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# Impact of Abstract Versus Concrete Conceptualization of Genetic Modification (GM) Technology on Public Perceptions

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Based on the scholarship of abstract/concrete cognition, mental schema, and the integrated model of behavior change, this study found that using concrete over abstract language increased support for specific genetically modified (GM) applications and GM in general, and improved intentions to purchase products containing genetically modified organisms (GMOs). An online survey with an embedded 3 × 2 experiment was conducted using a national sample of U.S. adults ($N = 1{,}470$). Participants were randomly assigned to conditions that varied in abstract/concrete conceptualization of GMOs and were prompted to assess GM risk and benefit perceptions with respect to human health and the environment. Regardless of whether they assessed risks or benefits, participants who assessed GMOs through concrete terms compared to abstract terms showed an increase in positive emotions, which in turn increased their support for specific GM applications and GM in general, and their intentions to buy products with GMOs.

**KEY WORDS:** Abstract; concrete; genetic modification

## 1. INTRODUCTION

Fulfilling the promise of a technology depends not only on scientists' ability to create it, but on the publics' understanding and willingness to accept it. The type, amount, and manner in which the information about a technology is communicated can influence publics' decision-making process. In this study, we explore the effects of concrete information on people's attitudes and intentions with respect to the emerging technology of genetically modified organisms (GMOs).

GMOs involve genetic engineering to alter specific traits of an organism (Phillips, 2008). For example, genetically modified (GM) corn has been altered to be resistant to certain pests, GM soybean has been engineered to be herbicide tolerant, and GM mosquitoes have the potential to reduce the spread of Zika virus (Harris et al., 2011; Phillips, 2008). GM products have been found to pose no health risks to humans, and in some instances, have led to better health outcomes compared to their non-GM counterparts (Dance, 2018; National Academies of Sciences, Engineering, and Medicine, 2016; Olena, 2017; Saplakoglu, 2017; Stein, 2017; Voytas & Gao,

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2014). However, there have been reports on some environmental concerns pertaining to their resistance management strategies, i.e., studies showing that weeds in some locations were developing resistance to the herbicide glyphosate (Borel, 2018; National Academies of Sciences, Engineering, and Medicine, 2016). As with any research involving emerging technologies, the short- and long-term risks and benefits of GM technology are evolving, which can add to the sense of uncertainty for the public and contribute to their limited support toward the technology (Binder, Hillbach, & Brossard, 2016; Funk & Kennedy, 2016).

Public opinion on GMOs is complex and nuanced, and while it is best to avoid generalized statements about their perceptions (Fischhoff & Fischhoff, 2001), recent scholarship does suggest that the U.S. public holds modest levels of awareness about GMOs in their diets, low levels of knowledge about GMOs in general (Hallman, 2018; Hallman, Adelaja, Schilling, & Lang, 2002; Hallman, Hebden, Aquino, Cuite, & Lang, 2003; Hallman, Hebden, Cuite, Aquino, & Lang, 2004), and low trust in scientists and scientific institutions studying GMOs (Funk & Kennedy, 2016). Moreover, recent studies have demonstrated that there is limited support for GMOs in general among the public (Funk & Kennedy, 2016; Tallapragada & Hallman, 2018).

However, while the general attitude toward GMOs has been unenthusiatic, specific applications of GMOs have received high levels of support (Desaint & Varbanova, 2013; Funk & Kennedy, 2016; Funk, Rainie, & Page, 2015; Hallman, 1996; Hallman et al., 2002; Hossain, Onyango, Schilling, Hallman, & Adelaja, 2003; Knight, 2006; McFadden, 2016). Research on public perceptions of GMOs shows that people with neutral or even negative attitudes about GMOs in *general*, often also express significant support for specific applications of the technology (Hallman et al., 2002; Knight, 2006). For example, people have expressed support for using GM technology to create more nutritious grain or to develop rice with enhanced vitamin A (see Hallman et al., 2002). In comparison to general attitudes toward GMOs, plant-based applications of GM typically garner more public support than animal-based applications; however, greater support for specific GM applications of many types has been identified in prior research (Frewer et al., 2013; Hallman et al., 2003; Knight, 2006; Puduri, Govindasamy, Lang, & Onyango, 2005).

Research in this area is typically descriptive and lacks theoretical perspectives regarding the cognitive mechanisms that explain *why* individuals change their opinions about GMOs when presented with specific applications. In addition, it is unclear whether these newly formed opinions about specific applications affect people's more general attitudes on GMOs. Informed by past scholarship on abstract and concrete cognition, mental schema, and the integrated model of behavior change, we investigate whether engagement with specific GM applications compared to abstract notions of GM technology impacts attitudes toward those specific applications, and whether these, in turn, affect overall attitude toward GMOs and intentions to purchase products with GM ingredients.

## 2. ABSTRACT AND CONCRETE COGNITION, MENTAL SCHEMA, AND ATTITUDE FORMATION

### 2.1. Cognition and Mental Schema

"GMO" is an abstract term that can trigger varied perceptions among individuals. However, stating that "GM technology can be used to develop rice that can reduce blindness among children" directs cognition by activating a much more concrete perception of GMOs. Concrete language has an advantage over abstract language for accurate and quick information processing (Binder, Westbury, McKieman, Possing, & Medler, 2005; Jones, 1985; Kieras, 1978). Although researchers first identified concreteness effects over a half century ago (see Paivio, 1991), there is still no agreed-upon universal theory that explains the reasons for the advantages of concrete over abstract language (Borghi et al., 2017).

There are a handful of theories and frameworks that situate the differences between concrete and abstract terms in information processing (see, Barsalou, 1999; Boot & Pecher, 2011; Borghi et al., 2017; Bransford & Johnson, 1972; Casasanto, 2008; Gentner, 1981; Lakoff, 2014; Paivio, Yuille, & Madigan, 1968; Schwanenflugel, Akin, & Luh, 1992; Schwanenflugel, Harnishfeger, & Stowe, 1988; Tverksy & Kahneman, 1974; Weimer-Hastings & Xu, 2005)[1]. There are two common underlying characteristics across these theories. First, concrete language

[1]There are also some theories that claim that regardless of words being abstract or concrete, it is the sensorimotor functions that determine whether individuals are able to process words quickly (see Chen & Bargh, 1999; Glenberg & Kaschak, 2002; Talmy, 1988) or the perceptual strength of words (Connell & Lynott,

has an advantage over abstraction in terms of quick and accurate processing. There is a sense of familiarity, imageability, and ease of context available to concrete words over abstract ones (see Stadthagen-Gonzalez & Davis, 2006). Second, abstract language triggers experiences grounded in one's schema. Every individual has a unique schema which is shaped by their experiences in physical, psychological, and social environments (DiMaggio, 1997). Compared to abstract language, concrete language can be used to guide individuals out of their default cognitive schema to process messages in a new context, which then in turn can influence and reshape their schema.

Take, for exmple, two scientists—one who is currently working on GM rice and the other who is working on GM beef. Without any additional information, the abstract term "GMO" would most likely activate very different aspects of GMOs between the two scientists because their schematic representations of GMOs vary based on their own experiences with the technology. If asked to assess opinions about an abstract concept like GMOs, their schema, influenced by their own specific research, will influence their responses. For individuals who are not scientists working on GMOs, forming a clear image with specific features of GMOs would be challenging and it is likely that they will rely on their existing schematic representations about GMOs (however fuzzy they may be) as the basis for their opinions. This would be especially true for those who have limited understanding of GMOs or little awareness of their presence in their daily lives. Concrete representations of GMOs can help individuals focus on the specific GM application, regardless of their prior knowledge. Concrete words then have the ability to let individuals edit their existing schema pertaining to GMOs.

Beliefs are a manifestation of schema. According to the integrated model of behavior change, beliefs are the building blocks of positive/negative attitudes which affect behavioral intentions (Fishbein & Yzer, 2003). The beliefs about the nature of GMOs, their characteristics, and their associated risks and benefits however vary and these affect their attitudes toward GMOs.

While attitudes toward GMOs in general have been unenthusiastic, studies have shown that even those who hold negative attitudes toward GMOs in the abstract do support some specific GM applications (Hallman et al., 2002; Knight, 2006). We expect to see similar results in this study, and thus predict that participants presented with specific applications (i.e., presented with concrete language) compared to the general terminology (i.e., presented with abstract language) are likely to report positive intentions toward buying GM technology. We test the following hypothesis:

H1: Participants presented with specific GM applications (i.e., using concrete language to describe GM applications) compared to the general terminology (i.e., using abstract language to describe GM in general without the mention of applications) are more likely to report positive intentions toward buying GM technology.

2012). These theoretical discussions on abstract and concrete are ongoing.

## 2.2. Risk–Benefit Perceptions

Applications of science and technology are often developed to improve human welfare and environmental conditions, so people often view the products of science and technology as positive developments (Funk, Kennedy, & Sciupac, 2016). Although there is an inherent positive bias toward technological applications perceived as beneficial, there needs to be space for an individual to consider both the potential risks and benefits of those specific applications when forming attitudes and opinons about them. In previous studies that have assessed public approval of these applications, participants have not been prompted to consider their potential risks (see Hallman et al., 2002; Knight, 2006). However, outside of surveys, people often make decisions about technologies based on both risk and benefit perceptions (Kim, Yeo, Brossard, Scheufele, & Xenos, 2013; Moon & Balasubramanian, 2001; Pidgeon, Hood, Jones, Turner, & Gibson, 1992; Savadori et al., 2004; Slovic, 2000; van Dijk, Fischer, & Frewer, 2010).

Researchers have found that beliefs about risks and benefits can influence attitudes and intentions toward technologies such as GMOs (see Siegrist & Gutscher, 2006; Tallapragada & Hallman, 2018). Several factors including the details of how much and who is affected by the risks and benefits from a technology, the affect generated from the risk–benefit perceptions, and details about the source and governance of the technology could all influence the attitudes and intentions toward a technology (Moon & Balasubramanian, 2004; Savadori et al., 2004; Townsend, 2006; Wilson, Evans, Leppard, & Syrette, 2004).

As is the case with other emerging technologies, new GM techniques, products, and applications are continually being developed, regulated, and introduced to the market. Therefore, having an informed public who can understand and engage in civic deliberation regarding GM (Shen, 1975) is important to ensure technological outcomes that are both safe and broadly acceptable to the public. As the public currently has low levels of awareness and knowledge about GMOs (Hallman et al., 2002, 2003, 2004), asking them to consider the risks or benefits of specific GM applications can provide an opportunity for them to directly engage with the potential of the technology, and by prompting them to deliberately consider their risks, benefits, or both, influence their opinion and understanding of GM in general. In this study, we are interested in exploring if, within the context of abstract or concrete conceptualizations of GMOs, prompting individuals to assess only risks, only benefits, or both, impacts their attitudes and intentions toward GMOs. We thus pose the following research question:

RQ: How will individuals engaged in assessing the risks, benefits, or both, impact their intentions toward buying GM technology?

### 2.3. The Role of Affect

Because of the generally affect-laden nature of the language used to communicate them, considerations of particular risks and benefits, and engaging with abstract or concrete terms, is likely to evoke emotions in participants. Some have argued that the emotions associated with risk–benefit perceptions are largely heuristic in nature (Kahneman, 2011; Slovic et al., 2002) while others have argued that they are the result of deep cognitive considerations (Haidt, 2001; Roeser & Pesch, 2015). Similarly, there are arguments presented for emotions being a dominant aid in processing abstract words over concrete words, giving abstract words an advantage in processing (which is counter to the concreteness effects discussed above—see Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011; Vigliocco et al., 2014), and counterarguments for emotion being more readily accessed with concrete words compared to the abstract words due to the greater ability of concrete words to evoke sensorimotor experiences (Yao et al., 2018).

In the context of this study, the abstract term used is "GM technology." Previous studies have shown that U.S. adults are not very familiar with the underlying concepts of GM technology (Fernbach, Light, Scott, Inbar, & Rozin, 2019; Hallman et al., 2002, 2003, 2004) and express mostly unenthusiastic affect toward it (Funk & Kennedy, 2016; Knight, 2006; McFadden, 2016). This suggests that the term "GM technology" in its abstract form is unable to activate a strong positive or negative emotion, whereas there is potential in activating positive or negative emotions when expressing GM technology with specific applications. Given that past research has shown that demonstrating concrete GM applications have often resulted in increased support toward GM technology, we hypothesize that those presented with concrete GM applications compared to the abstract GM terminology are more likely to experience positive emotions, which should translate into increased support for GM technology and intentions to purchase products with GM ingredients. We state the following hypothesis:

H2: Participants presented with concrete GM applications compared to the abstract GM terminology are more likely to experience positive emotions, which in turn, will increase support for GM technology and intentions to purchase products with GM ingredients.

While the first hypothesis is predicting the direct relationship between concrete GM applications and intentions to purchase products with GM ingredients, the second hypothesis is predicting that the relationship will be serially mediated through positive emotions and then attitudes of support toward GM technology.

## 3. METHOD

An online survey with an embedded experiment was conducted using a quota sample of U.S. adults ($N$ = 1,467) who were recruited through Qualtrics with quotas for gender, age, and ethnicity to match the U.S. census data using the 2015 American Community Survey (ACS) Public Use Microdata Sample (PUMS) (see The United States Census Bureau, 2020). Table I reports the descriptive statistics of the demographic composition of the sample.

Using a 3 × 2 between-subject design, participants were asked to assess (1) the risks only, (2) the benefits only, or (3) both the risks and benefits of GM (i) in the abstract, or (ii) related to specific, i.e.,

**Table I.** Demographic Composition of the Sample

| | Mean or % | *SD* |
|---|---|---|
| Age | 44.787 | 17.509 |
| Gender (Female) | 51.09% | – |
| Ethnicity (White) | 66.67% | – |
| Ethnicity (Black) | 12.86% | – |
| Education (Years of formal schooling) | 14.830 | 1.957 |
| Political ideology (five-point scale; "Very liberal" coded high) | 2.991 | 1.206 |

concrete applications. Each participant was randomly assigned to one of the six conditions (presented in Table II) or to a control condition.

All questions pertaining to each condition are outlined in the Appendix. The purpose of these questions was to have participants engage with either the abstract or concrete nature of GMOs and to have them consider either the risks, the benefits, or both the risks and benefits of these applications. These questions served as conditions only and not as measures analyzed below. Prior to fielding the survey, cognitive interviews were conducted with six individuals (one for each condition) using think-aloud and verbal probing techniques to ensure question wording was clear (Willis, 1999). No data pertaining to their perceptions was gathered during cognitive interviews, but their recommendations regarding question wording was incorporated into the final survey.

Participants in condition 1 (abstract-risk) were presented with randomized questions measuring risk perceptions with respect to health and the enviornment pertaining to using GM for plant- and animal-based applications in general. No specific GM applications were presented in this condition. For example, participants were asked on a five-point scale (with 1 = "very risky;" 2 = "risky;" 3 = "somewhat risky;" 4 = "not at all risky;" 5 = "I am not sure"), "how risky do you perceive plant-based GMOs are for your health?" and "how risky do you perceive plant-based GMOs are for the environment?," and two similar questions were asked with respect to animal-based GMOs.

In condition 2 (concrete-risk), participants were presented with the same randomized questions regarding risk perceptions with respect to health and the environment as in condition 1, for the 10 concrete plant- and animal-based applications (see Table III for the list of applications). Participants were also asked to assess on a five-point scale (1 = "not at all useful" to 5 = "extremely useful"), how personally useful each of the applications were to them. They were also asked to grade on a four-point scale their perception of the current availability of these applications in the market (1 = "already available in markets," 2 = "likely to be available in 5–10 years," 3 = "likely to be available in over 10 years," 4 = "not likely to be available in markets any time"). Finally, they were also asked on a three-point scale the morality of these applications (1 = "morally unacceptable;" 2 = "not sure;" 3 = "morally acceptable"). Participants in this condition were provided with matrix questions that listed all 10 applications in the same space with the same scale for each application.

In condition 3 (abstract-benefit), the same questions were asked as in condition 1, but instead of risk perceptions, they were asked about their perceptions of the benefits of GM in general. In condition 4 (concrete-benefit), the same questions were asked as in condition 2, but instead of risk perceptions, they were asked about their perceptions of the benefits of concrete GM applications. Condition 5 (abstract—risk and benefit) included questions from conditions 1 and 3. Condition 6 (concrete—risk and benefit) included questions from conditions 2 and 4. Participants in the control condition were directed to the set of questions that all participants responded to in the survey following the experimental manipulation.

### 3.1. Concrete GM Applications

The concrete GM applications selected for the survey are shown in Table III. To ensure that the specific GM applications used in the survey included some with human health benefits and some with environmental benefits, we conducted a preliminary analysis using a sample ($N = 355$ who passed all four attention checks) from Amazon's Mechanical Turk. Participants were asked to rate 27 GM applications currently being studied on how likely they thought the application had human health benefits on a four-point scale ranging from very unlikely (1) to very likely (4). Similar questions for each application were repeated for environmental benefits. Paired $t$-tests were conducted to test if applications were perceived as having more environmental benefits or health benefits (see Tables AI and AII). Nine applications were perceived as having more environmental benefits than human health benefits, and 18 were perceived as having more health benefits than environmental benefits. The six applications that were rated to have the

**Table II.** Conditions

| | GM in Abstract | Concrete GM Applications |
|---|---|---|
| Risks | Questions assessing risk perceptions of GM in abstract (condition 1) | Questions assessing risk perceptions of concrete GM applications (condition 2) |
| Benefits | Questions assessing benefit perceptions of GM in abstract (condition 3) | Questions assessing benefit perceptions of concrete GM applications (condition 4) |
| Risks and Benefits | Questions assessing risk and benefit perceptions of GM in abstract (condition 5) | Questions assessing risk and benefit perceptions of concrete GM applications (condition 6) |

**Table III.** Likelihood of Approval of the Concrete GM Applications

| | Variable Name | Mean | *SD* |
|---|---|---|---|
| *Plant-Based Applications* | | | |
| Grasses that do not need to be mown that often | Grass | 3.23 | 1.29 |
| Tomatoes with high levels of cancer fighting antioxidants | Tomato | 3.63 | 1.23 |
| Rice with enhanced vitamin A to prevent blindness | Rice | 3.57 | 1.23 |
| More nutritious grain that can feed people in poor countries | Grain | 3.80 | 1.19 |
| Trees that grow twice as fast to the size where they can be harvested and made into paper | Tree | 3.34 | 1.24 |
| Algae that can produce biofuels | Algae | 3.68 | 1.18 |
| *Animal-Based Applications* | | | |
| Male white rhinos able to breed with the few remaining females to save the species from extinction | Rhino | 3.58 | 1.22 |
| Sheep whose milk can be used to produce medicines and vaccines | Sheep | 3.38 | 1.26 |
| Cattle that produce beef with less cholesterol | Cattle | 3.14 | 1.30 |
| Pigs that produce low-fat bacon | Pig | 2.95 | 1.31 |

*Note*: Five-point scale: 1(extremely unlikely) to 5(extremely likely).

most health benefits and the four applications that were rated to have the most environmental benefits were selected to serve as stimuli within the current experiment.

### 3.2. Measures

To assess approval of GMOs in general (Hallman, Cuite, & Morin, 2013), respondents were asked, "how much do you approve or disapprove of the use of genetic modification to create plant-based products" (i.e., "support for abstract plant-based GMOs"). Response options included "1 = strongly disapprove," "2 = somewhat disapprove," "3 = neither approve nor disapprove," "4 = somewhat approve," "5 = strongly approve," and "6 = I am unsure of my opinion." If respondents chose "3 = neither approve nor disapprove" or "6 = I am unsure of my opinion" they were provided the follow-up question, "if you had to say which way you lean on that issue, would you say that you lean toward approving or leaned toward disapproving," with response options of "lean toward approving," "lean toward disapproving," and "I am not sure." Those who responded with "lean toward approving" were recoded as "2 = somewhat approve" and with "lean toward disapproving" were recoded as "4 = somewhat approve." Those who responded as "6 = I am not sure" in all questions were recoded as "3 = neither approve nor disapprove." These questions were repeated for animal-based products (plant-based products: $M = 3.30$, $SD = 1.27$; animal-based products: $M = 2.75$, $SD = 1.31$) (i.e., "support for abstract animal-based GMOs").

Participants were also asked to answer the question "when you think of GM, how do you feel?" on a five-point scale (1 = very slightly/not at all, 2 = a little, 3 = moderately, 4 = quite a bit, and 5 = extremely) and to assess their positive emotional responses (i.e., "positive emotions"): "interested" ($M = 2.67$, $SD = 1.26$), "excited" ($M = 1.90$, $SD = 1.14$); and, their negatively emotional responses (i.e., "negative emotions"): "scared" ($M = 2.28$, $SD = 1.27$), "enthusiastic" ($M = 1.92$, $SD = 1.40$), "nervous" ($M = 2.39$, $SD = 1.27$), and "disgusted" ($M = 2.01$, $SD = 1.26$) (Watson, Clark & Tellegan, 1988). Participants were also asked to answer the question "how likely are you to approve the immediate release of the following GM products for consumers in the United States?" on a six-point scale (1 = very unlikely, 2 = unlikely, 3 = somewhat unlikely, 4 = somewhat likely 5 = likely, and 6 = very likely) to assess their support toward each of the six specific plant-based GM applications (i.e., "support for concrete plant-based GMOs," i.e., "tomato," "rice," "grass," "grain," "tree," and "algae") and the four

**Table IV.** Mean (Standard Deviation) of Intentions toward Buying GM Products across Conditions

| Conditions | *M* (*SD*) |
|---|---|
| Risk general condition | 2.667 (1.055) |
| Risk specific condition | 2.821 (1.150) |
| Benefit general condition | 2.768 (1.125) |
| Benefit specific condition | 2.848 (1.122) |
| Benefit and risk general condition | 2.705 (1.136) |
| Benefit and risk specific condition | 2.673 (1.112) |
| Control condition | 2.600 (1.086) |

animal-based GM applications (i.e., "support for concrete animal-based GMOs," i.e., "sheep," "cattle," "rhino," and "pig"). Participants were also asked about their purchase intentions (Tallapragada & Hallman, 2018): "If you learned that a food product contained genetically modified ingredients, how likely would you be to purchase it?" using a six-point scale of "1 = much more likely," "2 = somewhat more likely," "3 = make no difference," "4 = somewhat less likely," "5 = much less likely," and "6 = don't know" (i.e., "intention to buy GMO"). Those who reported, "don't know" were recoded to the value of "3 = make no difference" ($M = 2.73$, $SD = 1.11$).

## 4. RESULTS

Before we conducted analyses to test our stated hypotheses, we checked randomization across conditions with the sample demographic variables age, gender, ethnicity, education, and political ideology. Because age ($F(6, 1{,}460) = 2.20$ $p < 0.05$) and gender ($F(6, 1{,}463) = 3.185$, $p < 0.05$) were significantly related to condition, they will be included as covariates in the following statistical analyses to rule out any potential spuriousness. There was no relationship between condition and ethnicity, education, or political ideology. There was also no significant difference in the amount of time spent on average across conditions ($F(6, 1{,}463) = 1.299$, $p = 0.254$).

To test H1, we examined the variation of intentions toward buying GM products across each condition (see Table IV for the means of intentions across conditions). We conducted an ANCOVA and found that none of the conditions appear to significantly affect intentions toward buying GM products ($F(6, 1{,}458) = 1.435$, $p = 0.198$). Thus, H1 was not supported.

We tested the research question and Hypothesis 2 simultaneously using a structural equation model (SEM). In the SEM, each condition is modeled as a dummy variable with the control condition serving as the reference group. Hypothesis 2 was supported. The results indicate that with respect to one's intention to buy GM products, there was no difference in whether individuals were asked to engage in risk, benefit, or risk and benefit assessments of the technology or its applications; however, what mattered was their engagement with concrete GM applications. According to Hu and Bentler (1999), for a model to be determined a good fit, the cutoff values for the comparative fit index (CFI) and the Tucker–Lewis index (TLI) should be close to or higher than 0.95, the standardized root mean square residual (SRMR) should be close to or lower than 0.08, and the root mean square error of approximation (RMSEA) should be close to or lower than 0.06. Overall, the model fits the data well, producing a CFI of 0.951 and TLI of 0.942, an RSMEA of 0.047, and an SRMR of 0.040. Table V reports the estimates of all directional paths of the measurement and structural models and Fig. 1 graphically illustrates the SEM.

### 4.1. Measurement Model and Latent Variables

The SEM modeled four latent constructs: (1) positive emotion toward GMO, (2) negative emotion toward GMOs, (3) support for concrete animal-based GMOs, and (4) support for concrete plant-based GMOs. The positive emotion latent variable was defined by the measures "excited" (referent indicator, $\lambda = 1.00$), "interested" ($\lambda = 0.865$, $p < 0.001$), and "enthusiastic" ($\lambda = 0.983$, $p < 0.001$). The negative emotion latent variable was defined by the measures "scared" (referent indicator, $\lambda = 1.00$), "nervous" ($\lambda = 0.981$, $p < 0.001$), and "disgusted" ($\lambda = 0.787$, $p < 0.001$). The concrete support for animal GMO latent variable was defined by the measures "sheep" (referent indicator, $\lambda = 1.00$), "cattle" ($\lambda = 0.958$, $p < 0.001$), "rhino" ($\lambda = 0.749$, $p < 0.001$), and "pig" ($\lambda = 0.896$, $p < 0.001$). The concrete support for plant GMO latent variable was defined by the measures "tomato" (referent indicator, $\lambda = 1.00$), "rice" ($\lambda = 0.999$, $p < 0.001$), "grass" ($\lambda = 0.771$, $p < 0.001$), "grain" ($\lambda = 0.939$, $p < 0.001$), "tree" ($\lambda = 0.787$, $p < 0.001$), and "algae" ($\lambda = 0.958$, $p < 0.001$).

### 4.2. Structural Model and Testing Hypotheses

All three conditions that elicited engagement with the specific/concrete GM applications were positively related to positive emotions toward GMOs

**Table V.** Unstandardized Coefficients from SEM

| *Measurement Model: Latent Variables* | Estimate | *S.E.* |
|---|---|---|
| **Positive Emotions** | | |
| Excited | 1.000 | – |
| Interested | 0.865*** | 0.028 |
| Enthusiastic | 0.983*** | 0.024 |
| **Negative Emotions** | | |
| Scared | 1.000 | – |
| Nervous | 0.981*** | 0.024 |
| Disgust | 0.787*** | 0.025 |
| **Support for Concrete Animal-Based GMOs** | | |
| Sheep | 1.000 | – |
| Cattle | 0.958*** | 0.030 |
| Rhino | 0.749*** | 0.029 |
| Pig | 0.896*** | 0.031 |
| **Support for Concrete Plant-Based GMOs** | | |
| Tomato | 1.000 | – |
| Rice | 0.999*** | 0.029 |
| Grass | 0.771*** | 0.029 |
| Grain | 0.939*** | 0.024 |
| Tree | 0.787*** | 0.028 |
| Algae | 0.810*** | 0.025 |
| *Structural Model* | | |
| ***Regressions*** | | |
| **Positive emotions** | | |
| Risk specific condition | 0.233* | 0.103 |
| Benefit specific condition | 0.298** | 0.102 |
| Benefit and risk specific condition | 0.255* | 0.102 |
| Risk general condition | 0.059 | 0.102 |
| Benefit general condition | 0.049 | 0.102 |
| Benefit and risk general condition | 0.110 | 0.102 |
| Age | −0.009*** | 0.002 |
| Gender (female coded 1) | −0.349*** | 0.055 |
| $R^2$ | 0.064 | |
| **Negative Emotions** | | |
| Risk specific condition | 0.053 | 0.116 |
| Benefit specific condition | −0.007 | 0.115 |
| Benefit and risk specific condition | −0.024 | 0.115 |
| Risk general condition | 0.038 | 0.115 |
| Benefit general condition | −0.125 | 0.115 |
| Benefit and risk specific condition | 0.066 | 0.115 |
| Age | −0.001 | 0.002 |
| Gender (female coded 1) | 0.450*** | 0.063 |
| $R^2$ | 0.042 | |
| **Support for Concrete Animal-Based GMOs** | | |
| Positive emotions | 0.404*** | 0.029 |
| Negative emotions | −0.317*** | 0.025 |
| $R^2$ | 0.328 | |
| **Support for Concrete Plant-Based GMOs** | | |
| Positive emotions | 0.366*** | 0.027 |
| Negative emotions | −0.313*** | 0.024 |
| $R^2$ | 0.288 | |
| **Support for Abstract Animal-Based GMOs** | | |
| Support for concrete animal-based GMOs | 0.499*** | 0.034 |
| Positive emotions | 0.350*** | 0.031 |
| Negative emotions | −0.282*** | 0.027 |
| $R^2$ | 0.499 | |
| **Support for Abstract Plant-Based GMOs** | | |
| Support for concrete plant-based GMOs | 0.549*** | 0.029 |
| Positive emotions | 0.313*** | 0.027 |
| Negative emotions | −0.281*** | 0.024 |
| $R^2$ | 0.543 | |
| **Intention to Buy GMO** | | |
| Support for abstract animal-based GMOs | 0.154*** | 0.026 |
| Support for abstract plant-based GMOs | 0.192*** | 0.027 |
| Concrete support: Animal | 0.100 | 0.084 |
| Concrete support: Plant | 0.013 | 0.079 |
| Positive emotions | 0.242*** | 0.027 |
| Negative emotions | −0.193*** | 0.023 |
| $R^2$ | 0.507 | |
| ***Covariances*** | | |
| Positive emotions–Negative emotions | −0.177*** | 0.033 |
| Support for concrete animal-based GMOs–Support for concrete plant-based GMOs | 0.653*** | 0.034 |
| Support for abstract animal-based GMOs–Support for abstract plant-based GMOs | 0.331*** | 0.024 |
| Cattle–pig | 0.399*** | 0.028 |
| ***Model Fit*** | | |
| $\chi^2$ ($df = 271$) | 1,152.667 | |
| Comparative Fit Index (CFI) | 0.951 | |
| Tucker–Lewis Index (TLI) | 0.942 | |
| Root Mean Square Error of Approximation (RMSEA) | 0.047 | |
| Standardized Root Mean Square Residual | 0.040 | |
| *N* | 1,467 | |

*Note*: $^{*}p \leq 0.05$, $^{**}p \leq 0.01$, $^{***}p \leq 0.001$.

(risk concrete condition: $b = 0.233$, $p < 0.05$; benefit concrete: $b = 0.298$, $p < 0.01$; benefit and risk concrete: $b = 0.255$, $p < 0.05$) but not related to negative emotions toward GMOs. Positive emotion toward GMO was postively related to concrete support for animal GMO ($b = 0.404$, $p < 0.001$), concrete support for plant GMO ($b = 0.366$, $p < 0.001$), abstract support for animal GMO ($b = 0.350$, $p < 0.001$), abstract support for plant GMO ($b = 0.313$, $p < 0.001$), and intention to buy GMOs ($b = 0.242$, $p < 0.001$). Concrete support for animal GMO was

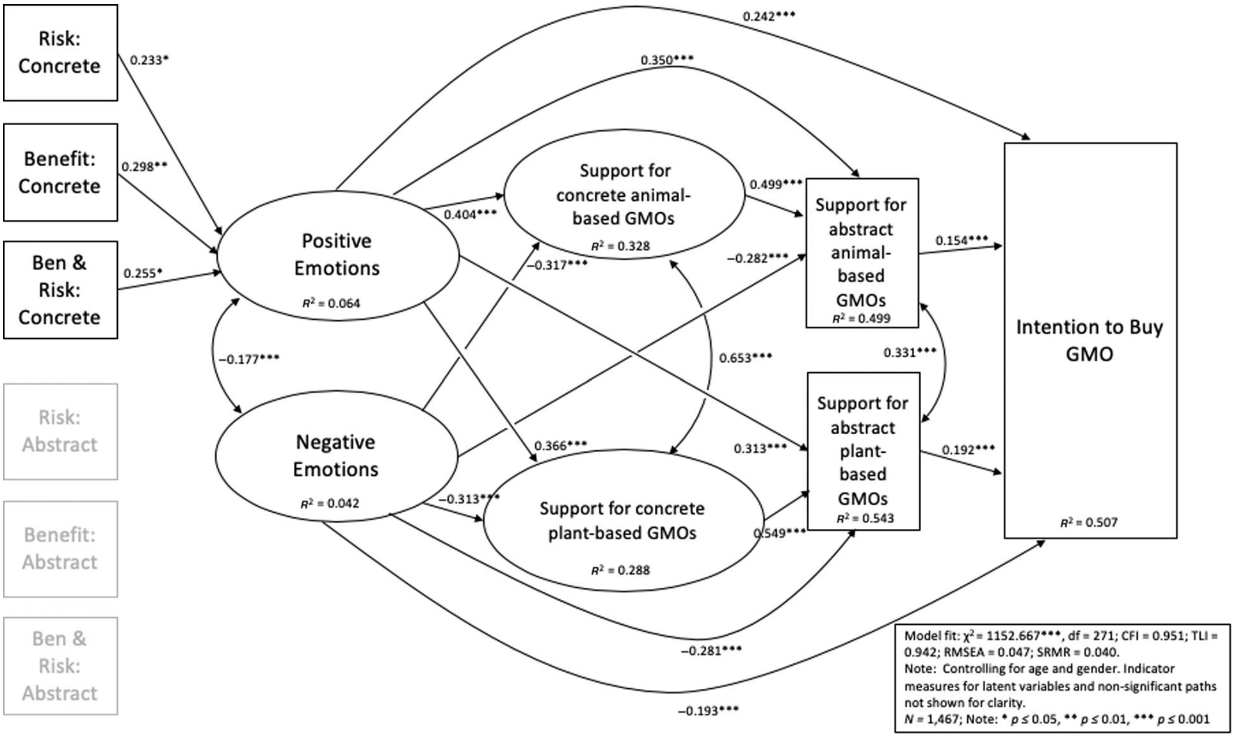


**Fig 1.** Effect of concrete GM applications on emotions, attitudes toward GM, and intentions to buy products containing GMOs.
*Note*: The latent variable indicators are not included in this figure for visual parsimony. Please refer to Table V for more information.

positively related to abstract support for animal GMO ($b = 0.499$, $p < 0.001$). Similarly, concrete support for plant GMO was positively related to abstract support for plant GMO ($b = 0.549$, $p < 0.001$). Abstract support for both animal GMO ($b = 0.192$, $p < 0.001$) and plant GMO ($b = 0.154$, $p < 0.001$) were positive predictors of intention to buy. Although negative emotions were not predicted by any conditions, they were negatively related to concrete support for animal GMO ($b = -0.282$, $p < 0.001$), concrete support for plant GMO ($b = -0.313$, $p < 0.001$), abstract support for animal GMO ($b = -0.282$, $p < 0.001$), abstract support for plant GMO ($b = -0.281$, $p < 0.001$), and intention to buy GMOs ($b = -0.193$, $p < 0.001$).

The positive and negative emotions latent variables were negatively correlated ($r = -0.177$, $p < 0.001$), while the concrete support latent variables were positively correlated ($r = 0.653$, $p < 0.001$). The abstract support variables are correlated ($r = 0.331$, $p < 0.001$).

## 5. DISCUSSION

Results indicate that regardless of whether participants are engaged in assessing their risk perceptions, benefit perceptions, or their risk and benefit perceptions, being engaged in assessing concrete GM applications increased positive emotions. This in turn, increased their support for specific GM applications and GM in general, and their intentions to buy products with GM ingredients. This study provides more evidence for concreteness effects, where using concrete language improves positive affect and thereby has an impact on public perceptions of technologies (Binder, Westbury, McKiernan, Possing, & Medler, 2005; Burghi et al, 2017; Jones, 1985; Kieras, 1978). All three conditions involving concrete applications were effective in improving affect and changing attitudes and intentions pertaining to GMOs. Changes in attitudes are a result of changes in beliefs (Fishbein & Yzer, 2003). With abstract language having the potential to trigger varied and subjective schematic representations, providing concrete applications of GM prompted participants to focus on the exact features (Barsalou, 1999; Borghi et al., 2017; Gentner, 1981; Weimer-Hastings & Xu, 2005), images (Paivio et al., 1968), or context (Bransford & Johnson, 1972; Schwanenflugel et al., 1988, 1992; Tverksy & Kahneman, 1974), or experienced enhanced perceptual strength (Connell & Lynott,

2012) with regards to GM technology, which resulted in an increase in positive affect. Future research can conduct think-aloud procedures to evaluate which of the following aspects are instrumental with concrete representations of technologies. Future work can also investigate the impact that concrete language has on related abstract terms.

All participants, including those in the abstract conditions (conditions 1, 3, and 5) were asked toward the end of the survey to assess their support for the specific applications right before being asked for their support of the technology in general. If the effects of our study were due to priming individuals to consider the specific applications, we should have seen an effect on the attitudes and intentions toward GM in general. However, it was only in conditions 2, 4, and 6, where participants were prompted through questions to thoroughly consider the applications that had an impact on attitudes and intentions toward GMOs. This finding suggests that there is a level of engagement (Kahneman, 2011) or involvement (Jamieson & Hardy, 2014) that aids deeper processing of the applications that could be confirming personal attitudes and intentions. Future research can explore the level of engagement/involvement that is sufficient to prompt informed decision making.

Our findings also indicate that while concrete conditions showed an increase in positive emotions, abstract conditions did not evoke any emotions measured. This could be revealing of the struggles associated with abstract conceptualization of terms that people do not know much about. Given the low levels of awareness or knowledge that many individuals have pertaining to GMOs (Hallman et al., 2002, 2003, 2004), it would be hard for them to have an emotional response to the abstract conditions in the study. Concrete conditions however, showed an increase in positive emotions. It should be noted that as stimuli, we only used GM applications that are actually being developed and are intended to improve human health or the environment. Future studies may explore whether negative emotions are evoked when specific applications are presented as harming human health or the environment. However, such applications would have to be fictional, or the harms unintential, as regulatory structures are designed to prevent applications with known harms from being released.

All concrete applications were intentionally varied with respect to their personal relevance, yet they all affected attitudes and intentions toward GMOs. Future research can explore the impact of psychological distance (Trope & Liberman, 2010) associated with each of these applications on attitudes and intentions toward GMOs.

Finally, the finding of this study indicating that concrete information has positive impacts on attitudes toward GMOs should not be interpreted as evidence in support of the deficit model. The deficit model of science communication states that public attitudes toward science and technology can be improved by filling the knowledge deficit among individuals (see Bucchi, 2008). Providing concrete information and allowing for engagement of specific applications does not necessarily lead to greater knowledge about GMOs, but can aid individuals in establishing informed beliefs that can eventually lead to informed opinions. In this study, we found those informed beliefs to impact opinions more positively, however future research should explore whether these concreteness effects depend on the types of applications and the language used to describe them.

## 6. LIMITATIONS AND FUTURE RESEARCH

While this study provides evidence to assess the influence of abstract and concrete language on attitudes and intentions toward GMOs, it is not without limitations. In conditions 2, 4, and 6, we asked participants to not only consider risks and/or benefits of the GM applications, but we also asked them to assess the usefulness, market availability, and the morality of these applications. While these questions were initially designed to prompt participants to think about GM in concrete terms, we recognize that these could be additional factors that we did not control for in the abstract conditions of 1, 3, and 5. Future researchers should take this additional layer into consideration where they design future studies exploring GM perceptions using abstract and concrete language. We recommend that future studies assess GM attitudes and intentions using the questions asked in the abstract conditions as we described, and to add conditions that both exclude and include concrete conditions, using questions measuring potential use, availability, and morality. This work will then determine if the effects of concrete conditions are amplified or attenuated due to the presence of these additional questions.

Our dependent variable of intentions to purchase was measured by asking if the participant would purchase a food product containing GM ingredients. However, we included applications that are not about human consumption. While our study suggests that learning about specific GM applications can have an impact on attitudes and intentions, we do recognize that there might be meaningful differences between intentions that involve consumption and others that might not involve direct human consumption. For example, people can buy GM grass seed to plant in their yard so they would not have to mow as often or they can purchase paper from GM trees, or use biofuels developed from GM algae. Future researchers may explore these potential differences with varying types of purchasing intentions.

It appears that priming participants to think of the risks or benefits of GM in the abstract or concrete conditions had no effect on emotions, attitudes, or intentions. Our study situates itself in the ongoing debate of priming effects (see Doyen, Klein, Pichon, & Cleeremans, 2012; Weingarten et al., 2016) but in the context of using abstract or concrete language to describe GM technology. While our findings could signify that priming is ineffective in this context, it could also be due to the inherent benefit-bias among all our concrete applications. Individuals mostly view products of science and technology as inherently beneficial (Funk et al., 2016) and with our use of GM applications that are all driven to improve human condition, it could have prevented our sample from exhibiting any underlying priming effects. Future research should address our limitation and explore presenting GM applications that present themselves as risky to explore the presence of priming effects. We do however recommend that researchers debrief their participants in these studies to ensure that they leave the experiment with scientifically accurate information on GMOs.

Another limitation of this study was the use of valanced emotions instead of discrete emotions. While our study found that concrete conceptualization of GM applications are able to elicit positive emotions, we urge future researchers to explore which discrete positive emotion—excitement, interest, or enthusiasm—is affecting attitudes and intentions toward GM technology (see Kim & Niederdeppe, 2014; Lu, 2016; Nabi, 2002). Similarly, researchers should also explore discrete negative emotions to assess if certain specific negative emotions, such as fear, anxiety, or disgust could be affecting their attitudes and intentions toward GM technology, when conceptualized as abstract or concrete (see Kahan, 2016; Royzman, Cusimano, & Leeman, 2017).

## 7. CONCLUSION

Using concrete language to describe the applications of GMOs compared to keeping it as an abstract concept has consequences on attitudes and intentions toward GMOs. The findings of this research have implications for public perceptions research designed to assess public support or opposition to emerging technologies and their resulting applications in particular. The study also demonstrates the benefits of using concrete language to assess public perceptions of these new technological advances, especially among groups who might not understand the advances, but are still expected to form informed decisions about them—including whether or not to purchase their products.

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## APPENDIX

### Survey questions [All questions within every condition were randomized]

- Condition 1: General/abstract—Risk condition
    - How risky do you perceive plant-based GMOs are for your health? [1 = very risky; 2 = risky; 3 = somewhat risky; 4 = not at all risky; 5 = I am not sure]
    - How risky do you perceive plant-based GMOs are for the environment? [1 = very risky; 2 = risky; 3 = somewhat risky; 4 = not at all risky; 5 = I am not sure]
    - How risky do you perceive animal-based GMOs are for your health? [1 = very risky; 2 = risky; 3 = somewhat risky; 4 = not at all risky; 5 = I am not sure]
    - How risky do you perceive animal-based GMOs are for the environment? [1 = very risky; 2 = risky; 3 = somewhat risky; 4 = not at all risky; 5 = I am not sure]
- Condition 2: Specific/concrete—Risk condition

**Table AI.** GM Applications that are Perceived as Having Significantly Higher Environmental Benefits over Health Benefits (MTurk Sample)

| Application | $M_h(SD_h)$ | $M_e(SD_e)$ | $t$-Test |
|---|---|---|---|
| Male white rhinos able to breed with the few remaining females to save the species from extinction. (Rhino) | 2.17(1.05) | 2.86(1.07) | $t(354) = 10.29^{***}$ |
| Grasses that do not need to be mown as often. (Grass) | 2.20(0.98) | 2.74(1.06) | $t(354) = 8.71^{***}$ |
| Trees that grow twice as fast to the size where they can be harvested and made into paper. (Tree) | 2.52(1.02) | 2.87(1.05) | $t(354) = 5.50^{***}$ |
| Algae that can produce biofuels. (Algae) | 2.97(0.96) | 3.22(0.91) | $t(354) = 4.97^{***}$ |
| Grasses that absorb carbon from the air, reducing its effects on climate change. | 3.30(0.85) | 3.50(0.83) | $t(354) = 4.73^{***}$ |
| Corn (or wheat or rice) that is able to absorb nitrogen from the air, reducing the need for fertilizers. | 3.05(0.89) | 3.26(0.91) | $t(354) = 4.03^{***}$ |
| Trees that can help clean water that was contaminated by chemicals. | 3.44(0.76) | 3.55(0.77) | $t(354) = 2.74^{**}$ |
| Aquarium fish that glow under blue lights. | 1.56(0.90) | 1.68(0.96) | $t(354) = 2.67^{**}$ |

*Note*: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.
$M_h$ = Mean$_{\text{health}}$; $SD_h$ = Standard Deviation$_{\text{health}}$; $M_e$ = Mean$_{\text{environment}}$; $SD_e$ = Standard Deviation$_{\text{environment}}$.

**Table AII.** GM Applications that Are Perceived as Having Significantly Higher Health Benefits over Environmental Benefits (MTurk Sample)

| Application | $M_h(SD_h)$ | $M_e(SD_e)$ | $t$-Test (Paired) |
|---|---|---|---|
| Tomatoes with high levels of cancer-fighting antioxidants. (Tomato) | 3.43(0.82) | 2.07(1.08) | $t(354) = -19.96^{***}$ |
| Peanuts without the protein that causes allergies. | 3.27(0.89) | 1.95(1.03) | $t(354) = -19.39^{***}$ |
| Sheep whose milk can be used to produce medicines and vaccines. (Sheep) | 3.34(0.84) | 2.11(1.03) | $t(354) = -18.20^{***}$ |
| Rice with enhanced vitamin A to prevent blindness. (Rice) | 3.33(0.84) | 2.02(1.05) | $t(354) = -18.16^{***}$ |
| Cattle that produce beef with less cholesterol. (Cattle) | 3.09(0.91) | 1.98(1.04) | $t(354) = -16.50^{***}$ |
| More nutritious grain that can feed people in poor countries. (Grain) | 3.42(0.82) | 2.34(1.05) | $t(354) = -16.11^{***}$ |
| Pigs that produce low-fat bacon. (Pig) | 2.90(0.94) | 1.89(0.99) | $t(354) = -15.29^{***}$ |
| Wheat that produces less gluten. | 2.91(0.92) | 1.98(1.03) | $t(354) = -14.90^{***}$ |
| Yeast used to brew beer that can reduce the chances of hangovers[2]. | 2.64(0.97) | 1.75(0.98) | $t(354) = -14.71^{***}$ |
| Mosquitos that can reduce the spread of Zika, and other diseases. | 3.41(0.85) | 2.63(1.07) | $t(354) = -12.19^{***}$ |
| Potatoes those are resistant to the disease that caused starvation during the Irish Potato Famine. | 3.10(0.88) | 2.44(1.03) | $t(354) = -10.72^{***}$ |
| Salmon that grow twice as fast to the size where they can be harvested and eaten. | 2.67(1.03) | 2.15(1.02) | $t(354) = -8.58^{***}$ |
| Hormones that enable cows to produce more milk. | 2.48(1.03) | 1.98(1.00) | $t(354) = -8.31^{***}$ |
| Potatoes that resist bruising, preventing food waste. | 2.82(0.94) | 2.39(1.06) | $t(354) = -6.84^{***}$ |
| Corn that is drought resistant. | 3.06(0.96) | 2.78(1.00) | $t(354) = -4.82^{***}$ |
| Rice that can continue to grow after severe flooding. | 3.12(0.90) | 2.73(1.01) | $t(354) = -6.55^{***}$ |
| Apples that do not turn brown when they are cut into pieces. | 2.25(0.99) | 1.91(0.97) | $t(354) = -6.14^{***}$ |
| Corn (or wheat or rice) that is able to absorb nitrogen from the air, reducing the need for fertilizers. | 3.05(0.89) | 3.26(0.91) | $t(354) = 4.03^{***}$ |

*Note*: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.
$M_h$ = Mean$_{\text{health}}$; $SD_h$ = Standard Deviation$_{\text{health}}$; $M_e$ = Mean$_{\text{environment}}$; $SD_e$ = Standard Deviation$_{\text{environment}}$.
[2]GM applications related to peanut and wheat were eliminated from consideration, given how they specifically deal with allergies and others do not.

- How risky do you perceive the following applications of GMOs are for your health? [For each application: 1 = very risky; 2 = risky; 3 = somewhat risky; 4 = not at all risky; 5 = I am not sure]
- How risky do you perceive the following applications of GMOs are for the environment? [For each application: 1 = very risky; 2 = risky; 3 = somewhat risky; 4 = not at all risky; 5 = I am not sure]

- ○ How personally useful are the following applications of GMOs? [For each application: 1 = not at all useful; 2 = slightly useful; 3 = Moderately useful; 4 = Very useful; 5 = Extremely useful]
- ○ In your opinion, the following applications of GMOs are: [For each application: 1 = already available in markets; 2 = likely to be available in 5–10 years; 3 = likely to be available in over 10 years; 4 = not likely to be available in markets any time]
- ○ How morally acceptable do you perceive the following applications of GMOs: [For each application: 1 = morally unacceptable; 2 = not sure; 3 = morally acceptable]

- Condition 3: General/abstract—Benefit condition
  - ○ How beneficial do you perceive plant-based GMOs are for your health? [1 = not at all beneficial; 2 = somewhat beneficial; 3 = beneficial; 4 = very beneficial; 5 = I am not sure]
  - ○ How beneficial do you perceive plant-based GMOs are for the environment? [1 = not at all beneficial; 2 = somewhat beneficial; 3 = beneficial; 4 = very beneficial; 5 = I am not sure]
  - ○ How beneficial do you perceive animal-based GMOs are for your health [1 = not at all beneficial; 2 = somewhat beneficial; 3 = beneficial; 4 = very beneficial; 5 = I am not sure]
  - ○ How beneficial do you perceive animal-based GMOs are for the environment? [1 = not at all beneficial; 2 = somewhat beneficial; 3 = beneficial; 4 = very beneficial; 5 = I am not sure]

- Condition 4: Specific/concrete—Benefit condition
  - ○ How beneficial do you perceive the following applications of GMOs are for your health? [For each application: 1 = not at all beneficial; 2 = somewhat beneficial; 3 = beneficial; 4 = very beneficial; 5 = I am not sure]
  - ○ How beneficial do you perceive the following applications of GMOs are for the environment? [For each application: 1 = not at all beneficial; 2 = somewhat beneficial; 3 = beneficial; 4 = very beneficial; 5 = I am not sure]
  - ○ How personally useful are the following applications of GMOs? [For each application: 1 = not at all useful; 2 = slightly useful; 3 = Moderately useful; 4 = Very useful; 5 = Extremely useful]
  - ○ In your opinion, the following applications of GMOs are: [For each application: 1 = already available in markets; 2 = likely to be available in 5–10 years; 3 = likely to be available in over 10 years; 4 = not likely to be available in markets any time]
  - ○ How morally acceptable do you perceive the following applications of GMOs: [For each application: 1 = morally unacceptable; 2 = not sure; 3 = morally acceptable]

- Condition 5: General/abstract—Risk and benefit condition
  - ○ *Questions from conditions 1 and 3 were asked*

- Condition 6: Specific/concrete—Risk and benefit condition
  - ○ *Questions from conditions 2 and 4 were asked*

- Control condition: None of the questions in any of the conditions were asked. Participants were directed to the set of questions that all participants responded to in the survey following their manipulation.

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