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ORIGINAL ARTICLE

Framing, Motivated Reasoning, and Opinions About Emergent Technologies

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How do individuals form opinions about new technologies? What role does factual information play? We address these questions by incorporating 2 dynamics, typically ignored in extant work: information competition and over-time processes. We present results from experiments on 2 technologies: carbon-nanotubes and genetically modified foods. We find that factual information is of limited utility—it does not have a greater impact than other background factors (e.g., values), it adds little power to newly provided arguments/frames (e.g., compared to arguments lacking facts), and it is perceived in biased ways once individuals form clear initial opinions (e.g., motivated reasoning). Our results provide insight into how individuals form opinions over time, and bring together literatures on information, framing, and motivated reasoning.

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The success of any emergent technology depends in large part on public acceptance. For many innovations, entry into the marketplace requires surviving a political and regulatory process that rarely succeeds in the face of public opposition. Then, these products must face market competition where public preferences determine survival. Recent examples of products that face these hurdles include nuclear power, various energy-efficient technologies, genetically modified foods, nanotechnology, stem-cell research, and biotechnology.[1] Over the last several decades, scholars have developed a field of study that explores how citizens perceive the risks associated with new products (e.g., Committee on Risk Perception and Communication, 1989). One, if not the, dominant theme of this literature is the need to inform the public about facts surrounding new technologies—that is, to make citizens scientifically literate (e.g., Bauer, Allum, & Miller, 2007; Miller, 1998). New information will presumably enable individuals to accurately assess the risks associated with new innovations. More generally, information at the preadoption stage of a product's diffusion plays a vital role in shaping public attitudes (Elliott & Rosenberg, 1987; Stamm, Clark, &

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Eblacas, 2000) and behaviors (Rogers, 2003; Southwell & Torres, 2006; Vishwanath, 2009, p. 177).

The implicit model of opinion formation underlying much of the work on risk perception and scientific literacy treats citizens and consumers as rational thinkers who carefully integrate new information in expected ways (e.g., individuals are treated as Bayesians). The realities of opinion formation, however, suggest otherwise—in many situations, individuals develop attitudes and take actions in more haphazard ways. Scholars who study public acceptance of emergent technologies are beginning to recognize that individuals form opinions even when possessing little information (e.g., Scheufele, 2006) and that attitudes depend on multiple factors beyond factual information. These factors include values (e.g., Nisbet & Goidel, 2007), trust in science (e.g., Rodriguez, 2007), and frames or arguments that typically lack factual content (e.g., Nisbet & Mooney, 2007; Nisbet, n.d.; also see Cobb, 2005).

Yet, even this recent work has not systematically explored the processing and causal impact of factual information, compared to other factors, over time. In this article, we study (a) the impact of background factual information relative to other influences including values and trust in science, (b) how newly presented factual information affects opinions *when* presented with consistent or contradictory frames/arguments (that lack factual content), and (c) how factual information is processed at a later point in time, once individuals have formed relatively coherent opinions about the new technologies.

We explore these dynamics with experiments on two technologies: carbon-nanotubes (CNTs) and genetically modified foods (GM foods). We find that factual information is of limited utility—it does not have a greater impact than other background factors, it adds little power to newly provided arguments (e.g., compared to frames that lack factual information), and it is perceived in biased ways once individuals form clear initial opinions. We conclude by discussing the implications of our findings for studies of emergent technology and opinion formation more generally.

Opinions about emergent technologies

A fruitful and oft-used approach for understanding opinions about emergent technologies focuses on individuals' assessments of benefits and costs/risks (e.g., Cobb & Macoubrie, 2004; Currall, King, Lane, Madera, & Turner, 2006; Macoubrie, 2006). For example, individuals weigh the health risks associated with nuclear power against the extent to which nuclear power would vitiate the energy shortage. As mentioned, a long-standing theme in past work concerns how factual knowledge affects individuals' risk–benefit assessments. The scientific literacy model of opinion formation holds that knowledge facilitates accurate assessment of risks and benefits, and that it "generates support for science and technology" (Gaskell et al., 1999, p. 386; Miller, 1998; Nisbet & Goidel, 2007, p. 421; Sturgis & Allum, 2006).[2] More recent work questions the scientific literacy approach, instead emphasizing how other factors shape emergent technology opinions, including values (Nisbet & Goidel, 2007), trust in science (e.g., Lee, Scheufele, & Lewenstein, 2005; Rodriguez, 2007), and the framing of the technologies (e.g., Cobb, 2005; Nisbet & Mooney, 2007; Nisbet, n.d.; Scheufele, 2006).

Yet, even this recent work largely ignores two elements critical to opinion formation about new innovations. First, by definition, these technologies emerge over time (Jasper, 1988); a very simple schematic would consider (a) how individuals form initial opinions, and particularly how background factors such as scientific knowledge and trust in science affect opinions, (b) how individuals then incorporate new factual information and arguments, and (c) how individuals interpret information once their opinions have somewhat crystallized.[3] Second, in the process of receiving new information and arguments, individuals will likely be exposed to *competing* sides, some of which favor the new technologies and others that oppose it. Indeed, nearly all new products generate some disagreement, even among experts, and in many circumstances, these competing messages about the product will be passed on to the public via the mass media, interest groups, and others.

We focus, here, on the impact of factual information at each of these three steps of opinion formation, in the presence of competing forces. Before discussing each stage, however, it is important to clarify (a) what we mean by "fact," and (b) what types of incentives individuals possess when forming opinions about most new technologies. In its most basic form, a fact is something that verifiably exists and has some objective reality (Merriam-Webster Online Dictionary). Facts come in a wide variety of forms and, on most issues, are ever-present (e.g., Shapiro & Block-Elkon, 2008). We focus on facts in the guise of "scientific *evidence*" that report a verified observation (e.g., an experimental outcome). For example, the statement "A recent study on genetically modified foods found that a type of rice ("golden rice") can be produced with a high content of vitamin A" constitutes a fact as it reports the confirmed results of a study. Facts differ from value judgments that contain subjective elements, often about prioritizing distinct considerations (e.g., Fairbanks, 1994). For example, the *claim* that "the most important implication of genetically modified foods concerns their availability for developing countries" contains no verifiable content and, as such, amounts to a value judgment.[4]

How individuals treat facts and other types of information depends on their incentives. Evidence from multiple disciplines makes clear that processes of opinion formation depend in fundamental ways on motivation and ability (e.g., Chaiken & Trope, 1999). For most emergent technologies, motivation and ability will be low; people typically know little about new technologies (i.e., low ability), and have scant incentives to learn more (i.e., low motivation) as the direct personal relevance of doing so is unclear at best (e.g., O'Keefe, 2002, pp. 141–143). Scheufele and Lewenstein (2005, p. 660) explain that "developing an in-depth understanding would require *significant* efforts on the part of ordinary citizens [and] the pay-offs... may simply not be enough" (emphasis in original; also see Lee et al., 2005; Kahan, Braman, Slovic, Gastil, & Cohen, 2007; Kahan et al., 2008; Scheufele, 2006). Consequently, people form their opinions in a less deliberate manner that does not involve careful integration of new information.

What this means at the first stage of opinion formation—when individuals draw on background factors—is that people will not systematically work through the (factual) information they possess, instead relying on simpler "gut reactions" or cues. People "do not use all available information to make decisions about issues, including new technologies or scientific discoveries.... Rather, they rely on heuristics or cognitive shortcuts, such as ideological predispositions..." (Scheufele & Lewenstein, 2005, p. 660).[5] This echoes cultural cognition theory, which posits that "persons conform their factual beliefs about the risks and benefits of putatively dangerous activity to their cultural appraisals of these activities" (Kahan et al., 2007, p. 4). Specifically, people who view the world in more individualistic terms (instead of communitarian terms) and/or more hierarchical terms (instead of egalitarian terms) will dismiss the risks posed by new technologies and support innovations because "they perceive (subconsciously) that crediting them would justify restraining markets and other kinds of private orderings ... or challeng[ing] societal and governmental elites" (Kahan et al., 2007, p. 4; also see Musham, Trettin, & Jablonski, 1999, p. 331). Other heuristic factors that appear to drive opinions about emergent technologies include trust in science (leading to more support), media exposure (leading to more support), and various demographics (i.e., females, minorities, liberals, less educated, and younger people tend to be less supportive; e.g., Bauer et al., 2007; Lee et al., 2005; Scheufele & Lewenstein, 2005). Our expectation is that these heuristic factors will play a significantly larger role than factual information in determining opinions about new technologies (Hypothesis 1).

The next stage concerns how new information or arguments affect individuals' opinions. As mentioned, the scientific literacy approach suggests that the provision of factual information (e.g., results from a scientific study) should have a notable effect, typically resulting in increased support. An alternative approach emphasizes the impact of frames, which are essentially a type of argument or claim (Cobb, 2005; Kahan et al., 2008; Nisbet & Mooney, 2007; Nisbet, n.d.; Scheufele, 2006). A framing effect occurs when, in the course of describing a new technology, a speaker's emphasis on a subset of potentially relevant considerations causes individuals to focus on those considerations when constructing their opinions, which may in turn lead to a change in overall support (Druckman, 2001, pp. 226–231). For example, a news article on nanotechnology that emphasizes its impact on human health may cause readers to focus on health risks and become less supportive, whereas an article focusing on the facilitation of consumer good production may cause readers to focus on those benefits and become more supportive (e.g., Cobb, 2005; Kahan et al., 2008). Frames are analogous to the aforementioned value judgments/claims insofar as they prioritize a consideration (which may but need not be a value). Although frames sometimes include factual content (e.g., a prioritizing judgment that also cites evidence from a health study or consumer production projections), it is not critical and, in practice, most frames are "fact free" (e.g., no citation of health statistics) (e.g., Berinsky & Kinder, 2006; Nelson, Oxley, & Clawson, 1997).

Countless studies—across issues, contexts, and individuals—show that frames, typically lacking factual content, can shape opinions by causing individuals to focus on the considerations emphasized in the frame (Chong & Druckman, 2007a). Recent work on competitive framing shows that exposure to two competing frames (e.g., health and consumer benefits) often cancels both of them, unless one of those two frames is inherently "stronger" or "more compelling" (Chong & Druckman, 2007b). An unanswered question, which we will explore, is whether the inclusion of a fact enhances a frame's strength—in other words, do facts add anything, beyond frames, to the opinion formation process? The scientific literacy approach would suggest they do; however, we are less sanguine. Chong and Druckman (2007a) explain that only motivated and able individuals will scrutinize a frame's content such that the inclusion of facts will enhance its strength. As our predictions presume no such motivation or ability (given our focus on unfamiliar new technologies), we expect that facts do not significantly affect opinions, beyond the effects of a frame absent factual content.[6] That is, frames that contain factual content will not have significantly greater impacts than frames without factual information (Hypothesis 2). This prediction echoes Lakoff's (2004, p. 17) statement that "People think in frames. . . . To be accepted, the truth must fit people's frames. If the facts do not fit a frame, the frame stays and the facts bounce off" (also see Eagly & Chaiken, 1993, p. 327; Fazio, 2000, p. 14; Kunda, 2001, p. 16). We will test our second hypothesis in two ways: (a) by comparing whether a frame containing factual content supportive of (opposed to) a new technology has a greater effect on opinions than analogous supportive (opposing) frames that lack factual content, and (b) by exploring whether a supportive (opposing) frame with a fact overpowers a competing opposing (supportive) frame that lacks factual content.

The final stage in our basic characterization of the opinion formation process involves how individuals interpret information once they have formed, at least relatively, coherent opinions. In the idealized, rational environment, individuals would process any new information in an even-handed and unbiased fashion. However, our portrayal of individuals as less than rational means that biases are likely. Absent substantial motivation to accurately process information, individuals subconsciously interpret new information in light of their extant attitudes. Lodge and Taber (2008, p. 33) explain that upon encountering new information, existing attitudes "come inescapably to mind, whether consciously recognized or not, and for better or worse these feelings guide subsequent thought." The result is motivated reasoning: the tendency to seek out and/or view new evidence as consistent with one's prior views, even if this is not objectively accurate (e.g., a disconfirmation bias) (see Lord, Ross, & Leeper, 1979; Kunda, 2001).

Whether they know it or not, people engage in motivated reasoning to arrive at a desired conclusion. For example, when people receive new information about George W. Bush, they interpret it in light of their existing opinions about Bush. Thus, a pro-Bush voter might interpret information suggesting that Bush misled voters about the Iraq war as either false or as evidence of strong leadership in a time of crisis, rather than an accurate indication of incompetence or deception. Such voters may then become even more supportive of Bush. Lodge and Taber (2008, pp. 35–36) explain that motivated reasoning entails "systematic biasing of judgments in favor of one's immediately accessible beliefs and feelings. . . . [It is] built into the basic architecture of information processing mechanisms of the brain."

We expect three particular dynamics. First, people will evaluate evidence that support their prior opinions as more effective than contrary arguments (Hypothesis 3, often called an "attitude congruency bias")[7] (e.g., Rudolph, 2006). Second, people will interpret neutral (i.e., ambiguous or balanced) evidence to be directionally (e.g., pro or con) consistent with the direction of their prior opinions (e.g., Kahan et al., 2008) (Hypothesis 4). Third, biased processing of new evidence will affect subsequent overall opinions, as individuals incorporate that evidence into their attitudes (Hypothesis 5a). This, in turn, will lead people to become more extreme in their positions and result in attitude polarization with individuals on opposing sides diverging further (Hypothesis 5b; e.g., Taber & Lodge, 2006).[8]

Experimental participants, procedure, and design

To investigate our hypotheses, we conducted experiments on distinct emergent technologies: CNTs and GM foods. CNTs, a type of nanotechnology, are tiny graphite with chemical properties that, among other applications, facilitate the conversion of sunlight into electricity. GM foods are biologically modified to alter nutritional content and/or to enhance their ability to withstand adverse conditions. Both technologies came to prominence in the early 1990s; although the mass public knows little about either, they are particularly unaware of CNTs with 49% reporting that they have heard nothing about them, compared to 25% when it comes to GM foods (Mellman Group, 2006; Peter D. Hart Research Associates, Inc., 2008). This difference presumably reflects some consumers inadvertently learning about GM foods (e.g., in grocery stores) as well as the negative attention that GM foods have periodically received in the media (e.g., Mad Cow disease). In contrast, CNTs remain more distant in their applications (e.g., in electrical circuits, transistors).

Our specific experiments took place in the context of an exit poll on Election Day in 2008. We opted for this approach for two reasons. First, it allowed us to include a heterogeneous sample of respondents. Second and more importantly, it enabled us to provide perspective to these relatively unfamiliar technologies by situating them within a context. Specifically, we explained that these technologies are likely to receive considerable attention during the next President's term (which coheres nicely with the attention energy received during the campaign). Although in some sense unusual, we believe this enhances experimental realism, compared to confronting respondents with novel technologies with no context whatsoever.[9]

We implemented the survey experiment by assembling 20 teams of student pollsters. We then randomly selected polling locations throughout the northern part of Cook County, IL. Each polling team spent a randomly determined 2 to 3 hour daytime period at their polling place. A pollster asked every third voter to complete a self-administered questionnaire in exchange for $5. As we will discuss, we also asked respondents to provide their e-mail addresses so that we could re-contact them to test our motivated reasoning hypotheses. Our sample ended up consisting of 621 individuals; we report their demographic profile below.

The Election Day survey provided respondents with brief descriptions of each technology (described below). The main dependent variables asked participants to rate on 7-point scales the extent to which they oppose or support "using CNTs" and "the production and consumption of GM foods," with higher scores indicating increased support (e.g., 1 = *oppose strongly*, 4 = *not sure*, 7 = *support strongly*).[10] To test Hypothesis 2, we incorporated the experimental conditions—which we will momentarily describe—by altering the brief descriptions of the technologies.

We also included measures of the previously discussed attitudinal, knowledge, and demographic factors shown to affect attitudes toward new technologies (that are relevant to testing Hypothesis 1). This includes measures of cultural cognition theory's worldview variables—hierarchical (as opposed to egalitarianism) and individualism (as opposed to communitarianism)—measured on 7-point scales tending toward hierarchical tendencies or individualism.[11] We measured political ideology with the standard (National Election Study) question where respondents placed themselves on a 7-point scale, with higher scores indicating conservativeness. Our trust in science measure asked respondents whether they believe "science creates unintended consequences and replaces older problems with new ones or enables us to overcome problems," on a 7-point scale with higher scores indicating higher credibility (i.e., overcoming problems; see Cobb & Macoubrie, 2004).

For scientific knowledge, we follow others (e.g., Lee et al., 2005, pp. 242–243) by drawing a distinction between general scientific knowledge and technology-specific knowledge. We asked two factual questions about general scientific knowledge, and two each on CNTs and GM foods. These questions queried knowledge about verified scientific dynamics.[12] Finally, we included standard demographic measures that asked for respondents' gender (0 = male, 1 = female), minority status[13], education[14], age[15], and media exposure.[16,17] In Table 1, we report the descriptive statistics for the sample. (The *N*s vary by variable because of nonresponses.) The table shows that the respondents come from fairly diverse backgrounds—although, as would be expected in northern Cook County, the sample is skewed toward liberal, well-informed, and educated individuals.[18]

Experimental conditions

We designed our experiment to test our second hypothesis concerning the impact of facts on frame strength. To identify frames and associated facts for each of our technologies, we explored the popular and scientific literatures. We then pretested a selection of frames and facts to pinpoint strong (i.e., compelling) examples. For CNTs, the frames/facts involved energy costs/availability (pro) and potential health

Table 1 Demographic and Political Profile of Sample

Variable	Scale (overall distribution)	Average (*SD*)
Individualism	Agreement with "Government should spend less time trying to fix everyone's problems." 1 = 23% (143) (total *N*: 614) 2 = 20% (123) 3 = 15% (90) 4 = 10% (59) 5 = 13% (82) 6 = 10% (59) 7 = 9% (58)	3.36 (2.00)
Hierarchical	Agreement with "We have gone too far in pushing equal rights in this country." 1 = 44% (270) (total *N* = 616) 2 = 18% (109) 3 = 10% (64) 4 = 6% (37) 5 = 10% (61) 6 = 6% (38) 7 = 6% (37)	2.63 (1.94)
Political ideology (conservativeness)	1 (very liberal) = 17% (107) (total *N* = 616) 2 = 26% (156) 3 = 18% (111) 4 (moderate) = 20% (124) 5 = 9% (57) 6 = 6% (36) 7 (very conservative) = 4% (25)	3.12 (1.64)
Science credibility	Agreement that science definitely overcomes problems, rather than creating new ones. 1 = 8% (49) (total *N* = 605) 2 = 11% (67) 3 = 12% (75) 4 = 19% (117) 5 = 23% (136) 6 = 18% (108) 7 = 9% (53)	4.25 (1.72)
Scientific knowledge	0 correct = 22% (135) (total *N* = 619) 1 correct = 29% (180) 2 correct = 49% (304)	1.27 (0.80)
CNT knowledge	0 correct = 35% (220) (total *N* = 620) 1 correct = 50% (307) 2 correct = 15% (93)	0.80 (0.68)
GM foods knowledge	0 correct = 27% (166) (total *N* = 620) 1 correct = 24% (147) 2 correct = 49% (307)	1.23 (0.84)
Ethnicity (minority status)	White = 69% (409) (total *N* = 595) African Americans = 15% (87), Asian Americans = 5% (31) Hispanic = 2% (13), Other = 4% (23), Prefer not to answer = 5% (32)	n/a
Sex (female)	Male = 42% (251) (total *N* = 592) Female = 58% (341)	n/a

Continued on overleaf

Table 1 (*Continued*)

Variable	Scale (overall distribution)	Average (*SD*)
Age	1 (18–24) = 27% (160) (total $N = 595$) 2 (25–34) = 15% (89) 3 (35–44) = 14% (82) 4 (45–54) = 15% (90) 5 (55–64) = 13% (79) 6 (65–74) = 10% (57) 7 (75+) = 6% (38)	3.27 (1.93)
Education	1 (less than high school) = 1% (5) (total $N = 595$) 2 (high school) = 9% (53) 3 (some college) = 30% (179) 4 (year college degree) = 27% (163) 5 (advanced degree) = 33% (195)	3.82 (1.01)
Newspaper reading	1 (never) = 5% (31) (total $N = 619$) 2 = 10% (64) 3 = 10% (60) 4 (a few times a week) = 18% (114) 5 = 13% (79) 6 = 11% (70) 7 (everyday) = 33% (201)	4.87 (1.93)

CNT = carbon-nanotubes; GM = genetically modified.

risks (con). For GM foods, the frames/facts focused on combating world hunger (pro) and biodiversity (con). The specific wordings appear in Table 2.[19] For the frames without facts, we included a consensus endorsement to ensure its credibility (O'Keefe, 2002). Our facts, as explained, consist of verified scientific evidence. Importantly, each factual statement implicitly includes the frame, given that each fact emphasizes particular dimensions of concern. For example, the fact that "CNTs will double the efficiency of solar cells in the coming years" obviously places emphasis on energy considerations. For simplicity, we hereafter typically refer to the framed facts merely as "facts"; however, these "facts" are, in essence, frames that include factual content. Likewise, we will often call the frames without facts "frames," even though they are more specifically frames with no factual content (as is typical; Nelson et al., 1997).

Our experimental conditions vary exposure to frames and facts (i.e., frames with facts). All conditions began with brief descriptions of the relevant technologies. For example, for CNTs, survey respondents read that "One of the most pressing issues facing the nation—as has been clear from the election—concerns the limitations to our energy supply (e.g., with regard to coal, oil, and natural gas). One approach to addressing this issue is to rely more on CNTs. CNTs are tiny graphite with distinct chemical properties. They efficiently convert sunlight into electricity, and thus, serve as an alternative to coal, oil, and natural gas. The uncertain long-term effects of CNTs are the subject of continued study and debate."[20] Respondents were then randomly assigned to one of nine conditions, as described in Table 3 (with the *N*s appearing in the cells). We randomly assigned conditions separately for CNTs and GM foods, and

Table 2 Frames and Facts

Direction	Frame Without Fact	Frame With Fact
CNTs		
Pro: Energy costs/availability	Most agree that the most important implication of CNTs concerns how they will affect energy cost and availability.	A recent study on cost and availability showed that CNTs will double the efficiency of solar cells in the coming years.
Con: Potential health risks	Most agree that the most important implication of CNTs concerns their unknown long-run implications for human health.	A recent study on health showed that mice injected with large quantities of CNTs reacted in the same way as they do when injected with asbestos.
GM foods		
Pro: Combating world hunger	Most agree that the most important implication of GM foods concerns their availability for developing countries that face nutritional and food supply challenges.	A recent study on availability showed that many of the 23 GM producing countries are developing nations that produce virus resistant GM foods with increased iron and vitamins.
Con: Biodiversity	Most agree that the most important implication of GM foods concerns their impact on biodiversity and their effect on other crops and animals in the food chain.	A recent study related to biodiversity showed that while a GM food (a sugar beet) limited destruction by insects, it also affected other animals (e.g., birds) that feed on those insects.

CNTs = carbon-nanotubes; GM = genetically modified.

thus, respondents were typically not in the same experimental condition for each technology.[21]

Our first condition served as a baseline (frameless/fact-free) control; these respondents read only the brief background description of the given technology, and then answered questions about their support. In Conditions 4 and 7, respondents—after reading the brief descriptions—received the pro frame (without fact) or the con frame (without fact) (e.g., see the first column of Table 2). These conditions mimic conventional framing experiments that expose participants to one frame or another (without factual content), with the expectation of the frames pushing opinions in distinct directions. Conditions 2 and 3 matched Conditions 4 and 7; however, instead of the frame (without fact) statement, respondents received the factual (frame) statement (e.g., see the second column of Table 2). If facts add strength to frames—which would be counter to our Hypothesis 2—then the effects from Conditions 2 and 3 (facts alone) should significantly exceed those found in Conditions 4 and 7 (frames sans facts), respectively.

Table 3 Experimental Conditions

	No Fact	Pro Fact	Con Fact
No frame	(*Condition* 1) CNT $N = 69$ GM Foods $N = 67$	(2) CNT $N = 69$ GM Foods $N = 66$	(3) CNT $N = 72$ GM Foods $N = 64$
Pro frame	(4) CNT $N = 71$ GM Foods $N = 71$	(5) CNT $N = 68$ GM Foods $N = 73$	(6) CNT $N = 67$ GM Foods $N = 70$
Con frame	(7) CNT $N = 70$ GM Foods $N = 71$	(8) CNT $N = 67$ GM Foods $N = 69$	(9) CNT $N = 68$ GM Foods $N = 70$

The other conditions combine multiple statements. Conditions 5 and 9 offer respondents both frames without facts and the factual evidence frames (e.g., see the first and second columns of Table 2).[22] Conditions 6 and 8 introduce facts that contradict the concomitant framed (without fact) statement; for example, for CNTs, the pro-frame-con fact condition (6) read "Most agree the most important implication ... concerns ... energy costs.... A recent study, unrelated to energy costs, showed that mice...."[23] These two conditions directly pit the relative power of contrasting frames without facts against framed facts, allowing us to assess whether the facts win out (counter to Hypothesis 2).[24] If, in contrast to Hypothesis 2, frames with facts overpower those without, Condition 6 would generate a significantly negative effect (relative to the control group), whereas Condition 8 would do the reverse.

Follow-up

At the point of the initial study, we made clear to participants that, by accepting compensation, they were agreeing to respond to a follow-up e-mail about the new technologies. We thus, in some sense, induced participants to form coherent opinions, in anticipation of taking part in another study on the technologies (e.g., Hastie & Park, 1986). This allowed us to assess how individuals with fairly coherent or crystallized opinions process new information.

In the follow-up, which occurred 10 days after the initial survey, participants received reminder information about CNTs and GM foods.[25] Then, for each technology, respondents evaluated the "effectiveness" of three distinct factually based scientific studies "in providing information or making an argument" (on 7-point scales with higher scores indicating increased effectiveness). Respondents also rated the extent to which each study opposed or supported the technology (on 7-point scales with higher scores indicating increased effectiveness), and rereported their overall support for each technology.[26] The specific study descriptions appear in Table 4.[27] We pretested the studies—which are akin to the (framed) facts used in the initial survey—with individuals who had not previously expressed technology

Table 4 Follow-up Studies (facts)

CNTs	
Pro: Improves applications	A recent study on CNTs found that they are nearly 100 times stronger than steel and six times lighter, making them nearly indestructible.
Con: Environmental risks	A recent study on CNTs found that material akin to CNTs, but used in agriculture, was already present in some rivers of Britain.
Neutral: Economics	A recent study on CNTs suggests that sales could reach $2 billion annually within the next 4 to 7 years. These sales, which would benefit companies that produce CNTs, will occur if CNTs can be used in applications in energy production and medicine.
GM foods	
Pro: Combating disease	A recent study on GM foods found that a type of rice ("golden rice") can be produced with a high content of vitamin A, which is used to prevent blindness.
Con: Potential health risks	There have not been studies on the long-term health effects of GM foods on humans. But, a recent study on animals found that genetically modified potatoes damaged the digestive tracts of rats.
Neutral: Economics	A recent survey showed that more than 400 companies are engaged in research, development, and production of GM foods. These companies benefit as usage of GM foods increase.

CNTs = carbon-nanotubes; GM = genetically modified.

opinions so as to (a) classify each study as pro, con, or neutral in its support of the technology, (b) confirm that each was perceived as "highly effective," and (c) verify that each focused on considerations orthogonal to the frames/facts in the original survey (at least with regard to the specific technology). The first column of Table 4 lists the direction and focus of each study. For each technology, respondents received all of these studies, but rated each individually.[28] In contrast to these average unadulterated pretest participants, we expect that our study respondents' opinions will evaluate these studies in a biased manner, corresponding to the direction of their previously reported opinions.[29] Specifically, for each technology, our third hypothesis predicts that increased support on the first survey will lead to higher effectiveness scores of the pro study and lower effectiveness scores of the con study. Our fourth hypothesis predicts that, for each technology, increased initial support will lead individuals to view the neutral study more directionally positively. Our fifth hypothesis suggests that all of this biased processing will influence subsequent overall opinions, and potentially lead to more extreme overall opinions.

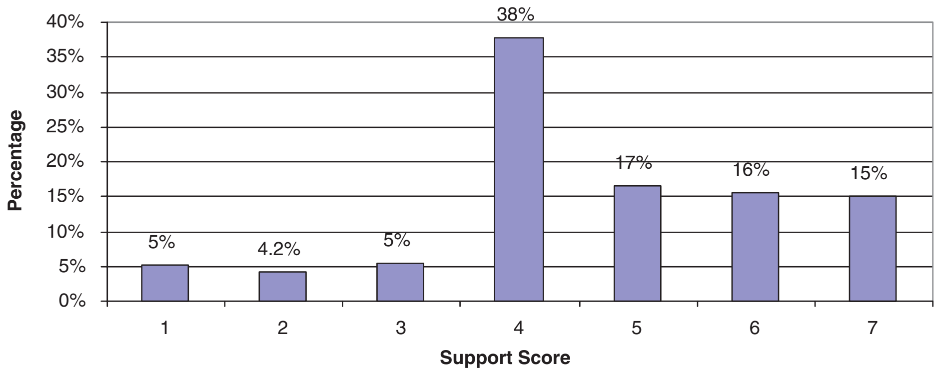

Figure 1 Distribution of support for carbon-nanotubes.

Results

We begin by presenting the distributions of each dependent variable—support for CNTs and GM foods—in Figures 1 and 2.[30] Although both figures reveal significant variance in support, they also show ostensibly greater ambivalence for CNTs with 38% opting for the mid point score of 4 which was labeled "not sure," compared to 17% for the more familiar GM foods. Moreover, individuals offer more support for CNTs with an average support score of 4.63 (*SD*: 1.56; *n*: 619) compared to 3.94 (1.84; 608) for GM foods ($t_{605} = 7.15, p \leq .01$ for a two-tailed test.

Before exploring our first hypothesis regarding the relative impact of background factors, we investigate the effects of our experimental conditions. Recall that our second hypothesis which predicts frames with facts will not exert greater influence than fact-free frames. We test these expectations by computing, for each technology's experimental condition, the relative percentage change in opinion, compared to opinion in the control group (where respondents received no frames or facts).[31] We plot the results for each technology in Figures 3 and 4 (using abbreviations of "Eg" for

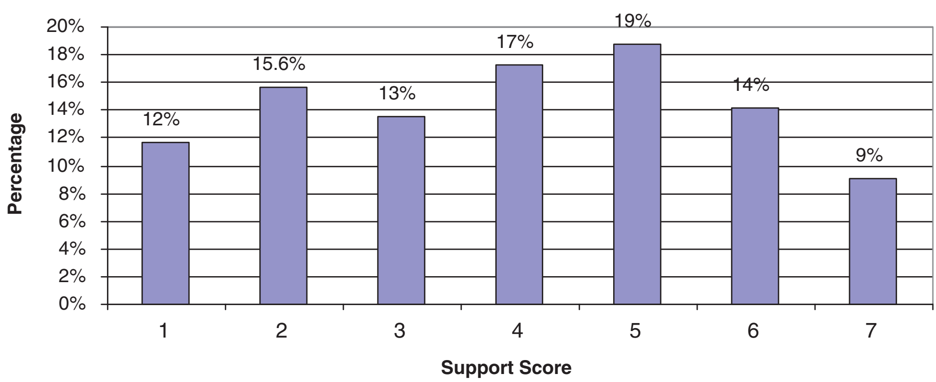

Figure 2 Distribution of support for genetically modified foods.

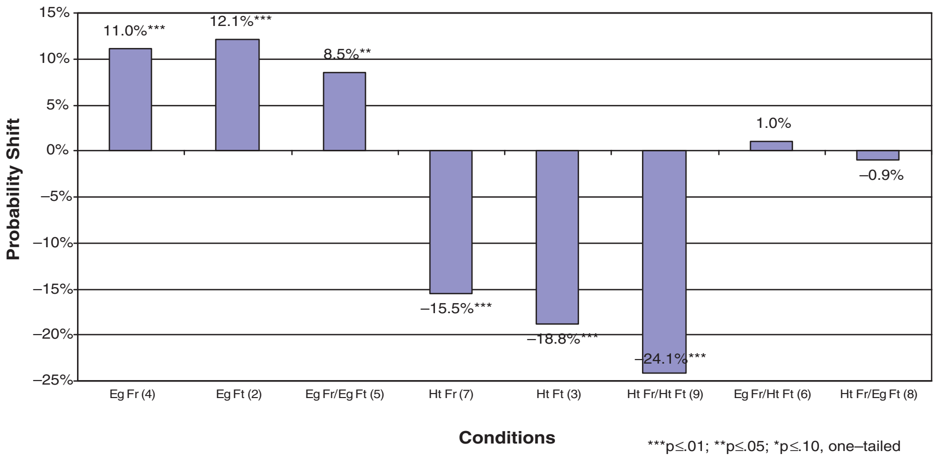

Figure 3 Support for carbon-nanotubes.

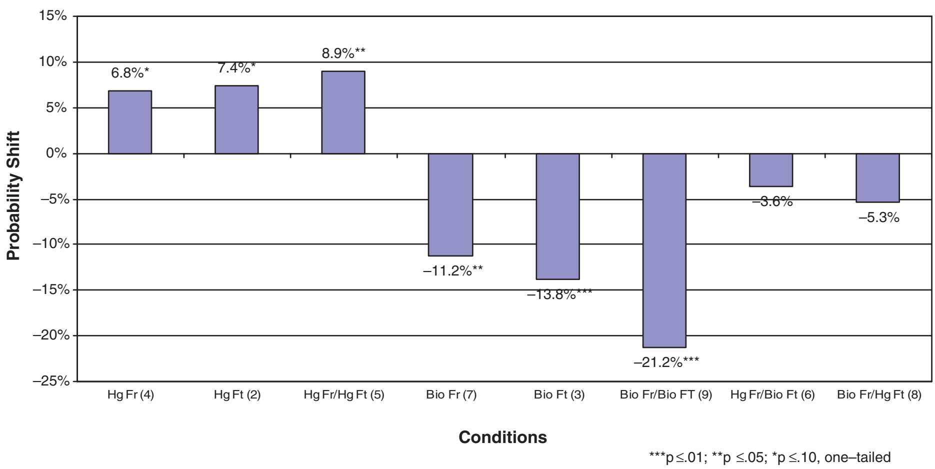

Figure 4 Support for genetically modified foods.

energy, "Ht" for health, "Hg" for hunger, "Bio" for bio diversity, "Fr" for frame, and "Ft" for fact). The figures also label the conditions consistent with numbers in Table 3.

We will test our second hypothesis in two ways: (a) by comparing whether a frame containing factual content supportive of (opposed to) a new technology has a greater effect on opinions than analogous supportive (opposing) frames that lack factual content, and (b) by exploring whether a supportive (opposing) frame with a fact overpowers a competing opposing (supportive) frame that lacks factual content.

The results are quite stark for both technologies. First, in every case, the pro frames, facts, and frame–fact combinations generate significantly more support (than the control group), whereas the con conditions do the reverse. Second and more importantly, facts do not significantly (e.g., at the 0.10 level) increase the power of frames. Although there is marginal evidence of a slightly larger effect from the facts (Conditions 2 and 3), compared to the frames without facts (Conditions 4 and 7), the differences are nowhere near significant. For example, the CNT health risk frame (Condition 4) alone versus the fact alone condition (Condition 2) produced the largest difference between these conditions (−18.8% vs. −15.5%) and the difference is far from significant ($t_{140} = 0.73, p \geq .20$ for a one-tailed test). In addition, opposing facts do not overpower frames without facts—the mixed conditions (6 and 8) never produce significant effects (at anywhere near the 0.10 level), further supporting the finding that facts add little. Instead, the frames cancel each other out regardless of factual content.

Third, although the most substantial effects occur for the frame and frame–fact combination conditions (Conditions 5 and 9) (in three of four cases, with the exception being the energy frame–fact for CNTs), this likely reflects the mix of both statements rather than just the additional fact. Indeed, these combination conditions are larger than the fact alone conditions, as well as the frame alone conditions (in all but the pro energy CNT case, where the combination exhibits the smallest effect).[32] Fourth, the negative conditions uniformly displayed larger effects than the positive effects, perhaps echoing the well-known negativity bias (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Rodriguez, 2007, pp. 478, 493). In summary, we find strong support for Hypothesis 2: facts do not significantly enhance the power of frames, which themselves have substantial effects on opinions. Counter to what is implied by the scientific literacy approach, facts add little to frames when it comes to influencing individuals' opinions about new technologies.[33]

To be clear, however, the factual statements do have effects. The fact alone statements (Conditions 2 and 3) significantly move opinions, and successfully counteract the frames without facts (Conditions 6 and 8). For example, the CNT health frame alone substantially moves opinion (Condition 7), but is blunted when the energy fact is added (Condition 8). Moreover, as just mentioned, the largest effects generally occur when the fact is added to the frame (Conditions 5 and 9), reflecting the power of reiteration. That said, what our results do suggest is that receiving factual information does *not* appear more impactful than exposure to analogous statements *without* factual content.

We next turn to an investigation of the relative impact of frames and other factors by regressing the support variables on the experimental conditions as well as values, scientific credibility, general, and issue-specific knowledge, and other demographic variables. We use ordered probit models and transform all independent variables to 0 to 1 scales. We present the results for CNTs and GM foods, respectively, in Tables 5 and 6.

The first column in each table reproduces the just discussed results regarding the experimental conditions. Of greater interest, the second columns show, as posited by cultural cognition theory, that more individualistic and hierarchical individuals offer increased support for new technologies. Conservatives are more likely to be

Table 5 Determinants of Support for CNTs

Dependent Variable: Support for CNTs (1 to 7)			
Experimental Condition		Demographic Variable	
Energy frame	0.52***	Individualism	0.38**
(pro frame) (4)	(0.19)		(0.18)
Energy fact	0.62***	Hierarchical	0.45***
(pro fact) (2)	(0.19)		(0.18)
Energy frame/Energy fact	0.37**	Conservativeness	0.21
(pro frame/pro fact) (5)	(0.19)		(0.20)
Health frame	−0.72***	Science credibility	0.77***
(con frame) (7)	(0.19)		(0.17)
Health fact	−0.76***	Scientific knowledge	0.20*
(con fact) (3)	(0.19)		(0.14)
Health frame/Health fact	−1.20***	CNT knowledge	−0.08
(Con frame/Con fact) (9)	(0.20)		(0.15)
Energy frame/Health fact	−0.05	Minority	−0.28***
(Pro frame/Con fact) (6)	(0.19)		(0.12)
Health frame/Energy fact	−0.11	Female	−0.24***
(Con Frame/Pro Fact) (8)	(0.19)		(0.10)
		Age	−0.22*
			(0.17)
		Education	0.12
			(0.20)
		Newspaper exposure	−0.20*
			(0.15)
τ_1 through τ_8		See below	
Log likelihood		−855.04	
Number of observations		563	

Note: Entries are ordered probit coefficients with standard errors in parentheses. The coefficient and standard errors for τ_1 through τ_8 are as follows: −1.69 (0.28), −1.27 (0.28), −0.91 (0.27), 0.45 (0.26), 0.46 (0.26), 1.01 (0.27), 1.02 (0.27), 1.67 (0.17). (There are eight cut-points due to two respondents who responded at intermediate values on the 7-point scale.)
$^{***}p \le .01$. $^{**}p \le .05$. $^{*}p \le .10$ for one-tailed tests.

supportive in the case of GM foods. In addition, individuals who perceive science as more credible offer greater support. Although these findings support our first hypothesis that heuristic factors play an important role in driving technology opinions, we also find that background knowledge matters. For CNTs, general scientific knowledge and, for GM foods, issue-specific GM food knowledge, drive support. The differential impact of distinct types of (factual) knowledge undoubtedly reflects the greater familiarity that individuals possess about GM foods (and it is an intriguing finding, given its implications for effects across technologies). The regression results also reveal varied impacts of other demographics, with women

Table 6 Determinants of Support for GM Foods

Dependent Variable: Support for GM Foods (1 to 7)			
Experimental Condition		Demographic Variable	
Hunger frame	0.34**	Individualism	0.35**
(pro frame) (4)	(0.19)		(0.17)
Hunger fact	0.30*	Hierarchical	0.56***
(pro fact) (2)	(0.19)		(0.17)
Hunger frame/Hunger fact	0.47***	Conservativeness	0.31*
(pro frame/pro fact) (5)	(.19)		(0.19)
Biodiversity frame	−0.39**	Science credibility	0.36**
(con frame) (7)	(0.19)		(0.16)
Biodiversity fact	−0.45***	Scientific knowledge	−0.02
(con fact) (3)	(0.20)		(0.15)
Biodiversity frame/Biodiversity fact	−0.74***	GM Foods knowledge	0.24**
(con frame/con fact) (9)	(0.19)		(0.13)
Hunger frame/Biodiversity fact	−0.12	Minority	0.14
(pro frame/con fact) (6)	(0.19)		(0.12)
Biodiversity frame/Hunger fact	−0.16	Female	−0.39***
(con frame/pro fact) (8)	(0.19)		(0.10)
		Age	−0.03
			(0.16)
		Education	−0.01
			(0.20)
		Newspaper exposure	0.05
			(0.15)
τ_1 through τ_6		See below	
Log likelihood		−994.01	
Number of observations		556	

Note: Entries are ordered probit coefficients with standard errors in parentheses. The coefficient and standard errors for τ_1 through τ_6 are as follows: −0.91 (0.28), −0.23 (0.27), 0.21 (0.27), .70 (0.27), 1.35 (0.28), 2.07 (0.29).
$^{***}p \leq .01$. $^{**}p \leq .05$. $^{*}p \leq .10$ for one-tailed tests.

being less supportive for both technologies (perhaps reflecting risk averse tendencies; Eckel & Grossman, 2008), and minorities, older individuals and those with more media exposure being less supportive for CNTs. The last result is curious and suggests a need to more carefully explore the nature of media coverage of nanotechnology (Lewenstein, Gorss, & Radin, 2005).

In Figure 5, we present the substantive impact of knowledge as compared to the key heuristic factors. Specifically, we graph the percentage impact on technology support for each variable, as one moves from the minimum value to the maximum value (e.g., from 1 to 7 on the values and scientific credibility and from 0 to 2 correct on the knowledge variables).[34] For example, the first bar shows that an increase from

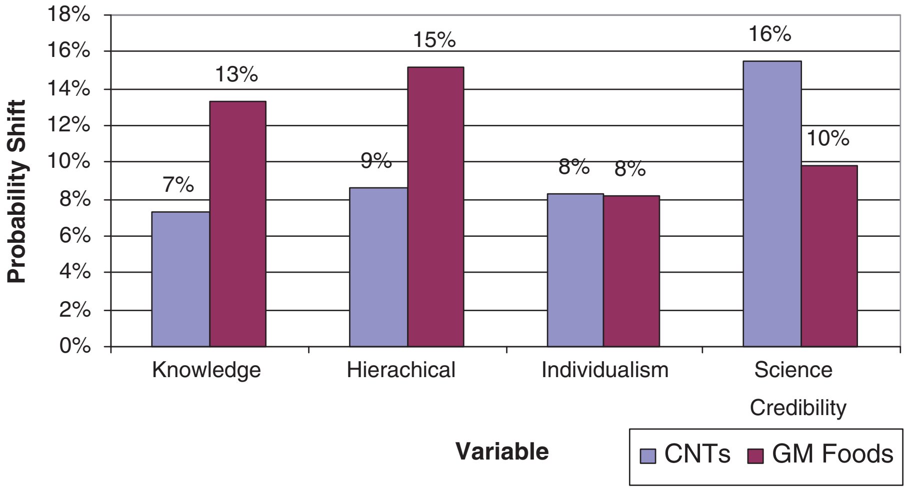

Figure 5 Support for technologies.

0 correct general science answers to 2 correct answers results in a 7% increase in support for CNTs. (For GM foods, we use issue-specific knowledge.)

The figure suggests that none of these variables stands out in its impact across technologies. Overall, the evidence thus offers mixed support for our first hypothesis—it contradicts the strong version of the hypothesis, which would suggest that the impact of background knowledge will pale in comparison to the other factors. Yet, insofar as knowledge does not exceed the impact of heuristics, the results show that there is much more to opinion formation than factual knowledge (in contrast to some strong versions of the scientific literacy approach). Moreover, it remains unclear whether knowledge leads to support or positively disposed individuals seek out additional information. In contrast, such causal ambiguity is less problematic in the case of values that reflect deeply entrenched worldviews (e.g., Kahan et al., 2007).

Follow-up results

We received follow-up responses from 33% (206/621) of participants, which is a respectable response rate for an Internet-based follow-up survey.[35] Recall that we asked respondents to rate the effectiveness and directionality of neutral, pro, and con factual studies (see Table 4) on 7-point scales with higher scores indicating higher effectiveness/more support. We report the mean scores in Table 7, along with the mean overall technology support score (which we asked again). The results contain few surprises—for both technologies, participants rated the supportiveness of each study in accordance with expectations (with all differences significant; the smallest difference between means is CNTs pro vs. neutral and that yields $t_{202} = 3.42$; $p \leq .01$ for a one-tailed test). Although the effectiveness ratings display some variation, it seems that the neutral studies generally were viewed as less effective (although the con CNT study is exceptionally low). Of note is the strength and firm negative

Table 7 Follow-up Mean Opinions and Evaluations

	CNTs	GM Foods
Pro study support score	5.46 (1.40; 205)	5.70 (1.20; 201)
Con study support score	3.10 (1.38; 203)	1.91 (1.03; 202)
Neutral study support score	5.00 (1.51; 205)	4.40 (1.53; 202)
Pro study effectiveness score	4.41 (1.95; 204)	4.49 (1.61; 202)
Con study effectiveness score	3.42 (1.69; 204)	5.04 (1.64; 201)
Neutral study effectiveness score	3.63 (1.66; 206)	3.34 (1.60; 202)
Overall support	4.50 (1.48; 194)	3.84 (1.74; 190)

CNTs = carbon-nanotubes; GM = genetically modified. The scores reported above are mean responses on a 7-point scale with higher scores indicating increased support / effectiveness; the standard deviation and N for each question is in parentheses.

direction of the negative GM food study, reflecting the power of health information. The follow-up overall opinions closely resemble those from the initial survey (i.e., they do not significantly differ).[36]

We are interested in the variance underlying these overall means; Hypotheses 3, 4, and 5 suggest that individuals' initial opinions, as expressed on the first survey, will shape their impressions of and reactions to the new factual information. We test these motivated reasoning predictions by regressing each of the follow-up reactions on initial overall opinion and then plotting the predicted scores. In Figures 6 and 7, for CNTs and GM foods, respectively, we plot the predicted effectiveness scores for each study against individuals' initial opinion scores. We note statistically significant relationships between prior opinion and subsequent evaluations in the figure's legend (using one-tailed tests).[37]

The figures support Hypothesis 3; for both technologies, there is a substantively strong and statistically significant relationship between prior opinion and the perceived effectiveness of the pro and con facts. For example, for CNTs, individuals who were initially strongly opposed to the technology (score = 1) rate the effectiveness of the negative study as 4.50 and the effectiveness of the positive study as 3.54. In contrast, the respective scores of individuals who strongly support the technology (score = 7) flip to 2.65 and 5.04. We find analogous dynamics for GM foods (Figure 7), although in that case we also see a somewhat curious significant effect on the neutral argument with increased support leading to the perception of increased effectiveness. Regardless, the evidence clearly shows that individuals do not "objectively" evaluate the strength of a given study, but rather their prior opinions bias their perceptions—there is motivated reasoning.

Bias is also evident when we turn to testing Hypothesis 4 in Figures 8 and 9, which offer analogous plots, but this time with the dependent variables being directional evaluations of the studies, as well as the follow-up overall opinion measure. Both figures show that as initial support increases so do perceptions of the neutral studies as being supportive; also consistent with the hypothesis, albeit not explicitly predicted,

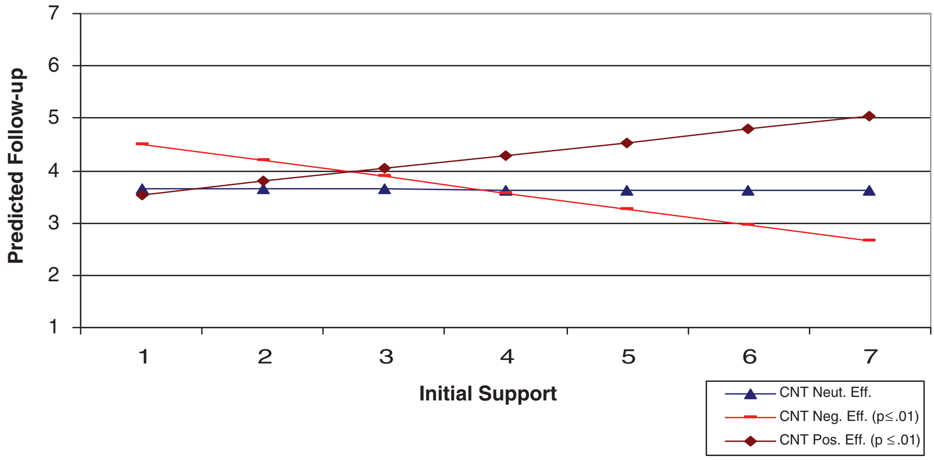

Figure 6 Effect of initial carbon-nanotube support on follow-up effectiveness.

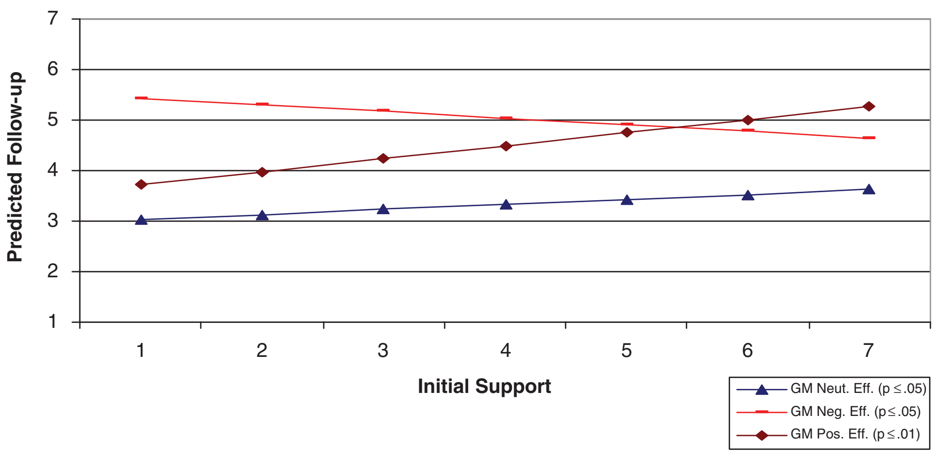

Figure 7 Effect of initial genetically modified foods support on follow-up effectiveness.

we see for GM foods that initial opinions shaped the directional evaluations of the pro and con studies.

The figures also show a strong relationship between initial and follow-up opinions. However, close examination suggests limited support for Hypothesis 5b. Specifically, the respective slopes for the overall opinion lines, for CNTs and GM foods, are 0.37 and 0.64. That these lie below 1.00 means that follow-up opinions are not more extreme, on average, than initial opinions: A unit increase in initial opinions leads to less than a unit increase in follow-up opinions (see Taber & Lodge, 2006, p. 765). This suggests opinion moderation (i.e., polarization would require a slope of greater than 1.00). We suspect that moderation comes from two factors. First, we exposed participants to a broad mix of pro, neutral, and con studies in the follow-up, possibly

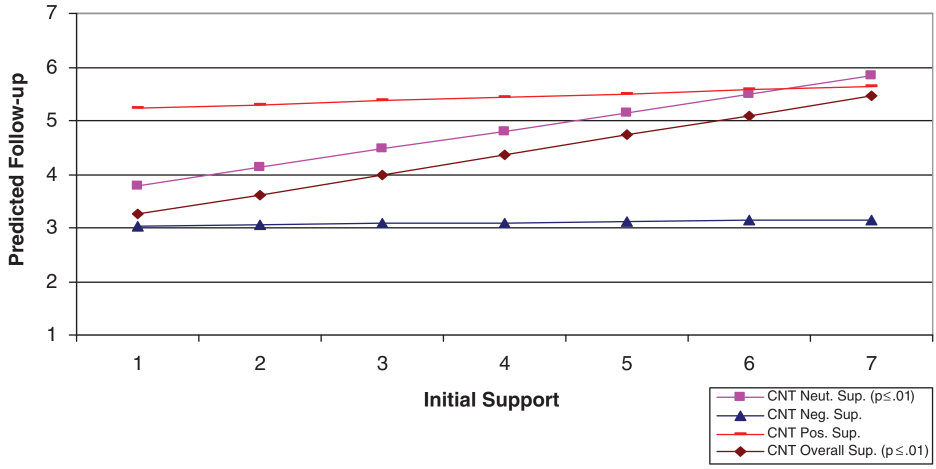

Figure 8 Effect of initial carbon-nanotube support on follow-up support.

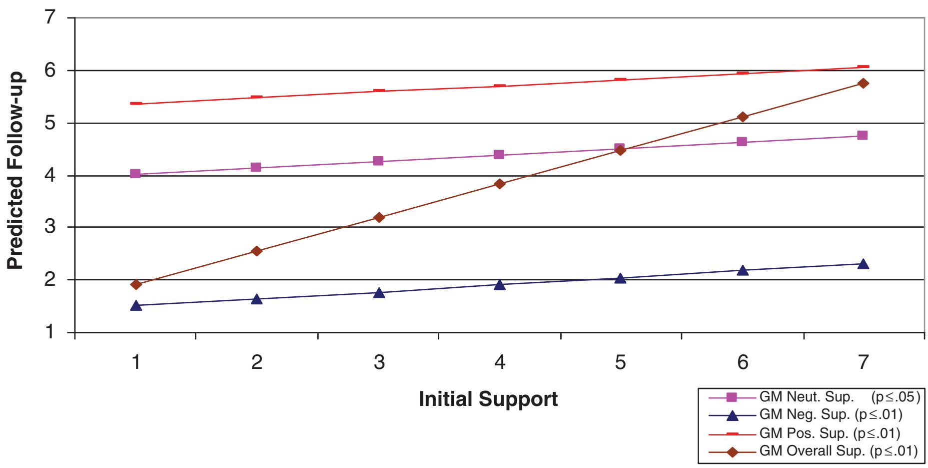

Figure 9 Effect of initial genetically modified foods support on follow-up support.

leading the overall aggregate effects to cancel and, in the end, moderate opinions. Second, it may be that opinions about emergent technologies are not sufficiently strong so as to induce skeptical appraisals (cf. Taber & Lodge, 2006).

Moreover, this does not constitute evidence that biased processing did not affect follow-up overall opinions. To more precisely explore the effects of biased processing (and Hypothesis 5a), we regress follow-up opinion on initial opinion, as well as the follow-up support and effectiveness evaluations. (We again scale all independent variables on 0 to 1 scales and use ordered probits.)[38]

The results, in Table 8, show that perceptions of the follow-up studies shape subsequent opinions about the technologies. For CNTs, the more supportive one

Table 8 Determinants of Follow-Up Support

Dependent Variable: Follow-up support for technology (1 to 7)		
	CNTs	GM Foods
Initial support	1.26***	3.20***
	(0.34)	(0.33)
Pro study support	0.71**	0.37
	(0.39)	(0.45)
Con study support	0.58*	−1.67***
	(0.38)	(0.53)
Neutral study support	0.69**	1.13***
	(0.38)	(0.35)
Pro study effectiveness	1.56***	1.75***
	(0.31)	(0.38)
Con study effectiveness	−1.14***	−1.35***
	(0.34)	(0.32)
Neutral study effectiveness	0.98***	0.30
	(0.33)	(0.32)
τ_1 through τ_6	See below	See below
Log likelihood	−233.41	−260.85
Number of observations	188	186

Note: Entries are ordered probit coefficients with standard errors in parentheses. The coefficient and standard errors for τ_1 through τ_6 are, respectively for CNTs and GM foods, 0.48 (0.43), 0.79 (0.43), 1.21 (0.42). 3.14 (0.46), 3.71 (0.48), 4.28 (0.50), and 0.68 (0.44), 1.48 (0.44), 2.09 (0.45), 3.27 (0.48), 4.05 (0.50), 5.11 (0.53).
$^{***}p \leq .01$. $^{**}p \leq .05$. $^{*}p \leq 0.10$ for one-tailed tests.

believed each of the studies to be, the greater his or her support for CNTs. Similarly, increased beliefs about the effectiveness of the pro or neutral studies significantly enhanced support. The positive neutrality result undoubtedly stems from the fact that participants generally saw the CNT neutral study as supportive (an average score of 5.00, as reported in Table 7). To get a substantive sense, consider perceptions of the pro study's effectiveness. Setting other variables at their means, we find that for those who view the pro study as completely non effective (minimum score), the probability of supporting CNTs (i.e., a score greater than 4) is 11%. The analogous probabilities for those who perceive the study as moderately effective is 32% and for those who see it as maximally effective is 61%. Other variables have comparably large effects.

Similar dynamics occur with GM foods, although with a few notable exceptions (see Table 8). First, greater perception of the pro study being supportive does not significantly increase subsequent support, likely reflecting a ceiling effect (the average score was 5.70, as reported in Table 7). Second, the neutral effectiveness coefficient is not significant, although that is not surprising given that the neutral study was viewed as generally more ambiguous for GM foods. Third, and most surprising, is the significant and negative impact of the con study—increased perceptions that this study is supportive generate declines in overall support. This may stem from the exceptionally low average support score of the study—1.91 combined with a high effectiveness score (5.04). In other words, even those with higher support scores still see this study as negative and perhaps these individuals were more influenced by this negativity than were those reporting the minimum score.

In summary, although we do not find evidence of attitude polarization (i.e., more extreme positions)—likely due to providing participants with such a mix of additional information—we find clear evidence (a) of biased processing of new factual studies, and (b) that this biased processing significantly shaped subsequent opinion. Once individuals form initial opinions, they do not "objectively" incorporate new factual information in ways often assumed by scientific literacy approaches. Instead, motivated reasoning drives opinion formation.

Conclusion

Public opinion about any new technology plays a critical role in determining whether the innovation fails or succeeds. The realities of opinion formation mean that citizens will not engage in exhaustive and objective evaluation of available factual information, as is assumed by models of scientific literacy. Instead, they use shortcuts and form opinions in less deliberate—although still systematic—ways. Our results accentuate the frailty of assuming that factual information provides an unmitigated path to rational opinion formation.

We find at every stage of the decision-making process, the processing of factual information is fraught with imperfections. First, facts have limited impact on initial opinions—no greater than alternative considerations including values and perceptions about science credibility (see also, e.g., Scheufele & Lewenstein, 2005). Second, we find that when provided with frames that lack factual information and frames that include facts, individuals do *not* privilege the facts (see also, e.g., Nisbet & Mooney, 2007). Facts do not enhance frame strength (although facts do have effects equivalent to that of frames without facts). Third, once they form initial opinions, individuals process new factual information in a biased manner (see also, e.g., Kahan et al., 2008). Specifically, they view information consistent with their prior opinions as relatively stronger and they view neutral facts as consistent with their existing dispositions.

Of course ours is just one study on two particular technologies, and as a result, caution needs to be taken in generalizing. It does seem clear, however, that factual information is not always as it appears (to a neutral observer). Our results suggest that the best route to facilitate reasonable opinion formation may be to provide alternative ways of thinking about new technologies—that is, different frames—and then to encourage individuals to weigh these frames against one another. Under distinct circumstances, facts may play a more salient and less biased role. Indeed, there undoubtedly are situations where facts matter and this could depend on a range of factors including contextual elements, individual motivations, and precise presentation.[39] For example, in his study of framing and nanotechnology, Cobb (2005) reports that adding explicit statements about health risks and/or benefits to relatively weak philosophical frames (that discuss the role of science) significantly increases the impact of the frames.

It may be that different facts—such as evidence based on an accumulation of scientific studies (e.g., meta-analyses)—may have more of an added impact. Moreover, although we have incorporated competition and time into the study of opinion formation, we have not done so explicitly with regard to facts. Facts themselves are contestable (e.g., Katz & Strange, 1998; Shapiro & Block-Elkon, 2008), as is made clear by the growing literature on how perceptions of scientific studies depend on economic and political pressures (Jotterand, 2006; Pielke, 2004). In addition, individuals often receive related facts over time. The impact of "fact competition" and over-time exposure to facts may matter; for example, repeated exposure to facts might moderate motivated reasoning.[40] Only once we explore these types of variations can general statements about factual information be made. We also encourage future work to further probe the factors that enhance frame strength and explore the relationship between competing frames and motivated reasoning. Most important is to continue expanding studies of opinion formation to account for the realities of competition over time.

Acknowledgments

We thank Adam Berinsky, David Dana, Regula Hänggli, Dan Hopkins, Jenn Jerit, Dan O'Keefe, Samara Klar, Chris Karpowitz, and Matt Nisbet for helpful comments.

Notes

1 Even products with demonstrable benefits are rejected (Rogers, 2003) or underutilized (e.g., Cabana et al., 1999) if they fail to garner public support.

2 Rodriguez (2007, p. 497) explains that "Often, scientists assume that simply informing consumers about the scientific facts regarding a new. . .technology will be sufficient to gain acceptance of it" (however, see Lee et al., 2005, pp. 242–243).

3 Nearly all studies ignore over-time dynamics. One exception is Rodriguez (2007) who employs a longitudinal design that measures attitudes 3 months after providing respondents' information (or not) on food irradiation. The information effect largely disappeared over time. In terms of the specific steps we have identified—most work focuses on the initial opinion formation process and how background factors influence opinions (e.g., Lee et al., 2005). Some recent experimental work looks at how individuals handle the receipt of new information and arguments at one point in time (Kahan et al., 2008), although these studies do not pit alternative types of information against one another (as we do). We are not aware of work that looks at how more crystallized specific opinions affect the interpretation of information.

4 Our focus on the relative impact of facts as scientific evidence follows a long-standing concern of risk analysts. Fischoff (1995, p. 139) explains, "Risk analysts have fought hard

to create a clear distinction between the facts and values of risk management." That said, we recognize that not all accept the fact-value distinctions—those readers can view our work as instead focusing on "evidence" and "claims."

5 Different scholars employ the term "heuristics" in distinct ways (see Druckman, Kuklinski, & Sigelman, 2009; Lau & Redlawsk, 2006, p. 230, for discussion). Our usage follows the original portrayal as depicting a process of opinion formation where people rely on bits of information, including values, rather than engaging in "extensive algorithmic processing" of information (Gilovich & Griffin, 2002, p. 1; Lau & Redlawsk, 2006).

6 Similarly, Petty and Wegener (1999, p. 42) explain that when motivation and/or ability are low, individuals examine "less information. . .or examine. . .information less carefully." However, also see O'Keefe (1998) who shows increasing an argument's explicitness (e.g., by citing evidence) can increase persuasiveness (also see Cobb, 2005).

7 This stems from what is often called a "disconfirmation bias"—the tendency to spend more time and resources counter-arguing incongruent messages.

8 A few comments are in order. First, another part of motivated reasoning involves individuals seeking out information that confirms their priors (i.e., a confirmation bias); we do not explore that here. Second, the theory suggests that biases should be more apparent among individuals who engage in on-line processing, possess stronger attitudes, and/or are more sophisticated (e.g., Lodge & Taber, 2000, p. 211). Third, although the application of motivated reasoning to the interpretation of neutral information is relatively novel (see Kahan et al., 2008), it has a strong basis in related work on priming (e.g., Higgins, 1996).

9 Perhaps the main disadvantage of our approach is that exit poll surveys need to be short, thereby constraining the number of items we could include.

10 We also included measures for each technology asking respondents to rate the extent to which the risks outweigh benefits or the benefits outweigh the risks of CNTs (GM foods), with answers on 7-point scales ranging from the low end of risks definitely outweighing the benefits to the high end of the benefits definitely outweighing the risks. We focus on our oppose–support measure because there is some evidence that the benefit–risk measure is less reliable and valid (Lee et al., 2005, p. 250). However, we find almost identical results with the risk–benefit measure as with the support measure. This is not too surprising given the high correlation, in our data, between the two measures: for CNTs, the correlation is .70 ($p < .01$; 626), and for GM foods, it is .80 ($p < .01$; 607). In addition, we included belief importance measures, as is common in framing studies, and results using these as dependent variables also are quite similar to those that we report below.

11 Kahan et al. (2008) use multiple items for each construct; due to space limitations we used only one item for each (as suggested to us in a personal communication from Kahan). For hierarchical tendency, we asked respondents to rate the extent to which they disagree or agree that "We have gone too far in pushing equal rights in this country," on a 7-point scale with higher scores indicating increased agreement. A similar item gauged individualism, but instead asked "if the government spent less time trying to fix everyone's problems, we'd all be a lot better off."

12 Our specific science, CNTs, and GM Foods knowledge questions are standard open-ended questions (e.g., Gaskell et al., 1999; Lee et al., 2005; Miller, 1998; Scheufele &

Lewenstein, 2005): (a) general science, Is it true or false that lasers work by focusing sound waves?," and "Which travels faster: light or sound?" (b) CNTs, "Is it true or false that nanotechnology involves materials that are not visible to the naked eye?" and "Is it true or false that a nanometer is about the same size as an atom?" and (c) GM foods, "Is it true or false that ordinary tomatoes do not contain genes whereas genetically modified tomatoes do?" and "Is it true or false that by eating a genetically modified fruit a person's genes could become modified?"

13 We asked respondents to identify their ethnicity and classified African Americans, Asian Americans, Hispanics, and Others as minorities.

14 Respondents reported their highest level of completed education (see Table 1).

15 Respondents reported their age as following on one of seven ranges (see Table 1).

16 We asked respondents how often they "read the front page of a major newspaper" on a 7-point scale ranging from *never* to *every day*.

17 We also included a few other items, including the household income. We do not include income in the analyses because there was significant non response on the item, and it was never significant in any of our analyses.

18 Given the experimental approach, along with our ability to control for these variables, the focus on these voters is not problematic; moreover, it is a representative sample of actual, heterogeneous individuals from the area (rather than being composed of the more homogenous samples typical in laboratory experiments).

19 We implemented a pretest with individuals who did not participate in the subsequent study to confirm that participants viewed our facts as facts ($N = 34$); specifically, we asked pretest participants to evaluate the extent to which distinct statements contained verifiable statements with an objective reality. Further details on this and other pretest assessments are available from the authors.

20 Analogous information was provided for GM foods.

21 The most notable point of concern is the carryover of negative information, given the well-established salience of negativity. To assess this, we carried out a small pretest ($N = 51$) where we randomly asked half of the sample about their GM foods opinions only and the other half about the GM foods opinion after telling them about CNTs along with a negative frame. We found no significant carryover frame effect on GM foods opinions, suggesting that the prior negative information on CNTs did not carryover.

22 In all cases, the frame (without fact) appeared first.

23 We pretested the exact wordings of all conditions to ensure adequate flow.

24 We exclude conditions with neutral frames/facts because we do not expect such information to impact opinions (and it would significantly increase the number of conditions).

25 We sent three reminders to participants.

26 We follow Taber and Lodge (2006) in asking respondents to evaluate multiple distinct items. Although all respondents received the CNT studies first (as in the initial survey), we presented the specific studies in a random order across participants. We differ from Lodge and Taber (and others), however, by including a neutral study (they only include pro and con arguments).

27 We also asked respondents to evaluate whether the study came across as more opposed to or supportive of the technology.

28 The neutral fact could be seen as pro in terms of investment or con in terms of evidence of companies just out for profits. There are two potential confounds for GM foods: (a) combating world disease is close to combating world hunger, and (b) health risks was used in the initial survey (as a frame for CNTs).

29 It may be that pretest participants also engaged in motivated reasoning; we have no way to assess this given we do not have measures of their prior opinions. The pretest established that, on average, the scientific studies have directional implications (i.e., pro, con, and neutral), and are viewed as "effective." With our study participants, we seek to investigate variance in these, on average, attitudes.

30 For the purposes of the figures, we rounded the scores of the few respondents who chose midpoints on the scales (e.g., 2.5). Also, for presentational purposes, we treat the dependent variables as interval level.

31 The respective averages for the CNT and GM food control groups are 4.82 (1.01, 68) and 4.16 (1.84, 63). Also, note that we checked and confirmed the success of random assignment to experimental conditions (e.g., in terms of demographics not being systematically related to conditions).

32 For CNTs, the health frame–fact condition is significantly greater than the health frame condition ($t_{136} = 1.96$, $p \leq .05$ for a one-tailed test) and marginally significantly greater than the health fact condition ($t_{138} = 1.22$, $p \leq .12$ for a one-tailed test). For GM foods, the biodiversity frame–fact condition is significantly greater than the bio diversity frame condition ($t_{138} = 2.18$, $p \leq .05$ for a one-tailed test) and significantly greater than the bio diversity fact condition ($t_{131} = 1.79$, $p \leq .05$ for a one-tailed test). For both CNTs and GM foods, the pro frame–fact condition is not significantly different than the single frame or single fact pro conditions.

33 As mentioned in a prior note, we also included belief importance measures. We used these measures to explore the meditational process through which frames work and the evidence does show that belief importance mediates the process (see, e.g., Nelson, Oxley, & Clawson, 1997). Details are available from the authors.

34 The analyses underlying Figure 5 employ OLS models, and thus, assume the support scores are measured on interval levels. We do this for presentational purposes, noting the results are robust if we produce analogous figures using our ordered probit regressions (e.g., Tables 5 and 6). We also do not report standard errors on the predicted effects as we took differences (e.g., at minimums and maximums). The precise predicted values are available from the authors.

35 One challenge with the follow-up was that a non trivial number of respondents failed to provide usable e-mail addresses.

36 We explored what increased the likelihood of responding to the follow-up and found that the likelihood of response increased with age, education, and knowledge about GM foods, and declined with conservativeness, newspaper readership, and ambivalence about supporting the new technologies (e.g., scores of 4 on the initial survey). Our follow-up sample thus does not perfectly mimic the demographics of our initial group of respondents. This is relevant insofar as more knowledgeable and less ambivalent individuals are more likely to engage in motivated reasoning (Lodge & Taber, 2000, p. 211), meaning our sample may work in favor of Hypotheses 3, 4, and 5.

37 To generate the predicted opinions, we used OLS regression as we are treating each of our dependent variables as interval level. The results are the same if we used ordered

probit instead (e.g., in terms of statistical significance and substantive impact, to the extent that comparisons can be made between ordinal and interval variables). Also, we do not include controls in these regressions; however, with one exception, the results are unchanged if we include a host of controls (e.g., the variables in Tables 5 and 6). The exception is that initial opinion does not significantly affect perception of the GM foods neutral study (which was not a relationship we had predicted in the first place). All regression results are available from the authors.

38 The results are unchanged when we include a full range of control variables.

39 Some readers of a working draft of this paper suggested that the wording of the frames "Most agree. . ." may be critical. We acknowledge that this may be true, but it does not detract from the finding that scientific factual information does not add power to non substantiated statements/frames.

40 Over-time effects also likely depend on the breadth of information (e.g., Barabas & Jerit, 2009), whereas competition depends on the nature of the messages (e.g., direct rebuttals; see Jerit, 2009).

References

Barabas, J., & Jerit, J. (2009). Estimating the causal effects of media coverage on policy-specific knowledge. *American Journal of Political Science*, **53**(1), 73–89.

Bauer, M. W., Allum, N., & Miller, S. (2007). What can we learn from 25 years of PUS survey research? *Public Understanding of Science*, **16**, 79–95.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology*, **5**, 323–370.

Berinsky, A. J., & Kinder, D. R. (2006). Making sense of issues through media frames: Understanding the Kosovo crisis. *The Journal of Politics*, **68**, 640–656.

Cabana, M. D., Rand C. S., Powe, N. R., Wu, A. W., Wilson, M. H., Abboud, P. C., et al. (1999). Why don't physicians follow clinical practice guidelines? *Journal of the American Medical Association*, **282**(15), 1458–1467.

Chaiken, S. & Trope, Y. (Eds.). (1999). *Dual-process theories in social psychology*. New York: The Guilford Press.

Chong, D., & Druckman, J. N. (2007a). A theory of framing and opinion formation in competitive elite environments. *Journal of Communication*, **57**(1), 99–118.

Chong, D., & Druckman, J. N. (2007b). Framing public opinion in competitive democracies. *American Political Science Review*, **101**(4), 637–655.

Cobb, M. D. (2005). Framing effects on public opinion about nanotechnology. *Science Communication*, **27**, 221–239.

Cobb, M. D., & Macoubrie, J. (2004). Public perceptions about nanotechnology. *Journal of Nanoparticle Research*, **6**, 395–405.

Committee on Risk Perception and Communication (National Research Foundation). (1989). *Improving risk communication*. Washington, DC: National Academy Press.

Currall, S. C., King, E. B., Lane, N., Madera, J., & Turner S. (2006). What drives public acceptance of nanotechnology? *Nature Nanotechnology*, **1**, 153–155.

Druckman, J. N. (2001, September). The implications of framing effects for citizen competence. *Political Behavior*, **23**, 225–256.

Druckman, J. N., Kuklinski, J. H., & Sigelman, L. (2009). The unmet potential of interdisciplinary research. *Political Behavior*, **31**(4), 485–510.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes.* Fort Worth, TX: Harcourt Brace Jovanovich College.

Eckel, C. C., & Grossman, P. J. (2008). Men, women and risk aversion. In C. R. Plott & V. L. Smith (Eds.), *Handbook of experimental results* (Vol. 1, pp. 1061–1077). New York: North-Holland.

Elliott, W. R., & Rosenberg, W. L. (1987). Media exposure and beliefs about science and technology. *Communication Research*, **14**, 164–188.

Fairbanks, A. H. (1994). *Fact, value, policy.* New York: McGraw-Hill.

Fazio, R. H. (2000). Accessible attitudes as tools for object appraisal. In G. Maio & J. Olson (Eds.), *Why we evaluate* (pp. 1–36). Mahwah, NJ: Erlbaum.

Fischhoff, B. (1995). Risk perception and communication unplugged. *Risk Analysis*, **15**, 137–145.

Gaskell, G., Bauer, M. W., Durant J., & Allum, N. C. (1999). Worlds apart? *Science*, **285**, 384–387.

Gilovich, T., & Griffin, D. (2002). Introduction—heuristics and biases. In T. Gilovich, D. Griffin & D. Kahneman (Eds.), *Heuristics and biases.* New York: Cambridge University Press.

Hastie, R., & Park, B. (1986). The relationship between memory and judgment depends on whether the judgment task is memory-based or online. *Psychological Review*, **93**(3), 258–268.

Higgins, E. T. (1996). Knowledge activation. In E. T. Higgins & A. W. Kruglanski (Eds.), *Social psychology.* New York: Guilford Press.

Jasper, J. M. (1988). The political life cycle of technological controversies. *Social Forces*, **67**, 357–377.

Jerit, J. (2009). How predictive appeals shape policy opinions. *American Journal of Political Science*, **53**(2), 411–426.

Jotterand, F. (2006). The politicization of science and technology. *Journal of Law, Medicine, and Ethics*, **34**(4), 658–666.

Kahan, D. M., Braman, D., Slovic, P., Gastil, J., & Cohen, G. L. (2007). *Affect, values, and nanotechnology risk perceptions*. GWU Legal Studies Research Paper No. 261

Kahan, D. M., Braman, D., Slovic, P., Gastil, J., Cohen, G. L., & Kysar, D. (2008). *Cultural cognition and nanotechnology risk perceptions*. Unpublished paper, Yale University.

Katz, E., & Strange, J. J. (1998). Preface. *Annals of the American Academy of Political and Social Science*, **560**, 8–16.

Kunda, Z. (2001). *Social cognition.* Cambridge, MA: The MIT Press.

Lakoff, G. (2004). *Don't think of an elephant?* White River Junction, VT: Chelsea Green.

Lau, R. R., & Redlawsk, D. P. (2006). *How voters decide.* Cambridge, MA: Cambridge University Press.

Lee, C., Scheufele, D. A., & Lewenstein, B. V. (2005). Public attitudes toward emerging technologies. *Science Communication*, **27**, 240–267.

Lewenstein, B. V., Gorss, J., & Radin, J. (2005, May). *The salience of small.* Paper presented at the 55th Annual Conference of the International Communication Association, New York, NY.

Lodge, M., & Taber, C. S. (2000). Three steps toward a theory of motivated political reasoning. In A. Lupia, M. D. McCubbins & S. L. Popkin (Eds.), *Elements of reason.* Cambridge: Cambridge University Press.

Lodge, M., & Taber, C. S. (2008). *The rationalizing voter*. Unpublished paper, Stony Brook University.
Lord, C. G., Ross, L., & Leeper, M. R. (1979). Biased assimilation and attitude polarization. *Journal of Personality and Social Psychology*, **37**, 2098–2109.
Macoubrie, J. (2006). Nanotechnology. *Public Understanding of Science*, **15**, 221–241.
Mellman Group. (2006). Public sentiment about genetically modified foods. Retrieved from http://www.pewtrusts.org/.
Miller, J. D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science*, **7**, 203–223.
Musham, C., Trettin, L., & Jablonski, R. (1999). Before the storm. *Journal of Public Health Policy*, **20**, 319–334.
Nelson, T. E., Oxley, Z. M., & Clawson, R. A. (1997). Toward a psychology of framing effects. *Political Behavior*, **19**(3), 221–246.
Nisbet, M. C. (n.d.). Framing science. In L. Kahlor & P. Stout (Eds.), *Understanding science.* New York: Taylor & Francis.
Nisbet, M. C., & Goidel, R. K. (2007). Understanding citizen perceptions of science controversy. *Public Understanding of Science*, **16**, 421–440.
Nisbet, M. C., & Mooney, C. (2007). Framing science. *Science*, **316**, 56.
O'Keefe, D. J. (1998). Justification explicitness and persuasive effect. *Argumentation and advocacy*, **35**, 61–75.
O'Keefe, D. J. (2002). *Persuasion* (2nd ed.). Thousand Oaks, CA: Sage.
Peter D. Hart Research Associates, Inc. (2008). Awareness of and attitudes toward nanotechnology and synthetic biology. Retrieved from http://www.pewtrusts.org/.
Petty, R. E., & Wegener, D. T. (1999). The elaboration likelihood model. In S. Chaiken & Y. Trope (Eds.), *Dual-process theories in social psychology.* New York: Guilford Press.
Pielke, R. A., Jr. (2004). When scientists politicize science. *Environmental Science & Policy*, **7**, 405–417.
Rodriguez, L. (2007). The impact of risk communication on the acceptance of irradiated food. *Science Communication*, **28**, 476–500.
Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.
Rudolph, T. J. (2006). Triangulating political responsibility. *Political Psychology*, **27**, 99–122.
Scheufele, D. A. (2006). Five lessons in nano outreach. *Materials Today*, **9**, 64.
Scheufele, D. A., & Lewenstein, B. V. (2005). The public and nanotechnology. *Journal of Nanoparticle Research*, **7**, 659–667.
Shapiro, R. Y., & Block-Elkon, Y. (2008). Do the facts speak for themselves? *Critical Review*, **20**, 115–139.
Southwell, B. G., & Torres, A. (2006). Connecting interpersonal and mass communication. *Communication Monograph*, **73**(3), 334–350.
Stamm, K. R., Clark, F., & Eblacas, P. R. (2000). Mass communication and public understanding of environmental problems. *Public Understanding of Science*, **9**, 219–237.
Sturgis, P., & Allum, N. (2006). *A literature review of research conducted on public interest, knowledge, and attitudes to biomedical science*. Report prepared for The Welcome Trust.
Taber, C. S., & Lodge, M. (2006). Motivated skepticism in the evaluation of political beliefs. *American Journal of Political Science*, **50**, 755–769.
Vishwanath, A. (2009). From belief-importance to intention. *Communication Monographs*, **76**(2), 177–206.