Impact of abstract versus concrete conceptualization of genetic modification (GM) technology on public perceptions

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Abstract

Based on the scholarship of abstract/concrete cognition, mental schema, and the theory of 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 3x2 experiment was conducted using a national sample of US adults (N=1470). Participants were randomly assigned to conditions that varied in abstract/concrete conceptualization of GMOs and were prompted to assess GM risk perceptions/benefit perceptions/ risk and benefit perceptions with respect to human health and the environment. Regardless of whether they assessed risks or benefits, participants engaged in assessing 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.

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Introduction

Fulfilling the promise of biotechnology depends, not only the scientists to create genetically modified organisms (GMOs), but the public's willingness to accept them. 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 suggests that in the US the public holds modest levels of awareness about GMOs in diets, low levels of knowledge about GMOs in general (Hallman, Adelaja, Schilling, & Lang, 2002; Hallman, Hebden, Aquino, Cuite, & Lang, 2003; Hallman, Hebden, Cuite, Aquino, & Lang, 2004), low trust in scientists and scientific institutions studying GMOs (Funk & Kennedy, 2016), and there is limited support for GMOs in general among public (Funk & Kennedy, 2016; Tallapragada & Hallman, 2018). While the general attitude towards GMOs has been somewhat unenthusiatic, specific applications of GMOs have received high levels of support (Desaint & Varbanova, 2013; Funk & Kennedy, 2016; 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 who report feeling somewhat neutral about GMOs in general, often shift their opinion to supporting several specific applications (Hallman et al, 2002; Knight, 2006). While, typically plant-based applications received more public support than animal-based applications, an overall trend of improved support towards specific GM applications has been consistently identified in past reserch (Frewer, van der Lans, Fischer, Reinders, Menozzi, Zhang, van der Berg, & Zimmerman, 2013; Hallman et al, 2003; Knight, 2006; Puduri, Govindasamy, Lang, & Onyango, 2005).

There has, however, been no theoretical explanation offered as to why individuals reassess their opinion when it comes to specific applications of GMOs and whether their newly formed opinions about these specific applications in turn affects their previously held position on GMOs in general. There are also questions about whether the previous studies primed individuals to only consider the benefits of the specific GM applications and not the risks of those specific applications. Informed by past scholarship on abstract and concrete cognition, mental schema, and the integrated model of behavior change, we test our hypotheses with a randomized experiment embedded in an online survey of US adults. We investigate whether engagement with specific/concrete GM applications impacts attitudes towards those specific applications and then in turn affects overall attitude towards GMOs and intention to purchase GM products.

Abstract and Concrete Cognition, Mental Schema, & Attitude Formation

"GMO" is an abstract term that can trigger varied perceptions among individuals, however stating that the "GM technology can be used to develop rice that can reduce blindness among children" can activate relatively more concrete perception of GMOs. Concrete language has an advantage over abstract language in accurate and quick information processing (Binder, Westbury, McKieman, Possing, & Medler, 2005; Jones, 1985; Kieras, 1978). Although researchers have identified concretness effects over a half century ago (see Paivio, 1991 for review), there is still not an agreed upon unified theory that explains the reasons why concrete words have an advantage over abstract terms (Borghi, Binkofski, Castelfranchi, Cimatti, Scorolli, & Tummolini, 2017).

Except for certain 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, 2012), most theories present evidence for the differences concrete and abstract terms have in information processing. Context availability theory states that concrete terms have fewer contexts available in memory compared to abstract terms and thus can be processed more accurately and quickly (Bransford & Johnson, 1972; Schwanenflugel, Harnishfeger, & Stowe, 1988; Schwanenflugel, Akin, Luh, 1992; Tverksy & Kahneman, 1974). Dual-code theory claims that concrete terms have higher imageability compared to abstract terms which is why concrete terms are easier to process more accurately and quickly (Paivio, Yuille, & Madigan, 1968). Other works have found that abstract terms are grounded in an introspection or situational properties lending them to be more subjective compared to concrete terms that are grounded in specific feature properties lending them to be more objective in their perceptions (Barsalou, 1999; Borghi et al, 2017; Gentner, 1981; Weimer-Hastings & Xu, 2005). The conceptual metaphor view states that one needs metaphors to scaffold abstraction and that these metaphors are often grounded in one's bodily, linguistic, and historical experiences (Boot & Pecher, 2011; Casasanto, 2008; Lakoff, 2014). There are also several multiple representation theories that suggest that language or words have the ability to trigger mutliple representations (where concrete words are likely to be grounded in perception and action, and abstract in emotion and linguistics) and depending on the task, different theories are able to provide an explanation (for a detail list and explanation of these theories, see Borghi et al, 2017).

While there is a debate over which theory more accurately explains the challenges with abstraction and the ease of concreteness, there are two common underlying characteristics that are often agreed upon by these theorists. First, concrete language has an advantage over abstraction in terms of quick and accurate processing. Presenting information in a straightforward manner that is clear and specific in its context can aid information processing. Second, abstract language triggers experiences that are 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). Using concrete language compared to abstract language can then be used to help individuals to step outside of their individual schemas to process messages, which in turn can eventually reshape their schema. Whether it is about needing to ground abstraction in a familiar context (context availability), an image (dual-code theory), a situation (introspective view), a metaphor (contextual metaphor view), or in a perceptual experience (mutliple representation theories), the terms need to exist in one's schema from them to draw from. Schema then becomes prominent when handling an abstract term.

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 affect 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 that have been formed (however fuzzy they may be) to base their opinions. This would be especially true for those who have limited understanding about GMOs or little awareness of their presence in their daily lives. Concrete rerpresentations of GMOs however can help bring individuals to 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). There is little contestation about the *belief in* the existence of GMOs (for a discussion on the difference between *belief in* and *belief about*, see Fishbein & Raven, 1962). The several investigations on the scientific consensus of GMOs (for example, see the report presented by the National Academies of Science, Engineering, and Medicine, 2016) and the recent widespread media coverage of the GM labeling law (for example, see Dewey, 2018; Harmon, 2018) indicate that there is not much debate about the existence of GMOs. The *beliefs about* the nature of GMOs and the manner in which they exist however varies and is typically what affects attitudes towards GMOs.

While the general attitudes towards GMOs have been somewhat neutral, when presented with specific applications of GMOs, several participants who held somewhat neutral attitudes, moved in their responses to support several specific GM applications (Hallman et al, 2002; Knight, 2006). Applications of science and technology are often developed to aid human and environmental conditions, and people often view products of science and technology as positive developments (Funk, Kennedy, & Sciupac, 2016). Although there is inherently a positive bias with technological applications being beneficial, there needs to be space for an individual to deliberate the potential risks and benefits of those specific applications. In previous studies (such as Hallman et al, 2002; Knight, 2006), the goal was to assess public approvals of these applications with no space given to intentionally deliberate their potential risks in addition to their benefits. People make decisions about technologies based on both risk and benefit perceptions (Moon & Balasubramnian, 2001; Pidgeon, Hood, Jones, Turner, & Gibson, 1992; Slovic, 2000). While GM products have been found to pose no health risks and in some instances have been found to be more beneficial for health outcomes compared to the non-GM products (Dance, 2018; National Academies of Sciences, Engineering, and Medicine, 2016; Olena, 2017; Saplakoglu, 2017; Stein, 2017; Voytas, 2014), there have been calls for long-term studies to explore their environmental impacts (Borel, 2018; National Academies of Sciences, Engineering, and Medicine, 2016). GM technology, similar to other emgering technologies is developing and having an informed public who can engage with these considerations through civic deliberations (Shen, 1975) is ideally what we need to ensure safe and acceptable technological outcomes. With public mostly having low levels of awareness and knowledge about GMOs (Hallman, et al, 2002; Hallman et al, 2003; Hallman et al, 2004), asking them to consider the risks or benefits of specific GM applications can then provide an opportunity for them to exercise informed deliberations and by prompting them to deliberately consider their risks, benefits, or both can influence their overall opinion.

Engaging with considerations of risks or benefits and abstract or concrete terms are likely to invoke emotions, due to the affect-laden nature of this language. There have been arguments made for risk-benefits perceptions invoking emotions due to a lack of engagement or reason and as heuristic (Kahneman, 2011; Slovic et al. 2002) and also for deep cognitive considerations (Haidt, 2001; Roeser & Pesch, 2015). Similarly, there are arguments presented for emotions as being present while making sense of abstract language (Borghi et al, 2017; Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011) and also for concrete language (Borghi et al, 2017; Kuenecke, Sommer, Schacht, & Palazova, 2015). Although there are conflicting discussions of the role of emotions in risk-benefit and abstract-concrete considerations, we propose the following hypotheses based on the increase in support that concrete applications have had in the past.

H1a: Participants in concrete conditions (2, 4, 6) will feel an increase in positive emotions pertaining to specific GMO applications and GMOs in general.

H1b: Participants in abstract conditions (1, 3, 5) will feel apathetic towards specific GMO applications and GMOs in general.

H2: The increase in positive emotions stemming from concrete conditions will increase support for GM applications and GM in general, and intentions to buy products with GMOs.

Research Question: How does having participants engage with considerations of risks, benefits, or risks and benefits in concrete conditions affect their emotions, attitudes, and intentions with GMOs?

Method

An online survey with an embedded 3x2 experiment was conducted using a national sample of US adults (N=1467) who were recruited through Qualtrics with quotas for gender, age, and ethnicity to match the census. Table 1 reports the descriptive statistics of the demographic composition of the sample. Participants were randomly assigned to one of the six conditions (presented in table 2) or the control condition. For participants in condition 1 (abstract-risk), randomized questions of risk perceptions with respect to health and the enviornment pertaining to using GM for plant-based and animal-based applications were provided. No specific GM applications were presented in this condition. For condition 2 (concrete-risk), participants were asked questions of risk perceptions with respect to health and the enviornment pertaining to using GM for ten specific plant-based and animal-based applications. Participants were also asked to assess how personally useful these applications were to them, their perception of the availability of these applications in markets, and the morality of these applications. Condition 3 (abstract-benefit), the same questions as condition 1 were asked, but instead of risk perceptions, they were assessing benefit perceptions of GM in general. Condition 4 (benefit-specific), the same questions as condition 2 were asked, but instead of risk perceptions, they were assessing benefit perceptions of concrete GM applications. Condition 5 (abstract – risk and benefit) included questions from conditions 1 and 3, and condition 6 (concrete – risk and benefit) included questions from conditions 2 and 4. These questions were asked to have participants engage with either the abstract or concrete nature of GMOs and to have them consider either the risks, benefits, or risks and benefits of these application. These questions served as conditions only and not as measures analyzed below. Prior to fielding the survey, cognitive interviews were conducted with six individuals 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 on question wording was incorporated into the final survey.

Measures: To assess approval toward 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." Response options included "strongly disapprove," "somewhat disapprove," "neither approve nor disapprove," "somewhat approve," "strongly approve," and "I am unsure of my opinion." If respondents chose "neither approve nor disapprove" or "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." 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).

These approval questions were asked before participants were separated into each of these conditions and were also asked towards the end of the survey.

Upon answering questions in each of their conditions, all participants were asked “when you think of GM, how do you feel?” a 5-point scale was used (1=very slightly/not at all, 2=a little, 3=moderately, 4=quite a bit, 5=extremely) to assess the following emotions: “interested” (*M* = 2.67, *SD* = 1.26), “excited” (*M* = 1.86, *SD* = 1.14), “scared” (*M* = 2.28, *SD* = 1.28), “enthusiastic” (*M* = 1.91, *SD* = 1.34), “nervous” (*M* = 2.39, *SD* = 1.27), and “disgusted” (*M* = 2.00, *SD* = 1.26) (Watson, Clark & Tellegan, 1988). Participants were also asked, “how likely are you to approve the immediate release of the following GM products for consumers in the US?” a 6-point scale (1=very unlikely, 2=unlikely, 3=somewhat unlikely, 4=somewhat likely 5=likely, and 6=very likely) to assess their support towards each GM application. All participants were asked the same question before they started the survey about levels of approval towards GMOs in general. Participants were also asked for their purchasing 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 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. Those who reported “don’t know” we recoded to the value 3 = make now difference (*M* = 2.73, SD = 1.11)

Concrete GM applications*:* The concrete GM applications selected for the survey are shown in Table 3. To ensure that the specific GM applications used in the survey included some with human health benefits and 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 4-point scale ranging from very unlikely (1) to very likely (4). Similar question for each application was 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 1 and 2 in the Appendix). Nine applications were perceived as having more environmental benefits over human health benefits, and 18 were perceived as having more health benefits than environmental benefits. The top 6 applications that had more health benefits than environmental benefits and the top 4 that had more environmental benefits over health benefits were selected for the Qualtrics sample survey[1].

Results

Before we conducted analyses to test our stated hypotheses, we checked randomization across condition with the sample demographic variables age, gender, ethnicity, education, and political ideology. Because age (F(6, 1460) = 2.20 $p < 0.05$) and gender (χ^2 18.86, $df = 6$, $p <$ 0.01.) 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.

All hypotheses are tested simultaneously using structural equation model (SEM). Hypotheses 1a, 1b, and 2 were supported. Overall, the model fits the data well, producing a Comparative Fit Index (CFI) of 0.951, Tucker-Lewis Index of 0.942, a root mean square error of approximation (RSMEA) of 0.047, and a Standardized Root Mean Square Residual (SRMR) of 0.040. Table 4 reports the estimates of all directional paths of the measurement and structural models and Figure 1 graphically illustrates the structural equation model.

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[1] GM applications related to peanut and wheat were eliminated from consideration, given how they specifically deal with allergies and others do not.

Measurement model and latent variables: The SEM modeled four latent constructs: 1) positve emotion towards GMO, 2) negative emotion towards GMO, 3) concrete support for animal-based GMOs, and 4) concrete support for plant-based GMOs. The positive emotion latent variable was defined by the measures excited (referent indicator, $\lambda = 1.00$), interested ($\lambda = 0.865$, $p < 0.001$), 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 ($\lambda = 0.958$, $p < 0.001$).

Structural model and testing hypotheses:

All three concrete conditions that elicited engagement with the specific GM applications were positively related to positive emotions toward GMOs (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 postive 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 positvely related to abstract support for animal GMO ($b = 0.499$, $p < 0.001$). Similarly, concrete support for plant GMO was positvely 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 predicted to intention to buy. Although negative emotions were not predicted by any conditions they were negatively related to 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 negative 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 ($r = 0.331$, $p < 0.001$).

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 increases positive emotions, which in turn increases 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 being concrete is improving positive affecr and thereby having an impact on public perceptions of technologies (Binder et al., 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, Yuille, & Madigan, 1968), context (Bransford & Johnson, 1972;

Schwanenflugel, Harnishfeger, & Stowe, 1988; Schwanenflugel, Akin, Luh, 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 conditions involving concrete applications (conditions 2, 4, and 6) required more engagement compared to the ones involving abstract language (conditions 1, 3, and 5). While condition 6 (concrete – risk and benefit perceptions) involved relatively more engagement with the materials than conditions 2 (concrete – risk perceptions) and 4 (concrete – benefit perceptions), all three conditions were effective in improving attitudes and intentions involving GMOs. It should also be stated that participants in the abstract conditions (conditions 1, 3, and 5) were asked towards the end of the survey to assess their support for the specific applications right before being asked for their support for the technology in general. If it was merely priming individuals to consider the specific applications, we should have seen an effect on the attitudes and intentions towards GM in general. However, it is was only conditions (2, 4, and 6) where participants were prompted through questions to thoroughly consider the applications that had an impact on attitudes and intentions towards GMOs. This finding suggests that there is a level of engagement (Kahneman, 2011) or involvement (Jamieson & Hardy, 2014) that is aiding deeper processing of the applications that could be confirming their 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. 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 individuals have pertaining to GMOs (Hallman, et al, 2002; Hallman et al, 2003; Hallman et al, 2004), it would be hard to have an emotional response and this is indicative of the apathetic result for the abstract conditions in the study. Concrete conditions however showed an increase in positive emotions. In order to maintain the scientific integrity of the applications, we only tested the applications that are geared towards aiding human health and the environment, however future studies can explore if there are negative emotions that are instilled when specific applications are presented as harming human health or the environment.

All concrete applications were varied in their relevance, and yet all of them together affected attitudes and intentions towards GMOs. It would be hard to conceive any relevance directly to participants in this study with regards to helping the rhinoceros from becoming extinct or developing nutritious grain to feed people in poor countries. However, there were other applications such as developing pigs with low-fat bacon or grass that don't need to be mown that can be somewhat relevant to few individuals. Future research can explore the impact psychological distance (Trope & Liberman, 2010) has with respect to each of these applications on attitudes and intentions towards GMOs.

Finally, the finding of this study indicating that concrete information has positive impacts on attitudes towards GMOs should not be interpreted as evidence to support the deficit model. The deficit model of science communication states that public attitudes towards science and technology can be improved by filling the knowledge deficit among individuals (Bucchi, 2008).

None of the concrete conditions showed any significant increase in perceived or objective knowledge of GMOs. This suggests that providing concrete information and allowing for engagement of specific applications does not necessarily improve knowledge about GMOs, but aids individuals to form informed beliefs that can then eventually lead to informed opinions. In this study, we found those informed beliefs to impact opinions more positively, however future research should explore if these concreteness effects depend on the types of applications and the language used to describe them.

Conclusion

Using concrete language to describe the applications of GMOs compared to simply stating GMOs and keeping it as an abstract concept has consequences on attitudes and intentions towards GMOs. Findings of this research has implications for public perceptions research that is interested in assessing public's support or opposition to technologies in general and towards specific applications. The study also demonstrates the benefits of using concrete language to assess public perceptions of emerging technologies, especially among publics who might not understand the technology, yet can be allowed to form informed decisions about those technologies.

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Table 1: Demographic composition of the sample

	Mean or %	**S.D**
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 (5-point scale; "Very liberal" coded high)	2.991	1.206

Table 2: 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 3: List of concrete GM applications

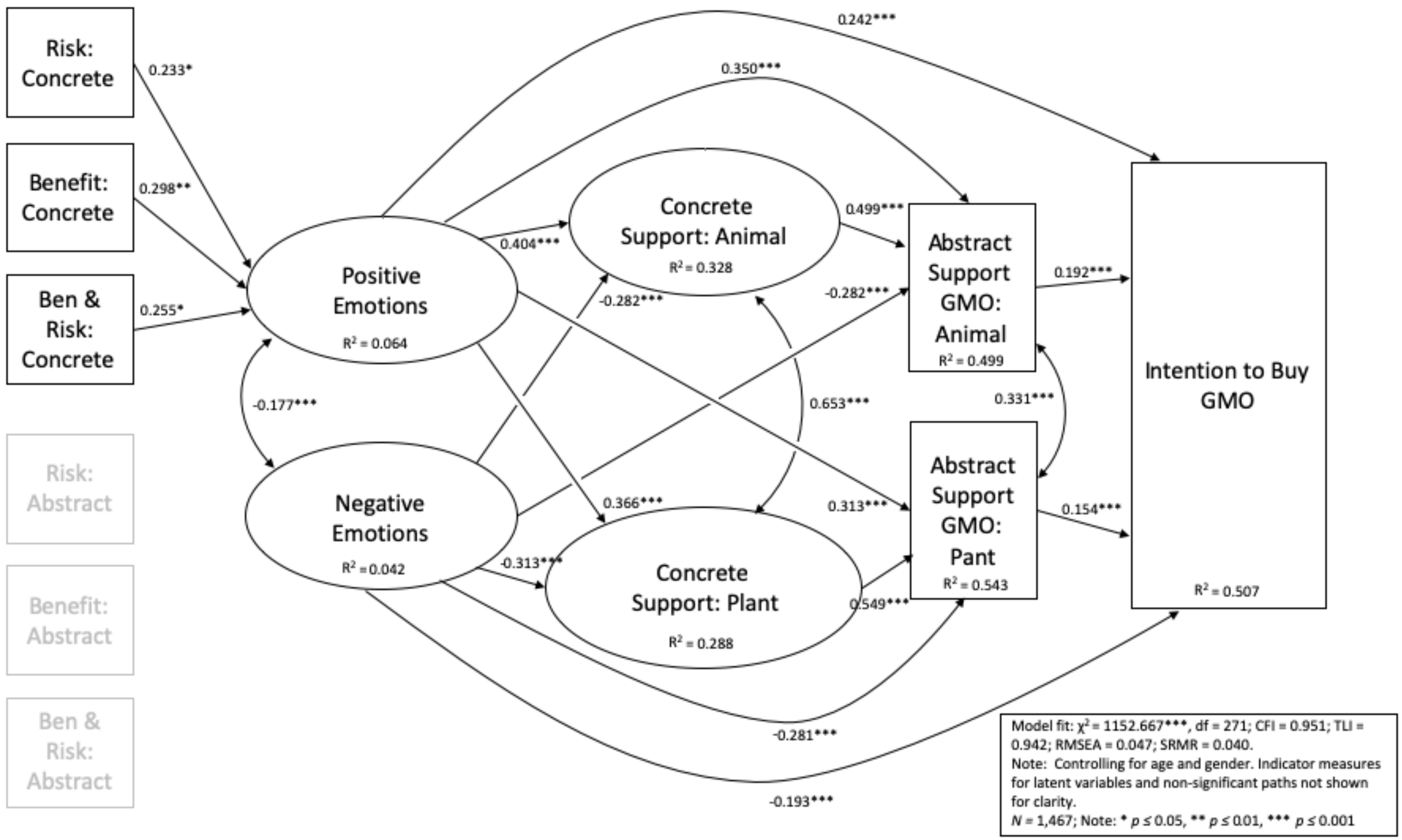
	Variable name	***Mean***	***S.D.***
Plant-based applications			
Grasses that don't need to be mown that often	Grass	3.24	1.29
Tomatoes with high levels of cancer fighting antioxidants	Tomato	3.63	1.23
Rice with enhanced vitamin A to prevent blindness	Rice	3.57	1.23
More nutritious grain that can feed 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	3.27	1.26
Cattle that produce beef with less cholesterol	Cattle	3.14	1.29
Pigs that produce low-fat bacon	Pig	3.00	1.31

Table 4: 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
Concrete Support: Animal		
Sheep	1.000	- -
Cattle	0.958***	0.030
Rhino	0.749***	0.029
Pig	0.896***	0.031
Concrete Support: Plant		
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 condition	0.255*	0.102
Risk general condition	0.059	0.102
Benefit general condition	0.049	0.102
Benefit and risk condition	0.110	0.102
Age	-0.009***	0.002
Gender (female coded 1)	-0.338***	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 condition	-0.024	0.115
Risk general condition	0.038	0.115
Benefit general condition	-0.125	0.115
Benefit and risk condition	0.066	0.115
Age	-0.001	0.002

Gender (female coded 1)	0.450***	0.063
R^2	0.042	
Concrete Support: Animal		
Positive emotions	0.404***	0.029
Negative emotions	-0.317***	0.025
R^2	0.328	
Concrete Support: Plant		
Positive emotions	0.366***	0.027
Negative emotions	-0.313***	0.024
R^2	0.288	
Abstract support GMO: Animal		
Concrete support: Animal	0.499***	0.034
Positive emotions	0.350***	0.031
Negative emotions	-0.282	0.027
R^2	0.499	
Abstract support GMO: Plant		
Concrete support: Plant	0.549	0.029
Positive emotions	0.313	0.027
Negative emotions	-0.281	0.024
R^2	0.543	
Intention to buy		
Abstract support GMO: Animal	0.154***	0.026
Abstract support GMO: Plant	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		
Covariances		
Positive emotions ~~ Negative emotions	-0.177***	0.033
Concrete support: Animal ~~ Concrete support: Plant	0.653***	0.034
Abstract support GMO: Animal ~~ Abstract support GMO: Plant	0.331***	0.024
Cattle ~~ pig	0.399***	0.028
Model Fit		
χ^2 (df = 271)	1152.667	
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	0.044	
N	1467	
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$		

Figure 1: Effect of concrete GM applications on emotions, attitudes towards GM, and intentions to buy products containing GMOs



Appendix

Table 1: 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 don't 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**

M_h=$Mean_{health}$; SD_h=Standard $Deviation_{health}$ ***p<0.001; **p<0.01, *p<0.05
M_e=$Mean_{environment}$; SD_e=Standard $Deviation_{environment}$

Table 2: 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 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.	2.64(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 that 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 don't 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***

M_h=$Mean_{health}$; SD_h=Standard $Deviation_{health}$ ***p<0.001; **p<0.01, *p<0.05
M_e=$Mean_{environment}$; SD_e=Standard $Deviation_{environment}$