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OMG GMO! Parent-child conversations about genetically modified foods

Andrew Shtulman[a,*], Ilana Share[a], Rosie Silber-Marker[a], Asheley R. Landrum[b]

[a] Occidental College, United States
[b] Texas Tech University, United States

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ABSTRACT

Studies indicate that Genetically Modified Organisms, or GMOs, are safe to consume, but many adults remain skeptical. What kind of input are children receiving about GMOs? And how does that input shape their understanding of what GMOs are? We investigated this question in the context of parent-child conversations about food product decisions. Seventy parent-child dyads were shown a series of food product pairings and asked to discuss their preferences. The products differed by whether they were made from GMOs, as well as whether they contained gluten and whether they were grown organically. Non-GM foods were preferred over gluten-free foods, and conversations about GM foods contained more moral language than conversations about gluten. Preferences for organic foods equaled preferences for non-GM foods, and conversations about organic foods were as morally charged, but parents were less knowledgeable about the meaning of *GMO* than they were about the meaning of *organic*. Children's knowledge of these terms varied with their parents' knowledge, and their participation in the food-product conversations varied with their parents' use of moral language. Taken together, these findings suggest that children's conceptions of GMOs are shaped by their parents' conceptions, despite the fact that parents' preferences and attitudes toward GMOs outstrip their knowledge of what GMOs actually are.

1. Introduction

Genetically Modified Organisms, or GMOs, are an increasingly common food commodity in the industrialized world. The World Health Organization defines GMOs as "plants, animals, or microorganisms in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination" such as when "individual genes [are] transferred from one organism into another" (World Health Organization, 2014). This definition applies specifically to organisms whose DNA has been altered through gene splicing, though humans have been altering genomes for millennia, through selective breeding. Apples, oranges, strawberries, tomatoes, almonds, peanuts, rice, and corn are some of the many foods that do not exist in nature, at least not in the form we consume them. The fact that most foods have been genetically modified through human intervention raises questions about the current definition of GMOs (Tagliabue, 2015). But the focus of recent controversy—and the focus of this paper—is on foods modified by gene splicing.

Large-scale investigations have found no health risks associated with GMO consumption (National Academy of Sciences, 2016), but many people remain skeptical of GM foods (Landrum, Hallman, & Jamieson, 2019) and want such foods labeled (Lang, 2016). National polls find that about half of Americans think that GM foods are worse for one's health than food containing no genetically-

* Corresponding author at: Department of Psychology, Occidental College, Los Angeles, CA 90041, United States.
E-mail address: shtulman@oxy.edu (A. Shtulman).

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modified ingredients and that GM foods will lead to health problems for the population as a whole (Pew Research Center, 2018). These views are widespread across demographic groups. Around 20% of Americans say they care a great deal about the issue of genetically modified foods, and this percentage varies little by gender, race, age, or political affiliation. Even those with high science knowledge claim that GM foods pose health risks nearly as often as those with low science knowledge (38% vs 52%; Pew Research Center, 2018).

Here, we investigated lay conceptions of GMOs in the context of parent-child conversation. Parents determine, to a large extent, what children eat and whether those foods contain GMOs, but most parents are not biological experts and are thus prone to GMO-related misconceptions. Accordingly, we sought to determine what parents know about GMOs (relative to other food dimensions), how strongly parents prefer non-GM foods to GM foods, how they talk about those preferences with their children, and what children learn about GMOs from those conversations. Children's food selections are a special case of trust in testimony—testimony about what is safe to eat, what is nutritious to eat, and what tastes good—and studying parental testimony about GMOs can provide insights into how trust is granted in a domain rife with public controversy. It can also provide insights into how children's understanding of scientific ideas is shaped by their parents' understanding, or lack thereof.

1.1. Opposition to GMOs

Public skepticism toward GMOs stems, at least in part, from confusion about what GMOs are. In one national survey (Lusk, 2015), the number of Americans who supported mandatory labels on foods produced with genetic engineering (82%) was nearly identical to the number who favored mandatory labels on foods containing DNA (80%). If most people do not realize that food in general contains DNA (because plants and animals contain DNA), then they probably do not understand what genetic modification entails. Indeed, the public's knowledge of genes and genetics is sparse (Christensen, Jayaratne, Roberts, Kardia, & Petty, 2010). Most Americans agree with the statements "Two women will always be more genetically similar to one another than a man and a woman," "There are different types of genes in different parts of the body," and "Single genes directly control specific human behaviors," even though all are false.

Direct evidence that knowledge of GMOs influences attitudes about GMOs comes from a teaching intervention by McPhetres, Rutjens, Weinstein, & Brisson, 2019. Over a five week period, McPhetres and colleagues surveyed adults' attitudes toward GMOs, their knowledge of GMOs, their willingness to eat GM foods, and their perceptions of risk. Half of the participants completed a tutorial on the science behind genes and genetic modification, and half completed a tutorial on nutrition and metabolism. While the group that received the nutrition tutorial exhibited no change in their stance toward GMOs, the group that received the genetics tutorial demonstrated increased knowledge of GMOs, more positive attitudes toward GMOs, greater willingness to eat GM foods, and lowered perceptions of GM foods as risky.

Consistent with these findings, Rutjens and colleagues found that skepticism about GMOs is more tightly linked to an understanding of science than to political beliefs or religious beliefs (Rutjens, Sutton, & van der Lee, 2018). In their study, political conservativism predicted skepticism toward climate change and religious identity predicted skepticism toward vaccines, but neither predicted skepticism toward GMOs. Rather, GMO skepticism was predicted mainly by trust in science and overall science literacy (Rutjens et al., 2018).

Another reason GMOs are viewed with suspicion is that they violate deep-seated intuitions about biology, namely, essentialism and teleology (Coley & Tanner, 2012; Shtulman, 2017). Essentialism is the belief that all members of a species share a common essence, which gives rise to species-typical traits (Gelman, 2003). Essences are commonly associated with genes, but the association is superficial; essences are viewed as immutable and species-specific whereas genes are neither. Essentialism is thus problematic for understanding genetics in general (Dar-Nimrod & Heine, 2011) and GMOs in particular (Blancke, Van Breusegem, De Jaeger, Braeckman, & Van Montagu, 2015). Genetic engineering is seen as tampering with an organism's inner nature, corrupting it or contaminating it. People are concerned about gene transfers within species (from, say, one tomato to another) but are even more concerned about gene transfers between species (from, say, a fish to a tomato; Kronberger, Wagner, & Nagata, 2014). And many think the gene recipient will come to resemble the gene's source, agreeing with statements like "Tomatoes modified with genes from a catfish would probably taste fishy" (Hallman, Hebden, Cuite, Aquino, & Lang, 2004).

GMOs also violate our intuition that plants and animals have certain traits for a reason—that their traits serve a purpose (Kelemen, 1999). Manipulating an organism's genes is seen as thwarting its God-given or natural-born purpose. When asked to rate the naturalness of different foods, people rate genetically modified foods as less natural than foods produced through all other technologies, including fertilizers, pesticides, vitamin supplements, mineral supplements, fat supplements, pasteurization, irradiation, and factory farming (Rozin, 2005). The distinction between natural foods and manufactured foods is highly salient (Aiello et al., 2018; Rumiati & Foroni, 2016), and manufacturing that involves genetic changes may be even more so. Genetic modifications are not only viewed as unnatural but also qualitatively different from modifications introduced through selective breeding (Shtulman, 2006), even though both processes yield heritable, endogenous outcomes.

The present study focuses on parents as a source of information about GM foods, and parents, like other adults, have limited knowledge of genes and genetic modification. They also hold essentialist biases and teleological biases. Thus, the information they provide children about GMOs may be unreliable, and the attitudes they convey about GMOs are likely to be negative. Even if the information is reliable and the attitudes are positive, children may not be receptive to such messages, as they too hold essentialist biases (Gelman, 2003) and teleological biases (Kelemen, 1999), just like their parents. GMOs provide a strong test of the inferential scope of such early-developing intuitions, but no research, to our knowledge, has explored GMO conceptions from a developmental perspective.

1.2. Transmission of food preferences

Food selection is a highly social process, influenced by whom we observe eating the food and how much we like them and trust them (Shutts, Kinzler, & Dejesus, 2013). Toddlers who watch an adult pick and eat a fruit from an unfamiliar plant will pick and eat the same fruit when given multiple plants to choose from (Wertz & Wynn, 2019). Preschoolers introduced to an unusual, blue-colored food are more likely to eat the food if they observe their peers eat it but less likely if they observe their peers reject it (Greenhalgh et al., 2009). Preschoolers also take the social characteristics of their peers into account, preferring foods eaten by children of the same gender to foods eaten by children of a different gender (Frazier, Gelman, Kaciroti, Russell, & Lumeng, 2012). Children will eat foods they initially dislike, such as beets or cauliflower, if they see their peers eating those foods (Birch, 1980) and will even eat sardine- and garlic-flavored jelly beans if they hear someone describe them as "yummy" (Lumeng, Cardinal, Jankowski, Kaciroti, & Gelman, 2008).

Food selection is a special case of trust in testimony. From an early age, we track the accuracy and reliability of the people around us to determine who we can trust, and we rely on the people we trust to provide us with accurate and reliable information (Landrum, Eaves, & Shafto, 2015). That information includes details about the health and taste of novel foods. In one study (Nguyen, Gordon, Chevalier, & Girgis, 2016), preschoolers were introduced to an informant who made false claims about the identity of an object hidden inside a bag, claiming it was a crayon when it was actually a ball. The informant then made claims about the health and taste of a hidden food. By age four, children were wary of endorsing the inaccurate informant's claims about the food, endorsing them less than they endorsed the claims of a stranger for whom they had no information about past accuracy.

Of all potential informants, parents are viewed as particularly trustworthy. Children trust their mother's testimony about a novel animal over that of a stranger (Corriveau et al., 2009), and the same holds for testimony about novel foods (Nguyen, 2012). Children are also more likely to accept novel foods from their mother than from a stranger and more likely to eat that food as well (Harper & Sanders, 1975). These findings suggest that information about higher-order food properties, such as GMO status, should be viewed as more credible coming from a parent than from another adult.

No studies, to our knowledge, have examined parents' role in spreading information (or misinformation) about GMOs, but studies have examined the characteristics of an informant that influence GMO acceptance, and trust is critical (Costa-Font, Gil, & Traill, 2008). The more individuals trust the stakeholders in GMO technology—the scientists, the regulators, the watchdogs—the more positively they view GM foods (Landrum, Hilgard, Lull, Akin, & Jamieson, 2018; Marques, Critchley, & Walshe, 2015). And the more individuals trust particular sources of information—reporters, environmental organizations, consumer associations—the more positively they evaluate the quality of the information provided (Rosati & Saba, 2004). If parents are children's most trusted informant, then their input should shape children's conceptions of GMOs, as well as their conceptions of other controversial food properties.

Precedence for the importance of parent-child conversations in fostering children's conceptual understanding can be found in many domains of knowledge, from math (Berkowitz et al., 2015) to science (Gleason & Schauble, 1999) to theory of mind (Sabbagh & Callanan, 1998). Parents shape their children's cognitive development by providing information about unobservable causal mechanisms and modeling epistemically-appropriate means of belief formation and belief justification (Callanan, Shrager, & Moore, 1995). But parents cannot provide accurate information about GMOs if they do not possess that information themselves, and they are unlikely to foster scientifically-informed attitudes toward GMOs if their own attitudes are based on other considerations.

1.3. Current study

Parents are a primary source of information about the safety and nutrition of their children's food. Here, we explored the dynamics of how that information is shared by engaging parent-child dyads in conversations about food products. The products differed along three dimensions—whether they were made from GMOs, whether they contained gluten, and whether they were grown organically. Dyads' reasoning about those dimensions was measured in several ways: parents' and children's ability to define the dimensions (a measure of *knowledge*), their identification of the products they would buy (a measure of *preference*), parents' language when describing the products (a measure of *attitudes*), and children's contribution to each conversation (a measure of *engagement*). We chose dyads as our unit of analysis because conversations among dyads allowed us to examine these variables comprehensively and authentically. We sought to characterize group-level trends in how GMOs are conceptualized and discussed, as well as individual differences among parents' conceptions and how those differences affect their children's conceptions.

Three questions guided our research. First, how does parents' knowledge of GMOs relate to their preferences and attitudes toward GM foods? One possibility was that knowledgeable parents would view GM foods as no different from any other foods but that unknowledgeable parents would view them with suspicion, thus preferring non-GM foods to GM foods and expressing more negative attitudes about GM foods in their conversations with their children. This possibility is consistent with the finding that knowledge of the science behind GMOs is associated with greater willingness to buy and consume GM foods (McPhetres et al., 2019). Another possibility was that knowledge would have no bearing on preferences or attitudes—that even knowledgeable parents might view GM foods with suspicion. This possibility is consistent with the idea that GMO opposition is fueled by deep-seated biases that all people share, such as teleology and essentialism (Blancke et al., 2015), as well as data from national polls indicating that GM skepticism does not vary with self-reported knowledge about the topic (Pew Research Center, 2018). The coherence of parents' knowledge, preferences, and attitudes is potentially important for what children might learn from their parents; the more cohesive the message, the more persuasive it is likely to be (Kintsch, 1998).

Second, how do parents' stance toward GM foods relate to their stance toward other socially-salient food dimensions, namely, whether a food has been grown organically and whether it contains gluten? From a political point of view, GM foods appear to be more controversial than other types of foods (Lang, 2016), with much recent legislation targeting the production and marketing of GM foods specifically. Public polls indicate that the perceived risks of GM foods are increasing (Frewer et al., 2013), whereas the perceived risks of non-organic foods are decreasing (Pew Research Center, 2018). Parents' stance toward GM foods may thus be an outlier, with parents exhibiting stronger preferences for non-GM foods and more negative attitudes toward GMOs relative to other food dimensions. They might also know more about GM foods, given their prominence in recent legislative debates.

On the other hand, attitudes toward GM foods are correlated with attitudes toward organic foods, both of which are predicted by reliance on intuition and magical beliefs about food and health (Saher, Lindeman, & Hursti, 2006). Less is known about public perceptions of gluten, but many Americans restrict their consumption of gluten just as they restrict their consumption of GMOs (Pew Research Center, 2018). In fact, the number of Americans who maintain a gluten-free diet has more than tripled over the last decade, despite no increase in the number of Americans who cannot digest gluten because of celiac disease (Kim et al., 2016). If GMOs are seen as one of several food properties to be avoided, then parents' stance toward GM foods may not be special. It may instead mirror their stance toward non-organics and gluten. While an undifferentiated stance against GMOs, non-organics, and gluten is unwarranted from a scientific point of view, it may be more powerful from a pedagogical point of view, as children would learn from their parents that all three are simply "bad."

Third, how do parents' knowledge, preferences, and attitudes about GMOs influence their children's engagement in conversations about GMOs and their subsequent learning? Given the strong influence of social factors on food selection (Shutts et al., 2013), we expected that children's contribution to conversations about GMOs would vary with their parents' contribution, but it was an open question whether some forms of parental input would be more impactful than others. Parental preferences and attitudes have been shown to influence children's willingness to eat new foods (Galloway, Fiorito, Lee, & Birch, 2005) and may thus shape children's understanding of higher-order food properties as well. That said, GMOs are a complex topic, and parents may not be able to convey what they know about GMOs, or they may convey misconceptions about GMOs, as has been documented in conversations about other complex topics, including robotics (Jipson, Gülgöz, & Gelman, 2016), marine life (Rigney & Callanan, 2011) and evolution (Shtulman & Checa, 2017). Children's ability to learn about GMOs from parental input may thus be constrained by children's age or by parents' language patterns. Children's learning about GMOs may also differ from their learning about other food dimensions, such as organics and gluten, depending on the clarity and consistency of the relevant input.

In sum, we sought to explore the coherence of parents' reasoning about GMOs, whether that reasoning is unique in comparison to other controversial food dimensions, and how that reasoning influences children's understanding of GMOs. We explored these questions in the naturalistic context of parent-child conversations about the everyday decision of what food products to buy.

2. Method

2.1. Participants

Our participants were 70 parent-child dyads recruited from local parks in Los Angeles County. Dyads were restricted to one parent and one child, none of whom took part in more than one dyad. The children ranged in age from 3.1–10.4, with a mean age of 6.9 years (SD = 2.1 years). We targeted children between the ages of three and ten because children of this age were unlikely to have received much formal instruction in biology and because an age span this wide maximized our chances of observing developmental trends in how GMOs and other food dimensions are discussed and understood.

About half the children were female (n = 38), though most of the parents were female (n = 57). Preliminary analyses revealed no reliable effects of child gender or parent gender on the findings reported below. Participants were not asked for their race or ethnicity, but they were sampled from a population that is 37 % white, 34 % Hispanic/Latino, 16 % Asian, 10 % black, 4 % mixed race, and 1 % Native American or Pacific Islander. Five additional dyads were sampled but excluded from the final dataset for failing to complete the task.

2.2. Materials

Dyads were given a book that contained nine types of food: bread, cereal, crackers, granola, pasta, popcorn, pretzels, tortillas, and yogurt. They were shown two products for each type and asked to decide which they would prefer to buy. Products were represented with generic images, devoid of any packaging. The products were labeled as to whether they contain genetically-modified ingredients ("contains GMOs" vs. "non-GMO"), whether they contain gluten ("contains gluten" vs. "gluten-free"), and whether they were grown organically ("organic" vs. "non-organic"), as illustrated in Fig. 1. The first three product pairings differed along a single dimension; the next three differed along two dimensions; and the final three differed along all three dimensions. We presented the materials in this order to encourage increasingly nuanced decision making.

Dyads received one of two books. In both books, products that differed by one dimension preceded those that differed by two, which preceded those that differed by three, but the three product pairings for each block were presented in different orders. The presentation of the products also differed by book, such that an option that appeared on the left in one book appeared on the right in the other book.

2.3. Procedure

Each study session began with three questions for the parent: "What does *GMO* mean?", "What does *gluten* mean?", and "What

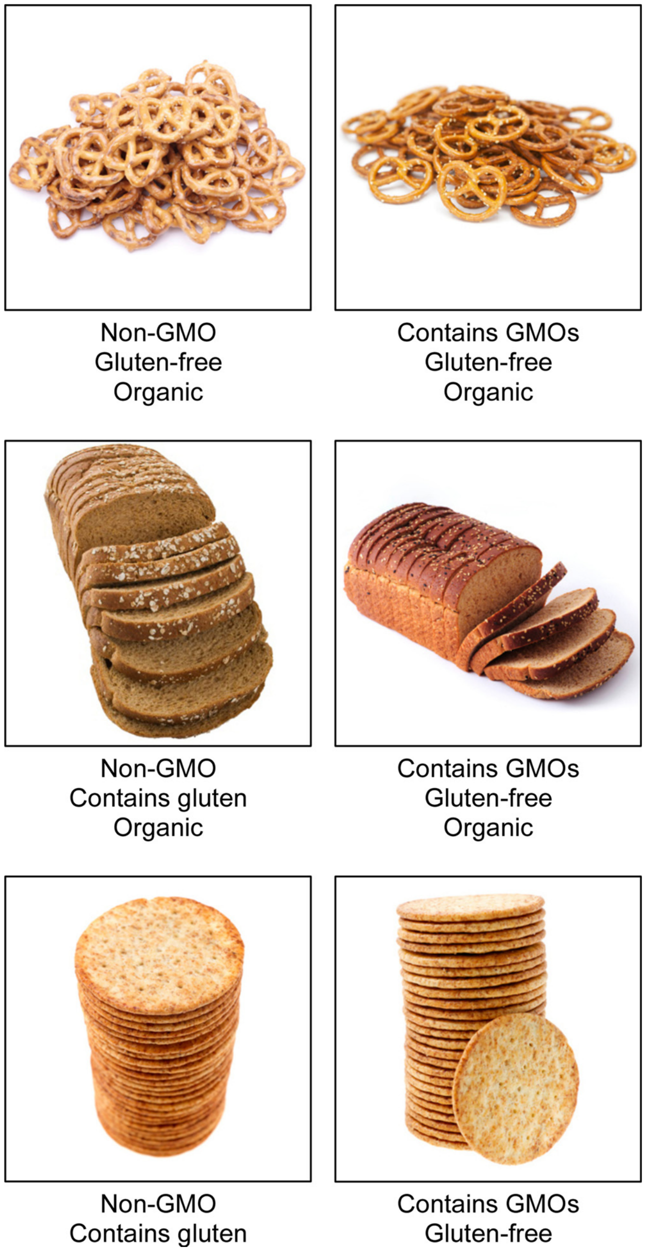

Fig. 1. Sample food products, differing by one, two, or three food dimensions.

does *organic* mean?". Regardless of the parent's answer, the experimenter then read the following definitions: "GMO stands for 'genetically modified organism,' or an organism whose genetic makeup has been altered by human engineering. Gluten is a substance present in wheat that can cause illness in people with celiac disease. And organic means the food was produced without the use of human-manufactured fertilizers or pesticides." These definitions are admittedly simplified. Our definition of "GMO" would include foods produced by cross-breeding and radiation treatments (i.e., mutagenesis), but these processes are excluded from being labeled "GMO" under the current food industry standard. Likewise, our definition of organic did not mention GMOs, even though the current standard excludes foods with genetically modified ingredients. These simplifications were made to ensure the definitions would be intelligible to non-experts (including children), and we saw no evidence in participants' definitions that they were aware of the technical nuances we had glossed over.

The experimenter then introduced the book of product choices, asking dyads to discuss each product pairing and select a preferred product. The study session concluded with three questions for the child: "What does GMO mean?", "What does gluten mean?", and "What does organic mean?". Children were present when parents provided their definitions, as well as when the experimenter read the correct definitions, so children's definitions were potentially informed by two sources of input. Parents were present when

Table 1
Sample parent and child definitions coded as complete (2), partial (1), or inadequate (0).

Food dimension	Score	Participant	Definition
GMO	2	Parent	Genetically modified organisms.
		Child	They changed the DNA.
	1	Parent	Made in the lab.
		Child	Something made by a human.
	0	Parent	Hormones.
		Child	Pink colored.
Organic	2	Parent	Grown with pesticides.
		Child	Free of things they use to keep the bugs off.
	1	Parent	Grown naturally.
		Child	Has bugs on it.
	0	Parent	Anything that's growing out of the ground.
		Child	Was once alive.
Gluten	2	Parent	Part of wheat that some people are allergic to.
		Child	Something to do with wheat; some people can't eat it.
	1	Parent	Something that has to do with wheat.
		Child	In bread and pastas.
	0	Parent	Like a fat.
		Child	Gives you a disease.

children provided their definitions but were discouraged from intervening. Each study session was audio-recorded and transcribed at a later date.

Sessions typically lasted 20 min and were conducted in the morning or early afternoon. Sessions occurred on site, typically in a quiet corner of the park where participants were recruited. The experimenter participated at the beginning of the session, when querying adults on the definitions of GMO, gluten, and organic, and at the end, when querying children on those definitions, but not in the middle, when parents discussed the nine food product pairings with their children. The experimenter did not intervene in the testing session other than to read the definitions noted above and to clarify the task instructions, if needed.

2.4. Coding

2.4.1. Definitions

Participants' definitions of GMO, gluten, and organic were scored as complete, partial, or inadequate. Complete definitions matched the model definition in content and specificity and were assigned 2 points (e.g., "GMO means genetically modified organism"). Partial definitions were either correct but vague (e.g., "GMO has something to do with genes") or specific but incomplete (e.g., "GMO is something made in a lab") and were assigned 1 point. Inadequate definitions referenced the wrong features and were assigned 0 points (e.g., "GMO is food made with chemicals"). "Don't know" responses were also assigned 0 points. Sample definitions for each coding category are provided in Table 1.

Two coders independently classified the 210 definitions provided by children and 210 definitions provided by parents. They agreed on 89 % of their codes (Cohen's kappa = .83) and resolved any disagreements through discussion.

2.4.2. Preferences

Dyads' product selections were coded for their value along food dimensions where the two products differed. If a dyad selected pretzels described as "non-GMO, gluten-free, and organic" over pretzels described as "contains GMOs, gluten-free, and organic," they were coded as preferring non-GMOs to GMOs. If a dyad selected crackers described as "contains GMO, gluten-free, and organic" over crackers described as "non-GMO, contains gluten, and non-organic," they were coded as preferring GMOs to non-GMOs, gluten-free foods to foods that contain gluten, and organic foods to non-organic foods.

The nine pairings that dyads considered represented all possible combinations of options. Six of those pairings involved foods that differed by a particular dimension, which meant that dyads' preference scores could range from 0 to 6. For the GMO dimension, a score of 6 indicated that dyads always chose the "non-GMO" option; for the gluten dimension, it indicated that dyads always chose the "gluten-free" option; and for the organic dimension, it indicated that dyads always chose the "organic" option. A score of 0 indicated that the opposite option was always selected.

2.4.3. Utterances

Dyads' discussions were coded separately for each product choice, and parents' utterances were coded separately from children's. Parents' utterances were coded for two types of language: moral evaluations and appeals to health. Moral evaluations were emotionally-valenced descriptions that implied the food dimension should be avoided. They included the words "bad," "yucky," "fake," "unnatural," "gross," "disgusting," "poison," or "toxic." Appeals to health referenced the body, digestion, nutrients, allergies, vitality, or physical strength. Examples of each type of utterance are included in Table 2.

Table 2
Sample parental descriptions of each food dimension.

Food dimension	Type	Description
GMO	Moral	It's like Frankenstein-food; someone changed it.
		Fake basically, made in a lab.
		Toxic, body-destroying.
	Health	It's not good for the body.
		More natural and healthier for our bodies.
		I'd buy the non-GMO one, cause I know it's healthier.
Organic	Moral	Doesn't have any yucky chemicals.
		No poison in it.
		The cow … wasn't pumped full of gross-ass hormones.
	Health	Healthy animals make healthy food and vice versa.
		They didn't add stuff that can possibly make you sick.
		Better for your body.
Gluten	Moral	Gluten free means they've taken out the bad stuff.
		Gluten is bad too.
		Yucky stuff.
	Health	Difficult for people to digest.
		Sometimes it's bad for your body.
		Good for us to lower our wheat intake so … we stay strong.

Parents' produced 630 sets of utterances—one for each of nine foods, provided by each of 70 participants. These utterances were coded for moral language and health language by two independent coders. They agreed on 85 % of their codes (Cohen's kappa = .70) and resolved their disagreements through discussion. It should be noted that the two codes were not mutually exclusive, but they were applied to the same utterance only 22 times, or 3 % of all utterances.

Children's utterances were short and infrequent. For most food discussions, children either said nothing (28 %) or made a single remark (25 %), and their typical remark was only a few words ("uh huh," "yeah," "okay," "that one," "I like this"). For these reasons, we analyzed children's remarks by frequency rather than content. We counted the number of times children spoke during each food discussion ($M = 1.9$, $SD = 1.6$), as well as the number of times they spoke across the entire session ($M = 17.2$, $SD = 14.8$). These figures provide a rough measure of engagement, which did vary by food dimension and by parental language patterns, as discussed below.

3. Results

Below we analyze parents' responses separately from children's before looking at relations between them. Parents provided four types of responses: definitions, preferences, moral language, and health language (summarized in Fig. 2). Children provided definitions and replies or reactions to their parents (summarized in Fig. 3). We analyze each type of response by food dimension, followed by relations among the dimensions and relations among the measures.

For moral language and health language, we focus on the product pairing where the products differed by a single dimension, to isolate dimension-specific commentary. These pairings were presented first, when participants were new to the task, and the conversations they prompted were typically longer and more-detailed than those prompted by later pairings. Parents used more moral language when discussing the first three pairings than when discussing the last three, even though the last three involved potentially harder decisions ($M = .23$ vs. $M = .14$, $t(69) = 2.48$, $p = .02$). The same was true for parents' use of health language ($M = .26$ vs. $M = .09$, $t(69) = 5.27$, $p < .001$) and children's total utterances ($M = 2.2$ vs. $M = 1.7$, $t(69) = 2.37$, $p = .02$), possibly due to task fatigue. The first three pairings thus provide a reasonable snapshot of the conversation as a whole, though we do look at language patterns across the entire conversation in the final section, to address the question of whether children's engagement varied with parents' language patterns.

3.1. Parent's responses

3.1.1. Definitions

Parents typically provided either partial definitions of the three food dimensions (35 %) or complete definitions (39 %) prior to receiving the correct definition from the experimenter. But some food dimensions were defined more accurately than others ($F(2,138) = 37.90$, $p < .001$, $\eta_p^2 = .36$). Parents defined "organic" more accurately than either "GMO" ($t(138) = 6.66$, Bonferroni-corrected $p < .001$, $d = 0.85$) or "gluten" ($t(138) = 8.19$, Bonferroni-corrected $p < .001$, $d = 0.94$), which they defined with equal accuracy ($t(138) = 1.53$, Bonferroni-corrected $p = .39$, $d = 0.18$). Parents thus demonstrated greater knowledge of how foods come to be classified as organic than how they come to be classified as containing GMOs or gluten.

Definition accuracy was generally correlated across food dimensions. Accuracy at defining GMOs was positively correlated with accuracy at defining organic ($r = .34$, $p = .004$) and with accuracy at defining gluten ($r = .30$, $p = .01$). Accuracy at defining gluten

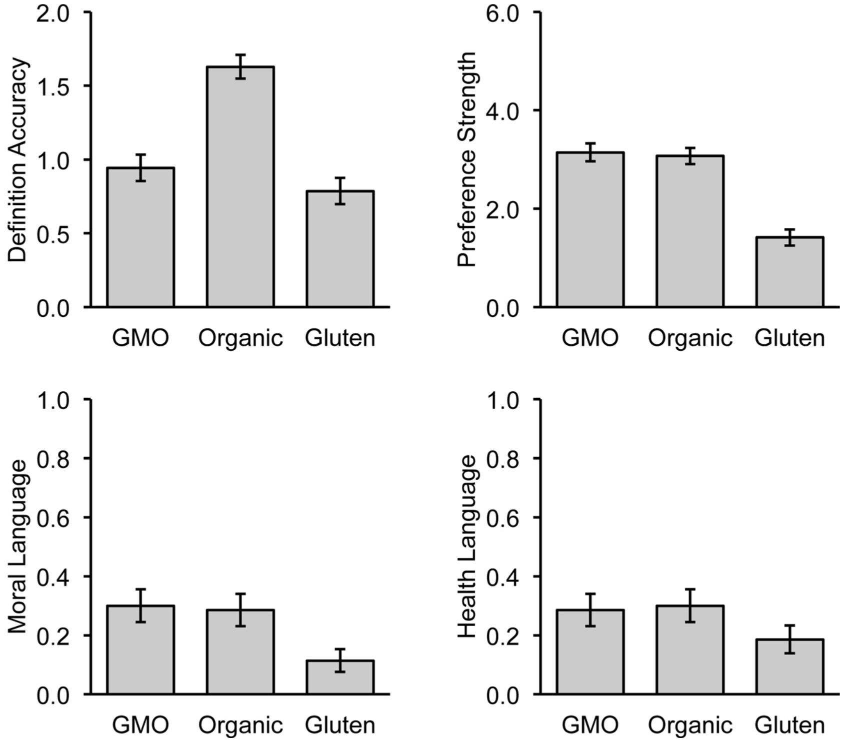

Fig. 2. Adults' mean accuracy at defining "GMO," "organic," and "gluten" (top left), their mean preference for non-GM foods, organic foods, and gluten-free foods (top right), and the proportion who used moral language (bottom left) or health language (bottom right) when discussing product choices involving these dimensions. Error bars represent *SE*.

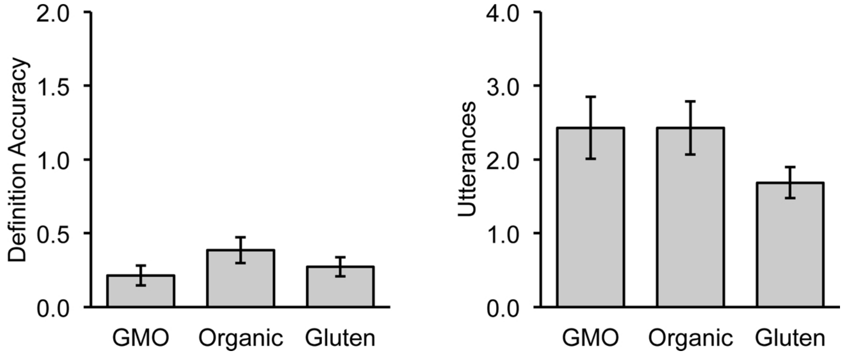

Fig. 3. Children's mean accuracy at defining "GMO," "organic," and "gluten" (left) and their mean utterances when discussing product choices involving these dimensions (right). Error bars represent *SE*.

was not significantly correlated with accuracy at defining organic ($r = .19$, $p = .12$), though the relationship was positive. This pattern implies that parents were either generally knowledgeable about the food dimensions or generally unknowledgeable.

3.1.2. Preferences

Parents encountered six product pairings (out of nine) in which the products differed by GMO status. The same was true for products that differed by organic status and gluten status. Parents selected the non-GMO option an average of 3.1 times ($SD = 1.5$), the organic option an average of 3.1 times ($SD = 1.4$), and the gluten-free option an average of 1.4 times ($SD = 1.4$). A repeated-measures ANOVA confirmed that the strength of participants' preferences varied by food dimension ($F(2,138) = 31.3$, $p < .001$, $\eta_p^2 = .31$). Non-GM foods were preferred more strongly than gluten-free foods ($t(138) = 7.00$, Bonferroni-corrected $p < .001$, $d = 0.82$), and organic foods were preferred more strongly than gluten-free foods ($t(138) = 6.71$, Bonferroni-corrected $p < .001$, $d = 0.82$), but non-GM foods were not preferred more strongly than organic foods ($t(138) = 0.29$, Bonferroni-corrected $p = 1.00$, $d = 0.03$). Thus, whether a food contained gluten was viewed as less important than whether it was organic or whether it contained GMOs.

3.1.3. Moral language

During conversations about the first three product pairings, parents used moral language 23 % of the time, and 47 % of parents used such language at least once. Moral language did vary by food dimension ($F(2,138) = 5.38$, $p = .006$, $\eta_p^2 = .07$). Product pairings that differed by gluten status evoked less moral language than pairings that differed by GMO status ($t(138) = 2.95$, Bonferroni-corrected $p = .01$, $d = 0.36$) or by organic status ($t(138) = 2.72$, Bonferroni-corrected $p = .02$, $d = 0.32$). The latter two pairings evoked moral language equally often ($t(138) = 0.23$, Bonferroni-corrected $p = 1.00$, $d = 0.03$). In sum, the dimensions that figured most prominently in participants' preferences—GMO status and organic status—also evoked the most moral language.

Parents who used moral language to discuss gluten status did not necessarily use moral language to discuss GMO status ($r = .16$, $p = .20$) or organic status ($r = .07$, $p = .56$). On the other hand, parents who used moral language to discuss GMO status used similar language to discuss organic status ($r = .35$, $p = .003$). The latter correlation, paired with parents' product preferences, suggests that GMOs and organic foods are more closely linked in parents' minds than either is linked to gluten.

3.1.4. Health language

Parents appealed to health considerations 26 % of the time when discussing the first three product pairings, and 56 % of parents did so at least once. Health language, like moral language, varied by food dimension ($F(2,138) = 1.47$, $p = .23$, $\eta_p^2 = .02$). The one dimension most legitimately tied to health concerns—gluten—was discussed in terms of health less often than either GMOs or non-organic foods, though none of these differences were reliable. Health language was also uncorrelated across food dimensions (with r averaging .04), indicating that appeals to health were comparable across dimensions and participants.

3.1.5. Relations among measures

To determine whether parents' responses were cohesive, we compared the accuracy of their definitions, the strength of their preferences, their use of moral language, and their use of health language for each food dimension. We found virtually no relations among these measures. The only exception was a negative correlation between participants' ability to define gluten and their preference for gluten-free foods ($r = -0.26$, $p = .03$), implying that those who know what gluten is are generally okay with buying foods that contain gluten. Otherwise, parents' knowledge of the food dimensions was not a predictor of their food preferences nor the language they used to discuss those preferences.

3.2. Children's responses

3.2.1. Definitions

Children's accuracy at defining "GMO," "organic," and "gluten" was much lower than their parents'. Children provided partial definitions 12 % of the time and complete definitions 9% of the time. Their accuracy varied by dimension, however ($F(2,138) = 4.35$, $p = .02$, $\eta_p^2 = .06$). They defined "organic" most accurately and "GMO" least accurately—a reliable difference ($t(138) = 2.90$, Bonferroni-corrected $p = .01$, $d = 0.32$). But they defined "organic" no more accurately than "gluten" ($t(138) = 1.93$, Bonferroni-corrected $p = .17$, $d = 0.24$) and defined "gluten" no more accurately than "GMO" ($t(138) = 0.97$, Bonferroni-corrected $p = 1.00$, $d = 0.12$).

Definition accuracy was correlated across food dimensions. Accuracy for "GMO" was correlated with accuracy for "organic" ($r = .68$, $p < .001$), accuracy for "organic" was correlated with accuracy for "gluten" ($r = .77$, $p < .001$), and accuracy for "gluten" was correlated with accuracy for "GMO" ($r = .62$, $p < .001$). These correlations remained significant even when controlling for children's age in months (GMO-organic: $r = .61$, $p < .001$; organic-gluten: $r = .72$, $p < .001$; gluten-GMO: $r = .55$, $p < .001$), indicating that children who could define one dimension were typically able to define the other two, regardless of how old they were.

To determine whether the accuracy of children's definitions tracked their parents' input, we ran a series of hierarchical regressions. For each food dimension, we regressed children's definition scores against their age (Model 1), followed by parents' definition scores (Model 2), followed by parents' preference scores, moral language, and health language (Model 3). The results of these analyses are displayed in Table 3. Children's age was a significant predictor of their definition accuracy for all food dimensions (GMO: $R^2 = .18$, $F(1,68) = 14.96$, $p < .001$; organic: $R^2 = .20$, $F(1,68) = 17.24$, $p < .001$; gluten: $R^2 = .15$, $F(1,68) = 12.38$, $p < .001$). Parents' definition scores explained a significant amount of variance beyond children's age (GMO: $R^2 = .26$, *F-change* $(1,67) = 7.11$, $p = .01$; organic: $R^2 = .25$, *F-change* $(1,67) = 4.19$, $p = .045$; gluten: $R^2 = .21$, *F-change* $(1,67) = 4.27$, $p = .04$), but the remaining variables did not explain any additional variance (GMO: $R^2 = .28$, *F-change* $(3,64) = 0.64$, $p = .59$; organic: $R^2 = .28$, *F-change* $(3,64) = 1.05$, $p = .38$; gluten: $R^2 = .21$, *F-change* $(3,64) = 0.11$, $p = .95$).

These findings indicate that children whose parents were able to define each food dimension were able to do so themselves, regardless of age. All children heard correct definitions provided by the experimenter, but only children whose parents correctly defined the terms (prior to hearing the definitions themselves) were able to define the terms at the end of the study. Other aspects of parental input—their food preferences, their moral language, their health language—were unrelated to children's definition accuracy, either in the regression model or when analyzed as zero-order correlations.

3.2.2. Utterances

Children spoke an average of 2.2 times in each of the first three conversations (for product pairings that differed by a single dimension), and 89 % of children spoke at least once. The number of times children spoke varied by food dimension ($F(2,138) = 3.76$, $p = .03$, $\eta_p^2 = .05$). They spoke less during conversations about gluten than conversations about GMOs ($t(138) = 2.38$, Bonferroni-corrected $p = .057$, $d = 0.26$) and conversations about organics ($t(138) = 2.38$, Bonferroni-corrected $p = .057$, $d =$

Table 3
Standardized estimates for predictors of children's ability to define each food dimension following the food-selection task.

Food dimension	Measure	Model 1	Model 2	Model 3
GMO	Child's age	.43***	.38***	.38***
	Parent's definition accuracy		.28*	.27*
	Parent's preference strength			−.04
	Parent's moral language			.12
	Parent's health language			.09
Organic	Child's age	.39***	.35**	.35**
	Parent's definition accuracy		.23*	.23
	Parent's preference strength			.04
	Parent's moral language			−.01
	Parent's health language			.05
Gluten	Child's age	.45***	.47***	.46***
	Parent's definition accuracy		.22*	.22
	Parent's preference strength			.03
	Parent's moral language			−.18
	Parent's health language			−.05

* $p < .05$.
** $p < .01$.
*** $p < .001$.

0.29), though the differences were marginal. For conversations about GMOs and organics, they spoke equally often ($t(138) = .00$, Bonferroni-corrected $p = 1.00$, $d = 0.00$).

Older children did not speak more than younger children during any of the conversations; all correlations with age were non-significant (with r averaging .02). But children's utterances were correlated across food dimensions. The more children spoke about GMOs, the more they spoke about organics ($r = .72$, $p < .001$); the more they spoke about organics, the more they spoke about gluten ($r = .60$, $p < .001$); and the more they spoke about gluten, the more they spoke about GMOs ($r = .54$, $p < .001$). These correlations could be due to differences in talkativeness, differences in engagement, or both. One reason to suspect that engagement mattered is that children's overall talk, across the entire session, was positively correlated with their parents' use of moral language ($r = .32$, $p = .007$) and marginally correlated with their parents' use of health language ($r = .23$, $p = .054$). The more parents framed each product choice as relevant to morality or health, the more children participated in the conversation.

4. Discussion

Most adults view GMOs with doubts and misgivings, even though they seem to have little understanding of what GMOs are. How do adults' views on GMOs influence their children's views? We investigated this question in a context where parents are particularly likely to share their views: deciding between food products that contain GMOs and those that do not. Three main findings emerged.

First, parents' views were not particularly coherent. Their ability to define GMOs was not correlated with their preference for non-GM foods ($r = .02$, $p = .87$), nor was it correlated with their use of moral language ($r = .18$, $p = .14$) or health language ($r = -.04$, $p = .76$) when discussing products that differed by GMO status. Their preference for non-GM foods also did not correlate with their use of moral language ($r = -.02$, $p = .86$) or health language ($r = -.02$, $p = .88$). Parents varied along all four measures, but that variance did not hang together, implying that parents are more confused than convinced about the status of GMOs. Even at the group level, parents' preferences across the three target dimensions—GMOs, organics, and gluten—were not aligned with their knowledge of those dimensions. They preferred non-GM foods significantly more than gluten-free foods but were no better at defining "GMO" than at defining "gluten." In contrast, they preferred non-GM foods equally to organic foods but were significantly better at defining "organic" than at defining "GMO."

On the other hand, parents' preferences across food dimensions were aligned with their attitudes toward those dimension, at least at the group level. Parents exhibited stronger preferences for non-GM foods and organic foods, relative to gluten-free foods, and they were also more likely to describe non-GM foods and non-organic foods with moral language. This correspondence suggests that GMO status is not unique in its influence on parents' consumer decisions; a food's organic status has equal weight. This finding echoes polling data indicating that about half of Americans think non-GM foods and organic foods are better for one's health (Pew Research Center, 2018). Yet parents were not particularly likely to cite health considerations when discussing GMOs and organics. Parents who cited health considerations when discussing GMO-based product decisions were similar in number to those who used moral language (30 % vs. 29 %). The same was true for discussions of organic-based product decisions (29 % vs. 30 %), which implies that parents' stronger preferences for non-GM foods and organic foods are not driven primarily by health considerations (consistent with findings from Royzman, Cusimano, Metas, & Leeman, 2019).

Finally, parents' understanding of GMOs, organics, and gluten appeared to influence children's understanding. Children's ability to define the three food dimensions was correlated with their parents' ability to do so even when controlling for children's age. Younger children had more difficulty than older children defining all three dimensions, consistent with prior research demonstrating that younger children are less able to think of food as a multidimensional concept (Nguyen & Murphy, 2003), but this difficulty was potentially assuaged by parents who provided more accurate information. Children's ability to define the food dimensions was not correlated with their parents' preferences or language patterns, but parents' language patterns did predict children's overall engagement in the conversation. The more parents used moral language, the more their children participated in the conversation, and a similar trend was observed for parents' use of health language.

It's an open question, though, whether children's increased participation reflects increased interest on the child's behalf or increased investment on the parent's behalf. Consider this conversation between a mother (labeled "P" for parent) and her 10-year-old daughter (labeled "C" for child):

C: I like both.

P: This one here is non-GMO.

C: Is it chewy?

P: I don't know if it's chewy, but basically they don't add anything to it. They don't engineer something artificial that's not natural.

C: But that one's organic.

P: Yeah, but this one has GMOs, which means it's not natural. But they're both gluten-free and they're both organic. So which one would you choose?

C: I don't know.

P: Let's just say the non-GMO because we don't want anything that's not real. We don't want fake food.

C: Isn't that fake food?

P: Yeah, that probably is. So we'll pick non-GMO granola bars.

This parent not only moralized GM foods, calling them "fake," "artificial," "not natural," and "not real," but also persisted at convincing her child that the non-GM option was better. A similar dynamic can be seen in this conversation, between a mother and her five-year-old daughter:

C: Non what?

P: G-M-O. Okay, so GMO means?

C: I forgot.

P: Okay, so see here's the thing: GMOs aren't good.

C: Okay.

P: So you know how food comes from the ground?

C: Uh-huh.

P: Well some places food comes from a laboratory, like a scientist place. Do we wanna eat food that comes from the ground or comes from a scientist?

C: Ground.

P: Yeah, what did you learn in school about food? How is it grown?

C: With a seed.

P: With a seed, good job. So which one should we have? We want the one that has no GMOs.

It would appear that the parents' motivation in these exchanges is to convince their children that GMOs are bad and should be avoided. Whether parents succeeded is unclear, as we did not ask children about their attitudes toward GMOs, nor did we measure their preferences toward GMOs independent of their parents. In future research, we plan to gauge the impact of parents' input on children's attitudes and preferences, as assessed in a private interview with the child. Future research might also explore the stability of children's attitudes and preferences over time, to determine whether parents' moral language or their health language engenders more stable dispositions. Children's attitudes and preferences could be measured not only with self-report but also with behavioral tests, such as children's selection of real food products or their willingness to eat GM foods when offered to them. Future research might also explore the frequency and consistency of parental input, to determine whether parents who discuss a food dimension mainly in moral terms or mainly in health terms raise the topic more often and whether the consistency of that input influences children's attitudes in addition to its content.

Our study provides some of the first evidence that parents are a potent source of information about GMOs and other controversial food dimensions, but it was limited in several ways. We did not measure whether children were paying attention to their parents' input, and differences in attention may have affected what children learned from the interaction. We did not measure children's prior knowledge of biological concepts or food concepts in particular, and differences in prior knowledge may have modulated learning, particular among younger children, who have demonstrably less knowledge of biological processes (Hatano & Inagaki, 1994; Solomon & Zaitchik, 2012). Finally, our definitions of the food dimensions, provided by the experimenters, may have introduced biases in what was discussed and what was learned. GMOs and organic foods were defined in terms of how they are produced, whereas gluten was defined in terms of its consequences for health ("a substance present in wheat that can cause illness in people with celiac disease"). While we did not observe an increase in health language or moral language for gluten relative to the other dimensions (we actually observed a decrease), future studies should explore the impact of how a food dimension is defined—by its properties or its consequences—on the thoughts and attitudes that dimension evokes.

On the whole, our findings suggest that children's conceptions of GMOs are shaped by their parents' conceptions, despite the fact that parents' preferences and attitudes may not be justified by their knowledge of what GMOs are. While some parents accurately conveyed the meaning of GMOs to their children, others conveyed misconceptions, which appeared to influence children's ability to define the terms on their own. And while some parents treated GMOs as a non-issue, others highlighted their artificial nature or their perceived risks, which influenced children's engagement with the conversation. These findings imply that parents are a potent source of information about GMOs, and other controversial food dimensions, and attempts to educate children about food science (e.g., Giordano, 2014) may need to involve their parents as well.

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