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What consumers don't know about genetically modified food, and how that affects beliefs

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ABSTRACT: In the debates surrounding biotechnology and genetically modified (GM) food, data from consumer polls are often presented as evidence for precaution and labeling. But how much do consumers actually know about the issue? New data collected from a nationwide U.S. survey reveal low levels of knowledge and numerous misperceptions about GM food. Nearly equal numbers of consumers prefer mandatory labeling of foods containing DNA as do those preferring mandatory labeling of GM foods. When given the option, the majority of consumers prefer that decisions about GM food be taken out of their hands and be made by experts. After answering a list of questions testing objective knowledge of GM food, subjective, self-reported knowledge declines somewhat and beliefs about GM food safety increase slightly. Results suggest that consumers think they know more than they actually do about GM food, and queries about GM facts cause respondents to reassess how much they know. The findings question the usefulness of results from opinion polls as a motivation for creating public policy surrounding GM food.—McFadden, B. R., Lusk, J. L. What consumers don't know about genetically modified food, and how that affects beliefs. FASEB J. 30, 000–000 (2016). www.fasebj.org

KEY WORDS: GM food · labeling · public acceptance · public knowledge

Debate about biotechnology in plant research and about genetically modified (GM) food in the United States has intensified in recent years, with mandatory labeling ballot initiatives appearing in California, Colorado, Connecticut, Maine, Oregon, and Washington. The Vermont legislature passed the first U.S. mandatory labeling law for GM food (1), an action that has prompted competing legislation in the U.S. Congress (2). At the heart of the debate is stated public opposition to GM food, and public opinion may be a proximate cause of policy (3). Indeed, public opinion polls are often used to characterize consumer sentiment and motivate more precautionary policies for GM food. Apparent consumer concern could lead to a climate that impedes particular research methods and lowers the potential return to investments in biotechnology applications.

The seemingly high level of public opposition is puzzling given the views of most scientists on the issue. It could be argued that gaps between science and the public have always existed (4) and are increasing (5). However, the gap is extraordinarily large regarding the safety of GM foods. Only 37% of U.S. consumers believe that GM food is safe to eat; in contrast, 88% of scientist members of the American Association for the Advancement of Science believe GM food is safe to eat (6). The gap between public and scientific assessment of GM food safety was the largest among all issues studied, including vaccines, climate change, and fracking, by a recent Pew Research Center study (6). The divide may indicate a need for better science communication. However, previous research on the topic has shown that simply providing statements from the scientific community does not substantively change beliefs about the safety of GM food, and in fact results in a backlash among a segment of the population (7, 8).

There are several psychologic and behavioral-economic factors that may cause the public to form beliefs inconsistent with those of scientists. The world is full of uncertainty, and consumers form beliefs subject to constrained time, information, and computational capabilities. These constraints often require consumers to use heuristics, or rules of thumb, which can lead to biases when decisions concern uncertain risks, benefits, and consequences (9). Biases are perhaps more pronounced when consumers have little knowledge about an issue that is contemporaneously covered by the media, as has been the case with GM food (10, 11). In addition to media, other social influences likely shape beliefs. For example, consumers are more likely form a belief about an issue that is reflective of others who share similar values, as suggested by cultural cognition theory (12). Moreover, consistent

ABBREVIATIONS: GM, genetically modified

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signaling from others within a group may cause some consumers to hold a belief that is perceived to be consistent with most scientists when it is not (7, 13).

Here we contribute to the understanding of public concern about GM food safety by examining consumer knowledge about genetics and agricultural production. While a large number of studies have asked questions about consumer knowledge (14–16), this survey delves into the issue more exhaustively and offers insight into the level of knowledge of U.S. consumers about genetics and agricultural production. Furthermore, although framing effects of GM food labels has been assessed (17), this study relates consumer knowledge to the emerging policy issue of mandatory labeling. Moreover, unlike prior research, we here show how consumers' expressed knowledge and safety beliefs are affected by such questioning. The results described within are from a nationwide survey conducted in September 2015 of over 1000 U.S. respondents.

MATERIALS AND METHODS

Data Collection

This study was approved by the institutional review board at the University of Florida. The survey was conducted online and was completed by a sample of 1004 participants enrolled onto an online panel maintained by Survey Sampling International and their associated partners. Opt-in online panels produce estimates that are as accurate as other data collection methods, like telephone surveys (18). The survey was fielded from September 16, 2015, through September 28, 2015. Survey Sampling International prescreened participants by gender, education, and income to ensure the sample was representative of the U.S. population. According to the 2012 U.S. Census Bureau, women represented 50.8% of the population, 28.2% of persons aged 25 and older held a bachelor's degree, and the median household income was $52,762. Our sample closely matched these population statistics. Fifty-three percent of the survey sample comprised women, 35% held a bachelor's degree, and the median income category was $40,000 to $59,999. Given the sample size, the margin of error is $\pm 3.2\%$ for dichotomous questions.

Survey Overview

For the sake of brevity, a brief overview of the questions asked are described below. The specific questions asked by the survey and summary statistics for responses may be found in the Supplemental Data. After consenting to take the survey, participants were asked 10 blocks of questions. Blocks 2 through 8 were randomized across participants to minimize order effects. Questions associated with each block were as follows: *1*) a question to determine subjective knowledgeable about GM food, with responses varying on a 5-point scale from "very unknowledgeable" to "very knowledgeable," a question that determined respondent level of agreement with a statement, "Food that has genetically modified ingredients is safe to eat," with responses varying on a 5-point scale from "strongly disagree" to "strongly agree," and a question that measured confidence in the response to the previous agreement question; *2*) a question that determined if respondents knew how many genes are altered by different plant breeding techniques (*i.e.*, selection, hybridization, genetic marker assisted breeding, genetic modification, mutagenesis) with response categories "none," "1 to 9 genes," "10 or more genes," "Impossible to know," and "I do not know," and questions that determined knowledge about the proportion of corn and wheat acres planted with GM seed; *3*) questions that tested knowledge about what crops on the market were GM, the purposes or outcomes associated with modification, and whether GM animals were currently being sold; *4*) questions that tested knowledge about when GM crops were first grown, and the average time it takes for a GM crop or animal to be approved for human consumption; *5*) questions that tested awareness of GM and non-GM herbicide-tolerant crops; *6*) questions that tested awareness of the time it takes to create a new variety of GM and non-GM corn; *7*) questions that determined support or opposition for mandatory labeling of food and how the issue of mandatory labeling should be decided; *8*) questions that tested general knowledge of food DNA; *9*) questions in block 1 were repeated; and *10*) demographic questions.

Thus, we have within-subject measures of how self-reported subjective knowledge, beliefs about GM food safety, and confidence in those beliefs changed after answering the questions asked in blocks 2 through 8. Participants were not informed of the correct responses to the questions asked, and therefore any changes in the within-subject measures were completely a result of self-reflection. Care was taken to word questions in an easy-to-read and understandable manner. Nevertheless, the issues are inherently technical in nature and may be difficult to answer correctly for many people. Nevertheless, it is important to understand the level of public knowledge about genetics and agricultural production, particularly when assertions are being made about consumer knowledge and preferences. Furthermore, responses to some of the questions asked may provide insight into why some of the public is not accepting of GM foods. For instance, there is a sentiment that GM is not natural because it alters genes in a lab; however, it is unclear whether people are averse to the altering of genes in general or averse to genes being altered in a lab setting that could not occur in nature.

RESULTS

Before asking questions that tested knowledge about genetics and agriculture production, respondents were first queried about self-reported, subjective knowledge of GM food and beliefs about the safety of GM food. On a 5-point scale, 8% rated themselves as "very knowledgeable" about GM food, and the highest proportion, 32%, rated themselves as "somewhat knowledgeable," with the remaining 60% being undecided or not knowledgeable. Results regarding the safety of eating GM food aligned with previous studies (6, 8). Thirty-four percent believed GM food was not safe to eat, 34% believed it was safe, and 32% were in the middle. Respondents in the middle were less confident in their beliefs about GM food safety ($P < 0.01$, Satterthwaite test).

Low levels of knowledge about genetics may invoke concerns about GM interfering with nature relative to other breeding techniques. Respondents were asked how many genes are typically altered by various plant breeding techniques. The various breeding techniques queried were genetic marker–assisted breeding, genetic modification, hybridization, mutagenesis, and selection. The results are illustrated by **Fig. 1**. Approximately half of the sample indicated they did not know how many genes were altered for the various breeding techniques. Nevertheless, beliefs about the number of genes altered were significantly dependent on breeding technique ($P < 0.01$, Pearson's χ^2 test). Moreover, compared to the other listed breeding

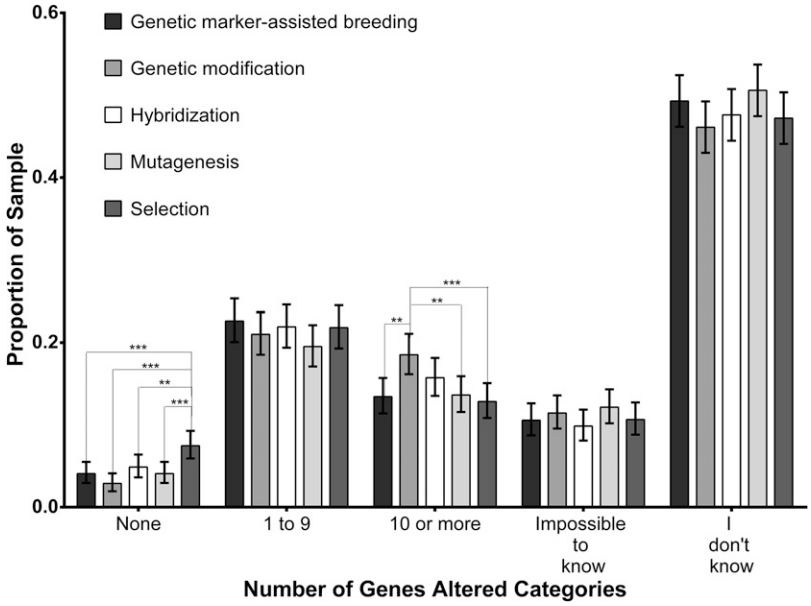

Figure 1. Consumer beliefs about number of genes altered by various breeding techniques. Significant differences were determined using Tukey's *post hoc* text. $^{**}P = 0.05$, $^{***}P = 0.01$.

techniques, a significant proportion of respondents thought selection did not alter any genes (Tukey's *post hoc* test). Conversely, compared to genetic marker–assisted breeding, mutagenesis, and selection, a significant proportion of respondents thought GM altered 10 or more genes (Tukey's test). Thus, respondents associate GM with more genetic alteration, which is not consistent with actual practice because selection alters thousands of genes while GM typically alters a select few.

Consumers had the option to choose "I don't know" for the pervious question. However, when forced to answer a question that asked if corn always contained the same genes before GM was possible, 49% of respondents thought corn had always contained the same genes. Further validating that some consumers have little knowledge of basic genetics were the responses to 2 other questions. Thirty-three percent of respondents thought non-GM tomatoes did not contain genes, and 32% thought vegetables did not have DNA. Taken together, these results indicate that at least of a third of consumers have little to no knowledge about genetics.

The most widely adopted GM crops, relative to total production for a given commodity, are corn, cotton, papaya, soybeans, and sugar beets. Respondents were asked what crops on the market were GM. Fifty-five percent of the sample thought corn was GM, and corn was the only commodity to receive more than 50%. A much smaller proportion thought that cotton, papaya, and sugar beets were GM, at 19, 14, and 18%, respectively. About a third, 34%, thought soybeans were GM. Approximately 15% of consumers thought all the crops present as response options were GM, including carrots and onions, which 28 and 21% of respondents, respectively, thought were GM. Thirty-two percent responded "I don't know."

Although respondents were more aware of GM corn than any other GM commodity, many respondents were not aware of the extent of GM corn adoption. In 2015, approximately 92% of all corn planted was GE (19). Yet on average respondents thought 56% (SD 24%) of corn planted was GM; they also thought 52% (SD 23%) of wheat planted was GM. Currently there are no acres of GM wheat; nevertheless, consumers thought GM corn and wheat were adopted at similar levels. In addition to crops, 46% of the sample thought there were GM animal food products on the market.

The commodities previously listed (*i.e.*, corn, cotton, papaya, soybeans, and sugar beets) were modified to be resistant to insects, herbicide, or disease. The reason for modification of GM commodities may not be obvious to consumers. Respondents were asked why GM commodities on the market may have been modified. A majority of consumers thought GM commodities currently on the market were modified to be resistant to insects and disease, at 53 and 52%, respectively. However, only 35% of consumers thought GM commodities on the market were modified to be resistant to herbicides. The result is curious in light of the recent heightened public discussion and debate about the safety of glyphosate relative to that of pesticides.

After answering numerous questions that tested objective knowledge, the questions at the beginning of the survey on expressed knowledge and safety beliefs were repeated. **Figure 2** illustrates the change in subjective self-reported knowledge for the sample. It is obvious that the mass shifts from the right (*i.e.*, the knowledgeable categories) to the left (*i.e.*, the neither and unknowledgeable categories) and there was a significant decrease in the number of respondents in the "somewhat knowledgeable" category. What is not obvious from the figure is how individual consumers flowed across these categories after answering questions. Paired t tests indicated that after answering questions, there were significant increases to the "very unknowledgeable" ($t = 2.68$) and "neither unknowledgeable/knowledgeable" ($t = 3.54$) categories and significant decreases to the "somewhat knowledgeable" ($t = -4.69$) and "very knowledgeable" ($t = -3.86$) categories. Together, these results suggest consumers think they know more than they actually do, and queries about

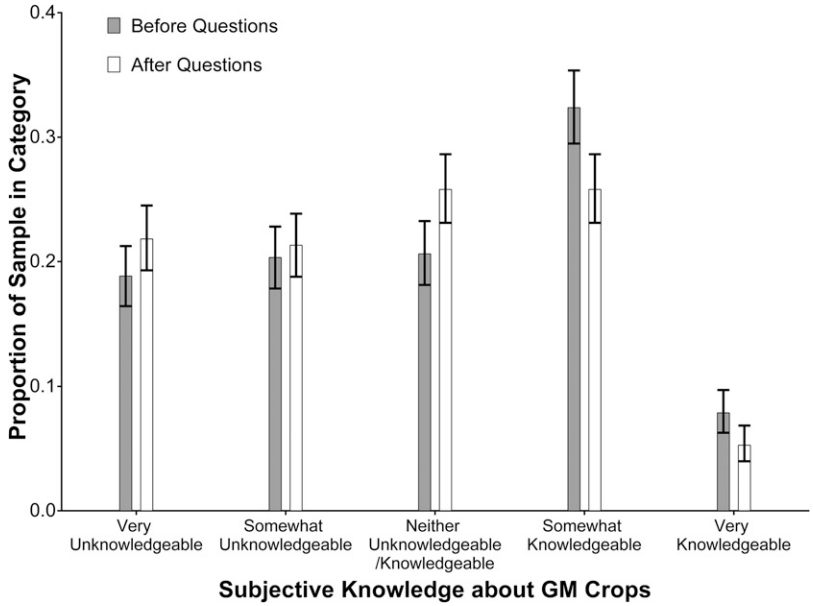

Figure 2. Subjective knowledge before and after answering questions about GM crops.

objective knowledge cause some respondents to reassess how much they know.

Unexpectedly, simply asking objective-knowledge questions slightly changed beliefs about GM food safety. Changes in beliefs are illustrated in **Fig. 3**. Consumers were significantly more likely to believe GM food was safe to eat after a series of questions that tested objective knowledge about genetics and GM food ($P < 0.01$, Student's t test and Wilcoxon signed rank test). At the individual level, there was a significant decrease to the "disagree" category ($t = -2.77$, paired Student's t test) and a significant increase to the "strongly agree" category ($t = 2.49$, paired Student's t test). While there was a modest change in beliefs, confidence in beliefs, on average, did not change after answering questions ($P = 0.84$, Student's t test; $P = 0.95$, Wilcoxon signed rank test). This was also true even when the sample was restricted to only those who had a change in belief ($P = 0.73$, Student's t test; $P = 0.67$, Wilcoxon signed rank test). However, consumers who changed safety beliefs were less confident both before ($P = 0.04$, Satterthwaite test) and after ($P = 0.02$, Satterthwaite test) answering knowledge questions than consumers who did not have a belief change.

Public concern about the safety of GM food is often expressed by demands for mandatory labeling; however, the public may prefer to default to experts for decisions related to biotechnology if they are uncertain or believe themselves to be unknowledgeable. Respondents were asked several questions to determine preferences for labeling (**Fig. 4**). While 84% of respondents supported mandatory labeling for food containing GM ingredients (Fig. 4*A*), there was also overwhelming support for mandatory labeling of food containing DNA (Fig. 4*B*). Eighty-percent of consumers supported a label for food indicating the presence or absence of DNA—an absurd policy that would apply to the majority of foods in a grocery store.

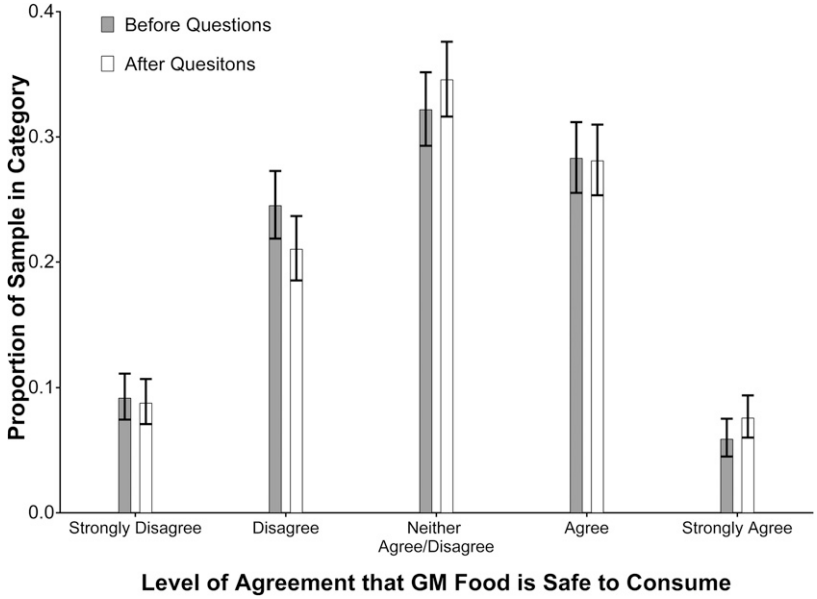

Figure 3. Beliefs about safety of consuming GM food before and after answering questions about GM.

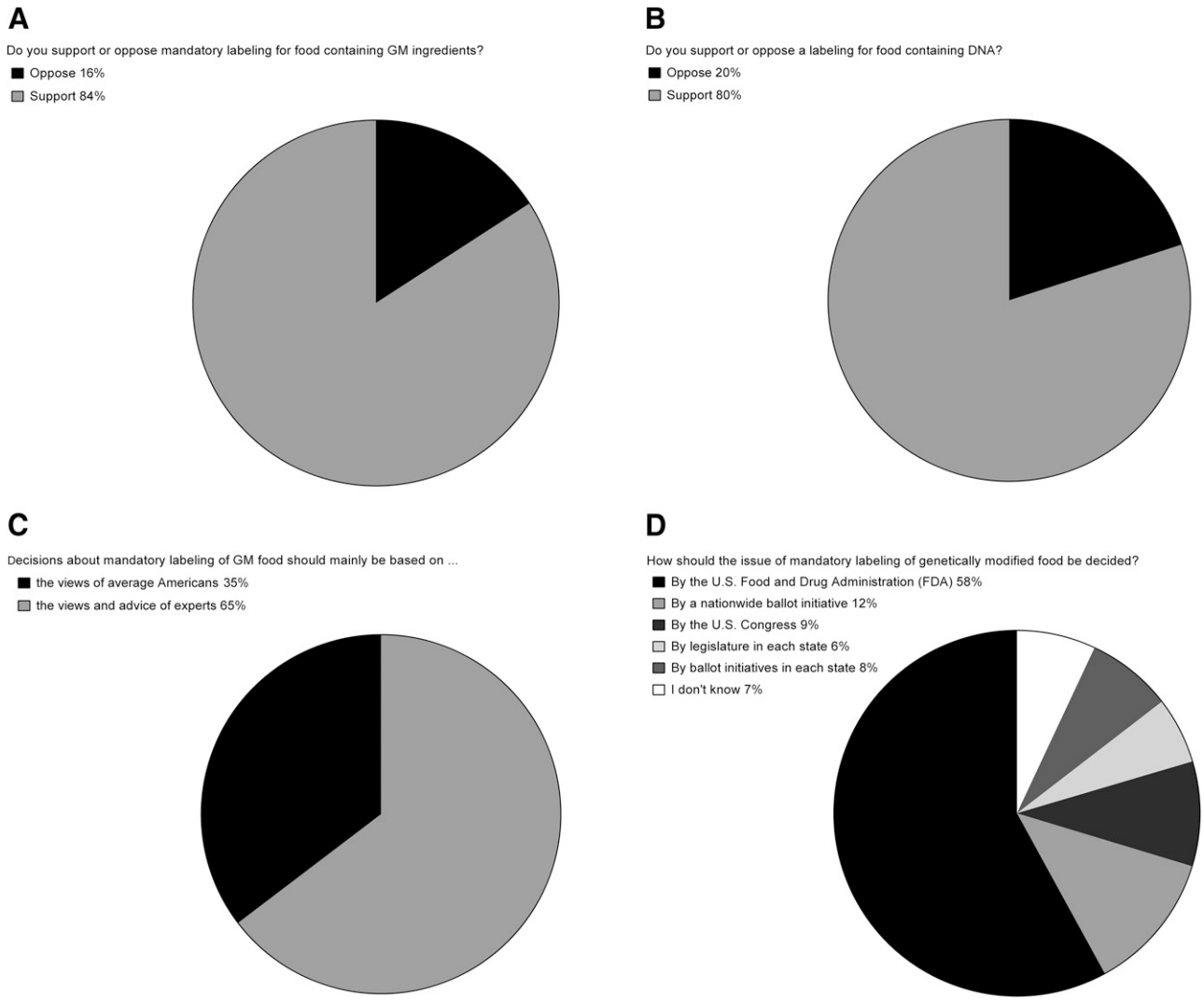

Figure 4. Views about mandatory labeling.

Rather than asking whether consumers want mandatory labeling, a more instructive question might be how they believe such an issue should be decided. A question similar to that posed by Gaskell *et al.* (20) was applied to the case of labeling, and results indicated that only 35% thought decisions about mandatory labeling should mainly be based on the views of average Americans, with the remainder believing that the issue should be decided by experts (Fig. 4*C*). Furthermore, only 8% thought the issue of mandatory labeling should be decided by a ballot initiative, and the majority, 58%, thought the issue should be decided by the U.S. Food and Drug Administration (Fig. 4*D*). Therefore, although most consumers support a mandatory label for GM food, most consumers also thought the decision should be made experts with more knowledge. Indeed, as previous results suggest, consumers had little knowledge of basic genetics.

DISCUSSION

Although many consumers claimed to be opposed to GM food, there was an overall lack of knowledge about GM food. Previous research determined that providing consumers with information from the scientific community about the safety of GM food did not affect opposition (8). However, simply asking knowledge questions about GM food appears to have informed consumers that opposition was formed without adequate knowledge, and subjective knowledge and beliefs did change.

Whether mandatory labels should be required for GM food is a highly contentious topic. In the debates surrounding mandatory labels, data from consumer polls are often presented as evidence for precaution and labeling. Our results here indicate that consumer polls are not an adequate proxy for the decision of whether a mandatory label should be required. Consumers also express support for absurd policies like DNA labeling. Such statements of support indicate a low level of knowledge about basic genetics, or they may indicate how consumers psychologically handle difficult questions. It has been argued that individuals attempt to economize on scarce cognitive resources by unconsciously substituting an easier question for a hard one (21). Rather than seriously weighing the pros and cons of mandatory labeling, the similarity in

responses to the DNA labeling question suggests that people may instead be substituting these questions with a simper question like, "Do you want free information about a topic about which you know very little?" This psychologic process would lead to similar levels of support to two very different policy questions.

In addition to asking whether people wanted mandatory GM labeling, respondents were also queried about their "meta" preferences for how such a decision should be made. When given the option, the majority of consumers prefer that decisions about mandatory labeling of GM food be taken out of their hands and be made by experts. This finding is consistent with the notion that consumers' self-assessed knowledge of the topic is low. Consumers routinely defer to experts on complex decisions (*e.g.*, obtaining retirement advice, filing taxes, or selling a house). Indeed, the choice to defer to an expert is itself an admission of knowledge inadequacy.

After a bit of reflection, and with the benefit of hindsight, it seems obvious that consumer polls may not be a proximate cause for policy. It is unlikely that someone would give a negative answer to a question that involves zero cost and may provide future benefit. Possibly confirming this idea was the result that nearly equal numbers of consumers prefer mandatory labeling of foods containing DNA as do those preferring mandatory labeling of GM foods. FJ

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REFERENCES

1. Vermont Act 120. An act relating to the labeling of food produced with genetic engineering. http://www.leg.state.vt.us/docs/2014/Acts/ACT120.pdf
2. United States Senate Committee on Agriculture, Nutrition, and Forestry. National voluntary bioengineered food labeling standard. http://www.agriculture.senate.gov/imo/media/doc/3450.pdf
3. Page, B. I., and Shapiro, R. Y. (1983) Effects of public opinion on policy. *Am. Polit. Sci. Rev.* **77**, 175–190
4. Ziman, J. (1991) Public understanding of science. *Sci. Technol. Human Values* **16**, 99–105
5. Bensaude-Vincent, B. (2001) A genealogy of the increasing gap between science and the public. *Public Underst. Sci.* **10**, 99–113
6. Funk, C., Rainie, L., and Page, D. (2015) Public and scientists' views on science and society. Pew Research Center. http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society.
7. Rabin, M., and Schrag, J. L. (1999) First impressions matter: a model of confirmatory bias. *Q. J. Econ.* **114**, 37–82
8. McFadden, B. R., and Lusk, J. L. (2015) Cognitive biases in the assimilation of scientific information on global warming and genetically modified food. *Food Policy* **54**, 35–43
9. Tversky, A., and Kahneman, D. (1974) Judgment under uncertainty: heuristics and biases. *Science* **185**, 1124–1131
10. Lusk, J. L., Roosen, J., and Bieberstein, A. (2014) Consumer acceptance of new food technologies: causes and roots of controversies. *Annu. Rev. Resour. Econ.* **6**, 381–405
11. Slovic, P. (1987) Perception of risk. *Science* **236**, 280–285
12. Kahan, D. M., Witlin, M., Peters, E., Slovic, P., Oullette, L. L., Braman, D., and Mandel, G. N. (2011) The tragedy of the risk-perception commons: culture conflict, rationality conflict, and climate change. Social Science Research Network. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1871503
13. Kahan, D. M., Jenkins-Smith, H., and Braman, D. (2011) Cultural cognition of scientific consensus. *J. Risk Res.* **14**, 147–174
14. Gaskell, G., Bauer, M. W., Durant, J., and Allum, N. C. (1999) Worlds apart? The reception of genetically modified foods in Europe and the U.S. *Science* **285**, 384–387
15. Onyango, B., Govindasamy, R., and Hallman, W. (2006) U.S. public awareness and knowledge of and interest in biotechnology: a principal component factor analysis. *J. Food Distribution Res.* **37**, 126
16. Marris, C., Wynne, B., Simmons, P., and Weldon, S. (2001) Public attitudes to agricultural biotechnologies in Europe: final report of the PABE research project. Centre for the Study of Environmental Change. http://csec.lancs.ac.uk/archive/pabe/docs/pabe_finalreport.pdf
17. Phillips, D. M., and Hallman, W. K. (2013) Consumer risk perceptions and marketing strategy: the case of genetically modified food. *Psychol. Mark.* **30**, 739–748
18. Ansolabehere, S., and Schaffner, B. F. (2014) Does survey mode still matter? Findings from a 2010 multi-mode comparison. *Polit. Anal.* 22, 285–303 doi:10.1093/pan/mpt025
19. U.S. Department of Agriculture. Adoption of genetically engineered crops in the U.S. http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx
20. Gaskell, G., Einsiedel, E., Hallman, W., Priest, S. H., Jackson, J., and Olsthoorn, J. (2005) Communication. Social values and the governance of science. *Science* **310**, 1908–1909
21. Kahneman, D. (2011) *Thinking, Fast, and Slow*, Macmillan, New York

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