throughout the body, and no child mentioned extraction of nutrients.

Together, these results reveal a picture of children's incipient knowledge that involves food entering the body

(text continued on page 1549)

Table 1. Measures and Results for the Concept of Variety

	Study 1			Study 2		
Question or task	Control group	Intervention group	Group difference	Alternative-treatment control group	Intuitive-theory intervention group	Group difference
"Pick-a-snack" task: Do children select different or the same foods for a puppet?						
Number of different foods selected (mean percentage of correct answers is shown)						
Out of four items	M = 54% (SD = 29%)	M = 67% (SD = 23%)	t(57) = 1.78, p = .08	M = 59% (SD = 20%)	M = 66% (SD = 27%)	t(100) = 1.73, p = .09
Out of two items (2AFC task)	M = 66%* (SD = 38%)	M = 83%*** (SD = 27%)	t(57) = 2.07, p = .04	M = 69%*** (SD = 32%)	M = 81%*** (SD = 31%)	t(100) = 1.87, p = .06
Out of three items (3AFC task)	M = 43%† (SD = 29%)	M = 50%*** (SD = 29%)	t(57) = 0.91, p = .37	M = 46%** (SD = 25%)	M = 51*** (SD = 32%)	t(99) = 0.89, p = .37
(In Study 2 only) After child selects each food, child is asked whether the snack is healthy and asked to explain why (number of children who gave each answer is shown).						
Children who appealed to need for variety	—	—	—	12% (n = 6)	30% (n = 16)	Fisher's exact probability = .03
Children who appealed to nutrients in food (not necessarily different nutrients)	—	—	—	14% (n = 7)	25% (n = 13)	Fisher's exact probability = .22
Children who said they were trying to provide different nutrients	—	—	—	2% (n = 1)	15% (n = 8)	Fisher's exact probability = .03
Children who mentioned any of the above (variety, nutrients in general, or different nutrients)	—	—	—	24% (n = 12)	45% (n = 24)	Fisher's exact probability = .04
"Is it okay to eat just vegetables, broccoli, or grain-based foods?"						
Yes/no answers (3 items; mean percentage of correct "no" answers is shown)	M = 63%† (SD = 36%)	M = 93%*** (SD = 18%)	t(57) = 4.07, p = .0001	M = 66%** (SD = 38%)	M = 82%*** (SD = 32%)	t(101) = 2.28, p = .03

(continued)

Table 1. (continued)

Question or task	Study 1 Control group	 Intervention group	 Group difference	Study 2 Alternative-treatment control group	 Intuitive-theory intervention group	 Group difference
For children who gave at least one "no" answer: "Why is it not okay to eat just one thing?"						
Children who appealed to nutrients	8% (n = 2 of 25)	47% (n = 14 of 30)	Fisher's exact probability = .002	16% (n = 7 of 43)	20% (n = 10 of 49)	Fisher's exact probability = .79
Children who explicitly mentioned needing different foods	40% (n = 10 of 25)	73% (n = 22 of 30)	Fisher's exact probability < .05	56% (n = 24 of 43)	73% (n = 36 of 49)	Fisher's exact probability = .09
Children who said the food itself was unhealthy	32% (n = 8 of 25)	37% (n = 11 of 30)	Fisher's exact probability = .78	55% (n = 24 of 43)	31% (n = 15 of 49)	Fisher's exact probability < .05
Children who said too much of the food would result in sickness	16% (n = 4 of 25)	10% (n = 3 of 30)	Fisher's exact probability = .69	16% (n = 7 of 43)	20% (n = 10 of 49)	Fisher's exact probability = .79
"Do we need lots and lots of oranges/cheese to get the nutrients we need, or is a little bit just right?" (2 items; mean percentage of correct "a little" answers)	M = 50% (SD = 41%)	M = 56% (SD = 43%)	$t(56) = 0.60$, $p = .55$	M = 56% (SD = 40%)	M = 72%*** (SD = 40%)	$t(101) = 2.0$, $p = .05$

Note: The asterisks and dagger indicate that performance significantly differed from chance (†$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$). 2AFC = two-alternative forced choice, 3AFC = three-alternative forced choice.

Table 2. Measures and Results for the Concept of Nutrients Inside Food

	Study 1			Study 2		
Question	Control group	Intervention group	Group difference	Alternative-treatment control group	Intuitive-theory intervention group	Group difference
"Is there anything you can't see inside of food *X*?" (yes/no, 4 items; 1 point for each "yes" answer)						
Four items (mean percentage of correct "yes" answers is shown)	$M = 42\%$ ($SD = 29\%$)	$M = 78\%^{***}$ ($SD = 30\%$)	$t(56) = 4.56$, $p = .00003$	$M = 49\%$ ($SD = 35\%$)	$M = 71\%^{***}$ ($SD = 37\%$)	$t(101) = 3.20$, $p = .002$
Items discussed in books (2: carrots, spinach)	$M = 48\%$ ($SD = 37\%$)	$M = 80\%^{***}$ ($SD = 34\%$)	$t(56) = 3.41$, $p = .001$	$M = 45\%$ ($SD = 40\%$)	$M = 73\%^{***}$ ($SD = 41\%$)	$t(101) = 3.48$, $p = .0007$
Items not discussed in books (2: cheese, bean)	$M = 36\%$ ($SD = 36\%$)	$M = 75\%^{***}$ ($SD = 37\%$)	$t(56) = 4.14$, $p = .0001$	$M = 52\%$ ($SD = 39\%$)	$M = 70\%^{***}$ ($SD = 40\%$)	$t(101) = 2.29$, $p = .03$
"*What* is inside of food *X*?" (Follow-up to "yes" answers for above questions. Of children who said "yes" at least once, the percentage is shown for those who said nutrients are what is inside)						
All items (4)	15% ($n = 4$ of 21)	89% ($n = 25$ of 28)	Fisher's exact probability $< .00001$	22% ($n = 9$ of 41)	70% ($n = 33$ of 47)	Fisher's exact probability $< .00001$
Items discussed in books (2: carrots, spinach)	19% ($n = 4$ of 21)	81% ($n = 22$ of 27)	Fisher's exact probability = .00003	22% ($n = 7$ of 32)	74% ($n = 31$ of 42)	Fisher's exact probability $< .00001$
Items not discussed in books (2: cheese, bean)	12% ($n = 2$ of 17)	85% ($n = 22$ of 26)	Fisher's exact probability $< .00001$	26% ($n = 8$ of 37)	70% ($n = 30$ of 43)	Fisher's exact probability = .00002
Given a definition of nutrients, children were asked, "Does all food have the same nutrients?" (1 item; percentage of children who said "no" is shown)	$82\%^{***}$ ($n = 23$)	$90\%^{***}$ ($n = 27$)	Fisher's exact probability = .46	73% ($n = 35$)	85% ($n = 45$)	Fisher's exact probability = .15

Note: The asterisks indicate that performance significantly differed from chance ($^{***}p < .001$).

Table 3. Measures and Results for the Concept of Nutrients and Bodily Functions

	Study 1			Study 2		
Question	Control group	Intervention group	Group difference	Alternative-treatment control group	Intuitive-theory intervention group	Group difference
"Does your body need nutrients from food to X?" (8 items; 1 point for "no" on foil items and "yes" on the rest)						
All items (8; mean percentage of correct answers is shown)	$M = 75\%^{***}$ ($SD = 10\%$)	$M = 90\%^{***}$ ($SD = 11\%$)	$t(56) = 5.37$, $p < .00001$	$M = 77\%^{***}$ ($SD = 18\%$)	$M = 83\%^{***}$ ($SD = 20\%$)	$t(97) = 1.61$, $p = .11$
Active items (X = run, climb; mean percentage of correct "yes" answers is shown)	$M = 96\%^{***}$ ($SD = 13\%$)	$M = 100\%^{***}$	$t(56) = 1.49$, $p = .14$	$M = 86\%^{***}$ ($SD = 57\%$)	$M = 89\%^{***}$ ($SD = 58\%$)	$t(97) = 0.48$, $p = .63$
Inactive items (X = think, write; mean percentage of correct "yes" answers is shown)	$M = 75\%^{***}$ ($SD = 35\%$)	$M = 95\%^{***}$ ($SD = 15\%$)	$t(56) = 2.87$, $p = .006$	$M = 71\%^{***}$ ($SD = 37\%$)	$M = 82\%^{***}$ ($SD = 36\%$)	$t(97) = 1.43$, $p = .16$
Biological items (X = have strong muscles, recover from illness; mean percentage of correct "yes" answers is shown)	$M = 89\%^{***}$ ($SD = 21\%$)	$M = 93\%^{***}$ ($SD = 17\%$)	$t(56) = 0.81$, $p = .42$	$M = 90\%^{***}$ ($SD = 25\%$)	$M = 92\%^{***}$ ($SD = 18\%$)	$t(97) = 0.58$, $p = .56$
Foil items (X = car start, computer turn-on; mean percentage of correct "no" answers is shown	$M = 41\%$ ($SD = 45\%$)	$M = 73\%^{**}$ ($SD = 43\%$)	$t(56) = 2.78$, $p = .007$	$M = 62\%^{\dagger}$ ($SD = 44\%$)	$M = 47\%^{**}$ ($SD = 45\%$)	$t(97) = 1.01$, $p = .32$
All items, excluding foil items (6; mean percentage of correct "no" answers)	$M = 90\%^{***}$ ($SD = 15\%$)	$M = 96\%^{***}$ ($SD = 8\%$)	$t(56) = 2.87$, $p = .006$	$M = 82\%^{***}$ ($SD = 24\%$)	$M = 88\%^{***}$ ($SD = 20\%$)	$t(97) = 1.19$, $p = .24$
Items discussed in books (X = run, think, strong muscles; mean percentage of correct "yes" answers is shown)	$M = 94\%^{***}$ ($SD = 13\%$)	$M = 98\%^{***}$ ($SD = 6\%$)	$t(56) = 1.84$, $p = .07$	$M = 87\%^{***}$ ($SD = 25\%$)	$M = 91\%^{***}$ ($SD = 19\%$)	$t(97) = 0.92$, $p = .36$
Items not discussed in books (X = climb, write, recover from illness; mean percentage of correct "yes" answers is shown)	$M = 78\%^{***}$ ($SD = 26\%$)	$M = 93\%^{***}$ ($SD = 16\%$)	$t(56) = 2.39$, $p = .02$	$M = 78\%^{***}$ ($SD = 32\%$)	$M = 85\%^{***}$ ($SD = 24\%$)	$t(97) = 1.14$, $p = .26$

Note: The asterisks and dagger indicate that performance significantly differed from chance ($^{\dagger}p < .1$, $^{**}p < .01$, $^{***}p < .001$).

Table 4. Measures and Results for the Digestion Concept

	Study 1			Study 2		
Question	Control group	Intervention group	Group difference	Alternative-treatment control group	Intuitive-theory intervention group	Group difference
(1) "What happens to food after you swallow it?" and (2) "What do you think the stomach does to the food?" (Responses to both questions were coded together; percentage of children who mentioned each detail is shown)						
Children who mentioned food entering stomach, throat, or body	54% ($n = 15$)	60% ($n = 18$)	Fisher's exact probability = .79	65% ($n = 31$)	73% ($n = 37$)	Fisher's exact probability = .52
Children who mentioned food being excreted	29% ($n = 8$)	33% ($n = 10$)	Fisher's exact probability = .78	27% ($n = 13$)	21% ($n = 11$)	Fisher's exact probability = .64
Children who mentioned the body becoming strong or healthy	21% ($n = 6$)	0%	Fisher's exact probability = .009	13% ($n = 6$)	6% ($n = 3$)	Fisher's exact probability = .31
Children who mentioned breakdown of food into smaller pieces	11% ($n = 3$)	47% ($n = 14$)	Fisher's exact probability = .004	19% ($n = 9$)	49% ($n = 25$)	Fisher's exact probability = .003
Children who mentioned extraction of nutrients by stomach	0% ($n = 0$)	27% ($n = 8$)	Fisher's exact probability = .005	0% ($n = 0$)	20% ($n = 10$)	Fisher's exact probability = .001
Children who mentioned that blood carries food	4% ($n = 1$)	3% ($n = 1$)	Fisher's exact probability = 1.0	2% ($n = 1$)	8% ($n = 4$)	Fisher's exact probability = .36
"After food gets to the stomach, do you think it just sits there?" (This question was asked between "What happens to food after you swallow it" and "What do you think the stomach does to the food?"; percentage of children who gave correct "no" answer is shown)	75%** ($n = 21$)	90%*** ($n = 27$)	Fisher's exact probability = .17	66%* ($n = 31$)	90%*** ($n = 46$)	Fisher's exact probability = .006
"How do nutrients get from the stomach to the muscles/eyes?" (percentage of children who implicated "blood" on either of two items)	11% ($n = 3$)	59% ($n = 17$)	Fisher's exact probability = .0002	4% ($n = 2$)	35% ($n = 18$)	Fisher's exact probability = .0001
"Why do we need blood?" (one question; percentage of children who mentioned circulation of food or nutrients is shown)	4% ($n = 1$)	31% ($n = 9$)	Fisher's exact probability = .01	2% ($n = 1$)	41% ($n = 21$)	Fisher's exact probability < .00001
Children who mentioned blood carrying food or nutrients on any of the digestion questions	14% ($n = 4$)	63% ($n = 19$)	Fisher's exact probability = .0001	4% ($n = 2$)	49% ($n = 25$)	Fisher's exact probability < .00001

Note: The asterisks indicate that performance significantly differed from chance (*$p < .05$, **$p < .01$, ***$p < .001$).

and providing the vital force necessary to carry out bodily functions. There is little, however, that could serve as a causal mechanism for how different foods affect bodily states or explain why the body needs different kinds of food.

Knowledge in the intervention group. Compared with children in the control group, children in the intervention group showed a much more elaborated understanding of nutrition. First, across three items, children in the intervention group claimed more often than children in the control group that it would not be healthy to eat just one kind of healthy food (M = 93% correct vs. M = 63% correct, respectively), $t(57) = 4.07$, $p = .0001$. Children in the intervention group were also more likely to appeal to the need for different nutrients when providing open-ended justifications for their "no" answers (47% of intervention children vs. 8% of children in the control group; Fisher's exact probability = .002). Across four items, intervention children also chose a different—rather than the same—kind of food for a puppet marginally more often than children in the control group did—intervention: M = 67% correct, control: M = 54% correct, $t(57) = 1.78$, $p = .08$.

Children in the intervention group claimed at an above-chance rate that four foods contain things too small to see (M = 78% correct), $t(29) = 4.97$, $p < .00001$, and they did so more often than children in the control group did (M = 42% correct), $t(56) = 4.56$, $p = .00003$. This measure included foods that both were and were not mentioned in the intervention. A mixed logistic regression with children's yes/no answers as the response variable, subject as a random effect, and condition plus item type (discussed vs. not discussed) as fixed effects revealed a main effect of condition ($\beta = 2.17$, $z = 3.98$, $p = .00007$) and no interaction with item type ($\beta = -0.29$, $z = 0.46$, $p = .64$). This analysis indicated that children in the intervention group were correct more often overall and performed just as well on new foods as on previously encountered items compared with children in the control group. Moreover, when asked what is inside food, 89% of children in the intervention group mentioned nutrients at least once, compared with 15% of children in the control group (Fisher's exact probability < .00001).

Across six items, children in the intervention group (M = 96% correct responses) affirmed more often than children in the control group (M = 90% correct responses) that bodily functions require nutrients from food (given a definition of nutrients), $t(56) = 2.87$, $p = .006$). This pattern held for bodily functions that were not discussed in the books: A mixed logistic regression with subject as a random factor and condition plus item type (discussed vs. not discussed) as fixed effects revealed a marginal main effect of condition ($\beta = 2.31$, $z = 1.67$, $p = .09$) and no interaction between condition and item type ($\beta = -0.56$, $z = -0.39$, $p = .69$). Thus, children in the intervention group learned that nutrients are required for a variety of biological functions, and they generalized this knowledge to new biological processes.

Assessment of digestion understanding was performed using exclusively open-ended questions substantially different in form from the intervention materials. Over half of children in the intervention group (63%) mentioned the role of blood in transporting nutrients on at least one question (compared with only 14% of children in the control group). Nearly half (47%) described how the stomach breaks food into smaller pieces (compared with 11% of children in the control group), and 27% mentioned nutrient extraction (compared with no children in the control group), Fisher's exact probabilities = .0001, .004, and .005, respectively.

Finally, scores for each item were standardized and averaged to form a composite score. The difference between composite scores was striking—control group: $M = -.28$; intervention group: $M = .28$, $t(57) = 5.98$, $p < .00001$.

In sum, although young children are beginning to understand some concepts related to nutrition, such as the dependence of bodily functions on food, the input/output relations of digestion, and the desirability of variety, children in the intervention group went well beyond this: They learned that foods have nutrients inside and that biological processes depend on nutrients. Moreover, they generalized both concepts to foods and processes not discussed in the intervention. Most intervention children affirmed that blood carries nutrients throughout the body, even in response to challenging open-ended questions. Almost all children in the intervention group said that it would not be healthy to eat just one kind of food. Furthermore, nearly half of intervention children appealed to the need for different nutrients to explain why one kind of food is insufficient. In other words, children acquired the key concepts from the intervention, generalized them beyond the specific foods and processes taught in the intervention, and appealed to the intervention's conceptual framework to explain the key message of variety.

No difference was found between conditions in total unique foods (either typical or new) or in unique new foods that children selected at snack time (ts < 0.4). The intervention group did, however, increase their intake of vegetables, from a mean of 3.8 pieces to 9.07 pieces, $t(21) = 3.10$, $p = .005$. This increase was greater than that of the control group, $t(38) = 2.28$, $p = .03$, who ate 6.9 pieces of vegetables at pretest and 6.8 pieces at posttest, $t(55) = -0.05$, $p = .96$. More analyses are presented in the Supplemental Material.

Discussion

Experiment 1 showed that presenting a coherent explanatory framework that helps children revise and elaborate concepts related to food composition, digestion, and substance kinds can enable young children to understand food as a source of diverse, microscopic nutrients. Furthermore, we demonstrated that this framework generalized to new foods and is explanatory: Many children appealed to it to explain why it is not healthy to eat just one kind of food.

In addition, we found preliminary evidence that this theory change also led to behavioral change—an increase in vegetable consumption. This increase is especially striking given that children were not instructed to eat more vegetables as part of the intervention.

Because we examined three measures of food selection but observed a change only in one, it was important to replicate this finding. Also, our no-treatment control group did not rule out other explanations. So, in Experiment 2, we used an alternative-treatment control group to (a) ensure that teachers in both conditions were equally invested in the outcome of the study, (b) expose children in both the control and intervention groups to the same amount of discussion of healthy eating, and (c) replicate our finding that children in the intervention group increased their vegetable intake.

Experiment 2

Method

Except for the alternative-treatment control group, the materials, measures, and design of Experiment 2 were essentially identical to those of Experiment 1. Participants were 103 children randomly assigned by classroom to participate in an intuitive-theory-based intervention (n = 53; 29 girls, 24 boys; mean age = 4.9 years, *SD* = 0.35) or the alternative-treatment control condition (n = 50; 24 girls, 26 boys; mean age = 4.7 years, *SD* = 0.28).

The alternative-treatment control group received an intervention based on the USDA's Team Nutrition materials (http://teamnutrition.usda.gov/). We included five child-friendly storybooks from the Team Nutrition Web site to control for the effects of talking about healthy eating during snack time and to ensure that teachers in both groups felt equally invested in the experiment. Team Nutrition materials emphasized the enjoyment of healthy eating and exercise and used techniques such as peer modeling to encourage children to try new healthy foods, especially vegetables. The five books were read to children in the control condition during snack time. Further methodological details are provided in the Supplemental Material.

Results and discussion

Generally, the results of the Experiment 2 conceptual interview paralleled those of Experiment 1 (see Tables 1–4 for detailed results of each task; more analyses are presented in the Supplemental Material). Here, we highlight the key findings.

As in Experiment 1, we compared the standardized composite scores across conditions and found that scores for our conceptual intervention (M = .20) were substantially higher than scores for the alternative-treatment control condition (M = −.25), $t(101)$ = 6.36, p < .00001. Regarding the concept of variety, when explaining their snack choices for a puppet, 45% of children in the intervention group appealed at least once to needing different kinds of food and nutrients, compared with 24% of children in the control group (Fisher's exact probability = .04). Thus, many children in the intervention group viewed the intervention's explanatory framework as relevant for explaining food choices on a novel task.

As in Experiment 1, across four items, the intervention group was more likely to claim that foods have tiny, invisible things inside—control group: M = 49% correct, intervention group: M = 71% correct, $t(101)$ = 3.20, p = .002, and that those things are nutrients (70% of intervention children vs. 22% of children in the control group said so at least once; Fisher's exact probability < .00001).

Nearly half of children in the intervention group (49%) mentioned blood carrying nutrients or food around the body, 49% mentioned food breakdown by the stomach, and 20% mentioned nutrient extraction by the stomach on at least one question, compared with 4%, 19%, and 0%, respectively, of children in the control group (Fisher's exact probabilities < .00001, = .003, and = .001, respectively).

Experiment 2 also replicated the finding that intervention children increased their vegetable intake by approximately the same magnitude as in Experiment 1, from 5.13 to 11.28 pieces, $t(47)$ = 4.09, p = .0002. Children in the control group marginally increased their vegetable intake as well, from 8.10 to 10.18 pieces, $t(41)$ = 1.70, p = .09. Children in the intervention group, however, increased their vegetable intake more than children in the control group did, $t(88)$ = 2.06, p = .04.

To test whether conceptual change mediated the relation between condition and vegetable consumption, we combined the data from Experiments 1 and 2 and performed a Sobel test of mediation (Bleise, 2012; Sobel, 1982). Condition alone significantly predicted vegetable-change scores, β = 4.43, p = .005. Condition was also a very strong predictor of conceptual composite, β = 0.52, p < .00001, and conceptual composite predicted vegetable-change scores, β = 4.48, p = .015. When conceptual composite and condition were combined to predict change in vegetables, this model as a whole still explained a significant amount of variance in vegetable-change scores, $F(2, 127) = 4.61$, $p = .01$, $R^2 = .07$; however, condition was marginally significant, $\beta = 3.34$, $p = .08$, overall composite was not significant $\beta = 2.12$, $p = .33$, and there was no mediation, $z = 0.96$. Thus, condition and conceptual change were very tightly linked, and both predicted vegetable-change scores, but we were unable to distinguish unique contributions of either variable.

General Discussion

We provided the first demonstration that young children can benefit from a conceptually based approach to understanding food as a source of nutrition. Following an intuitive-theory intervention, over half the children in these experiments spontaneously mentioned the role of blood in transporting food and nutrients throughout the body, nearly 90% named nutrients when asked what is inside food, and nearly half mentioned the need for different kinds of food and nutrients when explaining why eating just one kind of food would not be healthy and justifying their hypothetical food choices. Children learned an explanatory framework that is detailed and coherent but nevertheless consistent with a mechanical view of nutrition: that food contains tiny, invisible nutrients; that different foods contain different nutrients; that the stomach extracts nutrients from food during digestion and blood carries them throughout the body; and that every bodily function requires nutrients—even relatively inactive processes such as thinking and writing. Children were then able to use this explanatory framework to explain why their bodies need different kinds of food. Our materials were tailored to both the cognitive achievements and knowledge gaps that were likely to affect how young children made sense of our message.

The majority of the participants came from highly educated families. In general, our materials may prove more appropriate for early elementary school than for preschool children. But our results suggest that young children can acquire a complex and abstract set of concepts when these concepts are presented in a way that respects, utilizes, and helps children revise their developing theories.

Not only did our intervention provide a far more elaborated view of food as a source of nutrients, but it also boosted children's vegetable consumption. The twice-observed increase in vegetable consumption is especially striking given that children were given no specific instruction or training on eating vegetables. Of course, this finding must be interpreted with caution. We do not know, for example, whether these gains in healthy eating would generalize to other contexts, such as mealtimes at home, or for how long the gains would persist.

Children's increased selection of vegetables at snack time leaves us hopeful that an intuitive-theory-based nutrition intervention, in conjunction with other promising techniques, could be effective in helping children eat healthier foods. Several innovative approaches to fostering healthy eating include changing food landscapes (Wansink, 2010), community garden programs (Davis, Ventura, Cook, Gyllenhammer, & Gatto, 2011; Faber, Venter, & Benadé, 2007; McAleese & Rankin, 2007; Parmer, Salisbury-Glennon, Shannon, & Streumpler, 2009; Wang et al., 2010), and providing enjoyable activities or foods (Robinson & Borzekowski, 2006; Robinson et al., 2003; Spill, Birch, Roe, & Rolls, 2011; Weintraub et al., 2008). We view our approach as unique but potentially complementary to other approaches. Our conceptually based program may well boost the effects of these other techniques, resulting in greater improvements in eating behavior than either technique alone would.

In sum, we have shown that young children can transition from a view of food that includes little beyond eating, swallowing, and excreting it to a view that food contains diverse, invisible nutrients that are extracted during digestion and carried around in the blood. This constitutes quite an achievement and demonstrates that young children can benefit from a curriculum that capitalizes on their developing intuitive theories.

Author Contributions

S. J. Gripshover and E. M. Markman developed the theoretical rationale and design of the study. Data collection and data analyses were performed by S. J. Gripshover. Both authors collaborated on writing the manuscript and approved the final version of the manuscript for publication.

Acknowledgments

We thank Prangnalin Chaturaphat, Cate Gerrity, Anaya Hall, Hannah Jaycox, Patricia Limcaoco, Emma McCarthy, and Stephanie Nicholson for assistance with data collection. We also thank the teachers and parents at Bing Nursery School for their generous participation.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

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