Institute for Policy Research
Northwestern University
Working Paper Series

WP-09-03

Framing, Motivated Reasoning, and Opinions about Emergent Technologies

James N. Druckman
Faculty Fellow, Institute for Policy Research
Associate Professor of Political Science
Northwestern University

Toby Bolsen
Graduate Student
Department of Political Science
Northwestern University

Version: March 21, 2009

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2040 Sheridan Rd. ◆ Evanston, IL 60208-4100 ◆ Tel: 847-491-3395 Fax: 847-491-9916
www.northwestern.edu/ipr, ◆ ipr@northwestern.edu

Abstract

How do individuals form opinions about new technologies? What role does factual information play in that process? We address these questions by incorporating two critical dynamics, typically ignored in extant work: competition between information and over-time processes. We present results from experiments on two 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 that lack factual information), and it is perceived in biased ways once individuals form clear initial opinions (e.g., there is motivated reasoning). Not only do our results provide insight into how individuals form opinions, over time, when presented with novel technologies, but they also bring together various distinct literatures including work on information, framing and motivated reasoning.

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. 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 of, if not the, dominant theme of this literature is the need to inform the public about the facts of new technologies—that is, to make citizens scientifically literate (e.g., Miller 1998, Bauer et al. 2007). New information will presumably enable individuals to accurately assess the risks associated with new innovations.

The implicit model of opinion formation underlying much of this work treats citizens and consumers as rational thinkers who carefully integrate new information in expected ways (e.g., individuals are treated as Baysians). 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 and Goidel 2007), trust in science (e.g., Rodriguez 2007), and frames or arguments that typically lack factual content (e.g., Nisbet and Mooney 2007, Nisbet n.d.).

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 paper, we study (1) the impact of background factual information relative to other influences including values and trust in science, (2) how newly presented factual information affects opinions *when* presented with consistent or contradictory frames/arguments (that lack factual content), and (3) 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 and genetically modified 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 bias 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 and Macoubrie 2004, Savadori et al. 2004, Cobb 2005, Currall et al. 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: 386, Nisbet and Goidel 2007: 421; see Miller 1998, Sturgis and Allum 2006).[1] More recent work questions the scientific literacy approach, instead emphasizing how other factors shape emergent technology opinions, including values (Nisbet and Goidel 2007, Kahan et al. 2009), trust in science (e.g., Lee et al. 2005, Rodriguez 2007), and the framing of the technologies (e.g., Scheufele 2006, Nisbet and Mooney 2007, Nisbet n.d.).

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

[1] Rodriguez (2007: 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: 242-243).

very simple schematic would consider (1) how individuals form initial opinions, and particularly how background factors such as general scientific knowledge and trust in science affect opinions, (2) how individuals then incorporate new factual information and arguments, and (3) how individuals interpret information once their opinions have somewhat crystallized.[2] 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, it is important to clarify our portrayal of individuals' incentives. Evidence from multiple disciplines makes clear that processes of opinion formation depend in fundamental ways on motivation and ability (e.g., Larrick et al. 1993, Payne et al. 1993, Fazio 1995, Petty and Wegener 1998, Chaiken and Trope 1999, Camerer and Fehr 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) since the direct personal relevance of doing so is unclear at best (e.g., O'Keefe 2002: 141-143). Scheufele and Lewenstein (2005: 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, Scheufele 2006, Kahan et al. 2007, 2008a,b). Consequently, people form their

[2] Nearly all studies ignore over-time dynamics. One exception is Rodriguez (2007) who employs a longitudinal design that measures attitudes three 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 influences 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 (Cobb 2005, Kahan et al. 2008a,b), 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.

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 information they possess, instead relying on simpler "gut reactions" or cues. People "do not use all available information to make decision about issues, including new technologies or scientific discoveries... Rather, they rely on heuristics or cognitive shortcuts, such as ideological predispositions…" (Scheufele and Lewenstein 2005: 660). 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: 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 technological risks 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: 4; also see Musham et al. 1999: 331). Other heuristic factors that appear to drive emergent technologies opinions 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., Lee et al. 2005, Scheufele and Lewenstein 2005, Bauer et al. 2007). 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 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 (Scheufele 2006, Kahan et al. 2008a,b, Nisbet and Mooney 2007, Nisbet n.d.). 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: 226-231, Chong and Druckman 2007c). 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, while 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. 2008a,b). While frames sometimes include factual content (e.g., citing 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., Nelson et al. 1997, Berinsky and Kinder 2006).[3]

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 and Druckman 2007a). Recent work on competitive framing shows that exposure to two competing frames (e.g., health and consumer benefits) often cancels out, unless one of those two frames is inherently "stronger" or "more compelling" (Chong and 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; since our predictions presume no such motivation or ability, we predict that facts do not significantly affect opinions, beyond the effects of a frame absent factual content.[4] 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: 17) statement that "People think in

[3] This distinction between frames and facts echoes that found in the communication literature between fact arguments and value arguments (Fairbanks 1994).

[4] Similarly, Petty and Wegener (1999: 42) explain that when motivation and/or ability are low, individuals examine "less information…or examine…information less carefully."

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 and Chaiken 1993: 327, Fazio 2000: 14, Kunda 2001: 16, Turner 2001: 68-69, Bargh 2007: 39). We will test our second hypothesis in two ways: (1) by comparing whether a frame containing factual content supportive (opposed) to a new technology has a greater effect on opinions than analogous supportive (opposed) frames that lack factual content, and (2) by exploring whether a supportive (opposed) frame with a fact overpowers a competing opposed (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 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: 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 et al. 1979, Kunda 1990).

Whether they know it or not, people engage in motivated reasoning in order to arrive at a desired conclusion. For example, when people receive new information about George W. Bush, they interpret it in light of the 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 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" (2008: 35-36).

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")[5] (e.g., Redlawsk 2002, Rudolph 2006, Taber et al. 2009). 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. 2008a,b) (*hypothesis 4*). Third, biased processing of new evidence will affect subsequent overall opinions, since 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 and Lodge 2006).[6]

Experimental Participants, Procedure, and Design

To investigate our hypotheses, we conducted experiments on distinct emergent technologies: carbon-nanotubes (CNTs) and genetically modified food (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 in order to alter nutritional content and/or to enhance their ability to withstand adverse conditions. Both technologies came to prominence in the early 1990s; while 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

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

[6] 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 and Taber 2000: 211). Third, while the application of motivated reasoning to the interpretation of neutral information is relatively novel (although see Kahan et al. 2008a,b), it has a strong basis in related work on priming (e.g., Higgins 1996).

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). While in some sense unusual, we believe this enhances experimental realism (e.g., McDermott 2002), compared to confronting respondents with novel technologies with no context whatsoever.[7]

We implemented the survey experiment by assembling twenty teams of student pollsters. We then randomly selected polling locations throughout the northern part of Cook County, Illinois. Each polling team spent a randomly determined two to three 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).[8] To test hypothesis 2, we incorporated the experimental conditions—

[7] Perhaps the main disadvantage our approach is that exit poll surveys need to be short, thereby constraining the number of items we could include (e.g., Traugott and Lavrakas 2004).

[8] 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

which we will momentarily describe—by altering the brief descriptions of the technologies.

We also included measures of the previously discussed attitudinal, knowledge, 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.[9] 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) (Cobb and Macoubrie 2004).

For scientific knowledge, we follow others (e.g., Lee et al. 2005: 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.[10] Finally, we included standard demographic measures that asked for respondents' gender

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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: 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).

[9] Kahan et al. (2008a,b, 2009) 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."

[10] Our specific science, CNTs, and GM Foods knowledge questions are standard open-ended questions (e.g., Miller 1998, Gaskell et al. 1999, Lee et al. 2005, Scheufele and Lewenstein 2005): (1) general science: Is it true or false that lasers work by focusing sound waves?," and "Which travels faster: light or sound?," (2) 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 (3) GM foods: "Is it true or false that ordinary tomatoes do not contain genes while genetically modified tomatoes do?," and "Is it true or false that by eating a genetically modified fruit a person's genes could become modified?"

(0 = male, 1 = female), minority status[11], education[12], age[13], and media exposure.[14,15] In Table 1, we report the descriptive statistics for the sample. (The Ns vary by variable due to non-responses.) The table shows that the respondents come from fairly diverse backgrounds; although, as would be expected in northern Cook County, the sample is skewed towards liberal, well-informed, and educated individuals.[16]

[Insert Table 1 About Here]

Experimental Conditions

We designed our experiment to test our second hypothesis concerning the impact of facts on frame strength. To be clear—by fact, we mean something that verifiably exists and has some objective reality (Merriam-Webster Online Dictionary). To identify frames and associated facts for each of our technologies, we explored the popular and scientific literatures. We then pre-tested 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 risks (con). For GM foods, the frames/facts focused on combating world hunger (pro) and bio-diversity (con). The specific wordings appear in Table 2.[17] For the frames without facts, we included a consensus

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

[12] Respondents reported their highest level of completed education (see Table 1).

[13] Respondents reported there age as following on one of seven ranges (see Table 1).

[14] 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.

[15] 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.

[16] 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).

[17] We implemented a pre-test with individuals who did not participate in the subsequent study. We briefly described each technology to the pre-test respondents, and then we provided them with a list of frames and facts, asking them to evaluate each in terms of its (1) directional content (e.g., in opposition or support of the technology), (2) factual status (e.g., is it verifiable or debatable), and (3) effectiveness or strength in providing information or making an argument. For CNTs, we tested frames and accompanying facts that covered the following dimensions: energy costs/availability, promotion of clean energy, improvements in technological applications, potential health risks, potential environmental risks, and threat to personal privacy. For GM foods, we tested frames and accompanying facts that covered the following dimensions: food production, world hunger, world disease, bio-diversity, human health, and economic implications. The

endorsement to ensure its credibility (O'Keefe 2002: 150). Importantly, each factual statement implicitly includes the frame, given 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, Berinsky and Kinder 2006).

[Insert Table 2 About Here]

Our experimental conditions vary exposure to frames and facts (i.e., frames with facts).[18] 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 carbon nanotubes or 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."[19] Respondents then were randomly assigned to one of nine conditions, as described in Table 3 (with the Ns appearing in

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frames (and facts) we used in the experiment significantly differed from one another in terms of direction and were all rated as strong. The facts also were all rated as constituting facts (e.g., significantly more so than the frames without facts). Specific pre-test results are available from the authors.

[18] In all cases, the CNT condition (and relevant dependent variable questions) preceded the GM foods conditions (and questions). While pre-tests, where we varied the order of a selection of manipulations, indicated no significant carryover due to order effects, we nonetheless opted to not vary the order for fear of introducing another variable (i.e., order) that would reduce our sample sizes. Of course the flip side of this is that caution needs to be taken in generalizing the GM results if in fact order effects occur, which, again, were not evident in a pre-test. We opted for CNT first since its connection to the election context (e.g., and the importance of the energy issue during the campaign) was clearer.

[19] The analogous information for GM foods stated: "Another issue where new technologies are being discussed concerns the challenges of food production. One approach is to rely more on genetically modified or GM foods. GM foods are biologically modified so as to alter their nutritional content (e.g., by inserting vitamins) or their ability to withstand averse conditions (e.g., cold weather, destructive insects). The uncertain long-term effects of GM foods are the subject of continued study and debate."

the cells). We randomly assigned conditions separately for CNTs and GM foods, and thus, respondents were typically not in the same experimental condition for each technology.[20]

[Insert Table 3 About Here]

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.

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).[21] 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…"[22] 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

[20] 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 pre-test where we randomly asked half of 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.

[21] In all cases the frame (without fact) appeared first.

[22] We pre-tested the exact wordings of all conditions to ensure adequate flow.

hypothesis 2).[23] 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), while 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 and Park 1986). This allowed us to assess how individuals with fairly coherent or crystallized opinions process new information.

In the follow-up, which occurred ten days after the initial survey, participants received reminder information about CNTs and GM foods.[24] 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 re-reported their overall support for each technology.[25]

[Insert Table 4 About Here]

The specific study descriptions appear in Table 4.[26] We pre-tested the studies—which are akin to the (framed) facts used in the initial survey—with individuals who had not previously expressed technology opinions so as to (1) classify each study as pro, con, or neutral in its support of the technology, (2) confirm that each was perceived as "highly effective," and (3) verify that

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[23] 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).
[24] We sent three reminders to participants.
[25] We follow Taber and Lodge (2006) in asking respondents to evaluate multiple distinct items. While 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).
[26] We also asked respondents to evaluate whether the study came across as more opposed or supportive of the technology.

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.[27]

In contrast to these average unadulterated pre-test 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.[28] 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.

Results

We begin by presenting the distributions of each dependent variable—support for CNTs and GM foods—in Figures 1 and 2.[29] While 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 (std. dev.: 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).

[Insert Figures 1 and 2 About Here]

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[27] 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: (1) combating world disease is close to combating world hunger, and (2) health risks was used in the initial survey but for CNTs.

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

[29] For the purposes of the Figures, we rounded the scores of the few respondents who chose mid-points on the scales (e.g., 2.5). Also, for presentational purposes, we treat the dependent variables as interval level.

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 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).[30] We plot the results for each technology in Figures 3 and 4 (using abbreviations of "Eg" for 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.

[Insert Figures 3 and 4 About Here]

We will test our second hypothesis in two ways: (1) by comparing whether a frame containing factual content supportive (opposed) to a new technology has a greater effect on opinions than analogous supportive (opposed) frames that lack factual content, and (2) by exploring whether a supportive (opposed) frame with a fact overpowers a competing opposed (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), while the con conditions do the reverse. Second and more importantly, facts do not significantly increase the power of frames. While 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 no where near significant. For example, the CNT health risk frame (condition 4) alone versus fact alone condition (condition 2) produced the largest difference between these conditions (-18.8% versus -15.5%) and the difference is far from significant ((t_{140} = .73, $p \leq .25$ for a one-tailed test). Additionally, opposing facts do not overpower frames without facts—the mixed conditions (6 and 8) never produce significant effects, further supporting the finding that

[30] 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).

facts add little.[31] Instead, the frames cancel regardless of factual content.[32]

Third, while 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).[33] Fourth, the negative conditions uniformly displayed larger relative effects than the positive effects, perhaps echoing the well-known negativity bias (Baumeister et al. 2001, Rodriguez 2007: 478, 493). In sum, 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.

We next investigate 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

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[31] Kahan and his colleagues (2007, 2008a,b) explore how worldviews (i.e., individualism and hierarchical tendencies) moderate the effects of new information and frames. Our design differs from theirs in that we incorporate a broader range of framing conditions. While this enables us to examine variations in frame combinations, it limits our ability (due to sample size issues) of investigating moderators (within a given condition/frame treatment). Our design also differs from Kahan and his colleagues' work insofar as, in contrast to their approach, we do not pinpoint particular frames that likely resonate with distinct worldviews.

[32] These results, in some sense, are contrary to Chong and Druckman's (2007b) finding that competition stimulates motivation. That is, competition between contrasting arguments (i.e., pro and con) did not induce sufficient motivation for respondents to more deliberately process the content of the frames and privilege facts. This may stem from a lack of ability or simply from the technologies being so distant (e.g., not personally important) that competition in this case was not sufficient.

[33] 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 bio diversity 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.

foods, respectively, in Tables 5 and 6.

[Insert Tables 5 and 6 About Here]

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 supportive in the case of GM foods. Additionally, individuals who perceive science as more credible offer greater support. While 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 knowledge undoubtedly reflects the greater familiarity 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 being less supportive for both technologies, and minorities, older individuals and, curiously, those with more media exposure being less supportive for CNTs.

[Insert Figure 5 About Here]

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 0 to 2 correct on the knowledge variables).[34] For example, the first bar shows that an increase from 0 general science answers correct to 2 correct results in a 7% increase in support for CNTs. (For GM foods, we use issue specific knowledge.)

The figure suggests that no one of these variables stands out in its impact across

[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 since we took differences (e.g., at minimums and maximums). The precise predicted values are available from the authors.

technologies. Overall, the evidence thus offers mixed support for our first hypothesis—it contradicts the strong version 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 influences, 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., Douglas 1970, Feldman 2003, Kahan et al. 2007).

Follow-up Results

We received follow-up responses from 33% (206/621) participants, which is a respectable response rate for an internet based follow-up survey (e.g., Couper 2008).[35] Recall 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 re-asked). 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 versus neutral and that yields $t_{202} = 3.42$; $p \leq .01$ for a one-tailed test). While 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 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]

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[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

[Insert Table 7 About Here]

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 individual's initial opinion scores. We note statistically significant relationships between prior opinion and subsequent evaluations in the figure's legend (using one-tailed tests).[37]

[Insert Figures 6 and 7 About Here]

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 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.

[Insert Figures 8 and 9 About Here]

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our initial group of respondents.

[37] To generate the predicted opinions, we used OLS regression since 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 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.

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 does perceptions of the neutral studies as being supportive; also consistent with the hypothesis, albeit not explicitly predicted, we also see for GM foods that initial opinions shaped the directional evaluations of the pro and con studies.[38]

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 .37 and .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 and Lodge 2006: 765). This suggests opinion moderation (i.e., polarization would require a slope of greater than 1.00). We suspect that moderation comes from the fact that we exposed participants to a broad mix of pro, neutral, and con studies in the follow-up. While respondents exhibited relative bias in their reactions to these studies, their overall aggregate effects canceled and, in the end, moderated opinions.

Moreover, this does not constitute evidence that biased processing did not affect follow-up overall opinions. To more precisely explore the effects of bias processing (and hypothesis 5a), we regress follow-up opinion on initial opinion as well as the follow-up support and effectiveness

[38] Motivated reasoning is more likely to occur among individuals who engage in on-line processing and/or have strong attitudes on the issue (e.g., Lodge and Taber 2000: 211, Taber and Lodge 2006). We included an individual difference measure that captures tendencies to evaluate on-line as well as an attitude strength measure (as noted in the text). In results available from the authors, we show that this individual difference measures does in fact display some moderating effect. We expect that we may have stunted the full extent of the moderation, however, given the nature of our survey which encouraged all participants to engage in on-line processing. Specifically, respondents were told at the point of the initial survey that they would participate in a follow-up on the same technologies; such induced anticipation of having to re-express an opinion is the standard method used to induce on-line processing. Hastie and Park (1986: 262) explain that individuals engage in on-line processing "when they believe that a judgment is likely to be required at a later point in time." Also, our focus on attitudes toward precise technological applications also may have promoted on-line processing (e.g., McGraw and Dolan 2007). Finally, note that we did nothing to encourage that respondents form "accurate" attitudes, which sometimes limits motivated reasoning (e.g., Taber and Lodge 2006).

evaluations. (We again scale all independent variables on 0 to 1 scales and use ordered probits.)[39]

[Insert Table 8 About Here]

The results show that perceptions of the follow-up studies shape subsequent opinions about the technologies. For CNTs, the more supportive one believed each of the studies, 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 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. 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 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 generates 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 those reporting the minimum score.

[39] The results are unchanged when we include a full range of control variables.

In sum, while we do not find evidence of attitude polarization (i.e., more extreme positions)—likely due to providing participants such a mix of additional information—we find clear evidence (1) of biased processing of new factual studies, and (2) 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 (also see, e.g., Scheufele and 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 (also see, e.g., Nisbet and Mooney 2007). Facts do not enhance frame strength. Third, once they form initial opinions, individuals process new factual information in a biased manner (also see, e.g., Kahan et al. 2008a,b). 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). Future work needs to identify the contexts, technologies, and individuals where factual information will have alternative effects. Only then can general statements about factual information be made. This is critical if we are to develop mechanisms for facilitating the formation of reasonable opinions about emergent technologies.

Our results suggest that this might best be done by providing alternative ways of thinking about new technologies—that is, different frames—and then encouraging individuals to weigh these frames against one another. Under distinct circumstances, perhaps facts play a more salient and less biased role. 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.

References

Bargh, John A. 2007. “Social Psychological Approaches to Consciousness.” In *The Cambridge Handbook of Consciousness,* eds., P. Zelazo, M. Moscovitch, and E. Thompson. New York: Cambridge University Press.

Bauer, Martin W., Nick Allum, and Steve Miller. 2007. “What Can We Learn From 25 Years of PUS Survey Research? Liberating and Expanding the Agenda.” *Public Understanding of Science* 16: 79-95.

Baumeister, Roy F., Ellen Bratslavsky, Catrin Finkenauer, and Kathleen D. Vohs. 2001. “Bad Is Stronger Than Good.” *Review of General Psychology* 5: 323-370.

Berinsky Adam J., and Donald R. Kinder. 2006. “Making Sense of Issues Through Media Frames: Understanding the Kosovo Crisis.” *The Journal of Politics*. 68: 640-656.

Camerer, Colin F., and Ernst Fehr. 1999. “When Does ‘Economic Man’ Dominate Social Behavior.” *Science* 311: 47-52.

Chaiken, Shelly, and Yaacov Trope (eds.). 1999. *Dual-Process Theories in Social Psychology*. New York: The Guilford Press.

Chong, Dennis, and James N. Druckman. 2007a. “A Theory of Framing and Opinion Formation in Competitive Elite Environments.” *Journal of Communication* 57 (1): 99-118.

Chong, Dennis, and James N. Druckman. 2007b. “Framing Public Opinion in Competitive Democracies.” *American Political Science Review* 101 (4):637-655.

Chong, Dennis, and James N. Druckman. 2007c. “Framing Theory.” *Annual Review of Political Science* 10 (1):103-126.

Cobb, Michael D. 2005. “Framing Effects on Public Opinion about Nanotechnology.” *Science Communication* 27: 221-239.

Cobb, Michael D. and Jane Macoubrie. 2004. “Public Perceptions About Nanotechnology: Risks, Benefits and Trust.” *Journal of Nanoparticle Research* 6: 395-405.

Couper, Mick P. 2008. *Designing Effective Web Surveys*. New York: Cambridge University Press.

Currall, Steven C., Eden B. King, Neal Lane, Juan Madera, and Stacy Turner. 2006. “What Drives Public Acceptance of Nanotechnology?” *Nature Nanotechnology* 1: 153-155.

Committee on Risk Perception and Communication (National Research Foundation). 1989. *Improving Risk Communication*. Washington D.C.: National Academy Press.

Douglas, Mary. 1970. Natural symbols: Explorations in Cosmology. New York: Pantheon Books.

Druckman, James N. 2001. “The Implications of Framing Effects for Citizen Competence.” *Political Behavior* 23(September): 225-256.

Eagly, Alice Hendrickson, and Shelly Chaiken. 1993. *The Psychology of Attitudes*. Fort Worth, TX: Harcourt Brace Jovanovich College Publishers.

Fairbanks, A. Harris. 1994. *Fact, Value, Policy: Reading and Writing Arguments*. New York: McGraw-Hill.

Fazio, Russell H. 1995. "Attitudes as Object-Evaluation Associations." In Richard E. Petty, and Jon A. Krosnick (eds.), *Attitude Strength: Antecedents and Consequences*. Hillsdale: Erlbaum.

Fazio, Russell. H. 2000. "Accessible Attitudes as Tools for Object Appraisal: Their Costs and Benefits." In *Why We Evaluate: Functions of Attitudes*, eds., G. Maio and J. Olson. Mahwah, NJ: Erlbaum, 1-36.

Feldman, Stanley. 2003. "Values, Ideology, and the Structure of Political Attitudes. In *Oxford Handbook of Political Psychology*, eds., David O. Sears, Leonie Huddy, and Robert Jervis. Oxford: Oxford University Press,477-510.

Gaskell, George, Martin W. Bauer, John Durant, Nicholas C. Allum. 1999. "Worlds Apart?: The Reception of Genetically Modified Foods in Europe and the U.S." *Science* 285: 384-387.

Hastie, Reid, and Bernadette Park. 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. Tory. 1996. "Knowledge Activation: Accessibility, Applicability, and Salience. In E. Tory Higgins, and Arie W. Kruglanski (eds.), *Social Psychology*. New York: Guilford Press.

Kahan, Dan M., Donald Braman, Paul Slovic, John Gastil and Geoffrey L. Cohen. 2007. "Affect, Values, and Nanotechnology Risk Perceptions: An Experimental Investigation." GWU Legal Studies Research Paper No. 261; Yale Law School, Public Law Working Paper No. 155; GWU Law School Public Law Research Paper No. 261; 2nd Annual Conference on Empirical Legal Studies Paper. Available at: http://ssrn.com/abstract=968652.

Kahan, Dan M., Donald Braman, Paul Slovic, John Gastil and Geoffrey L. Cohen. 2008a. "The Future of Nanotechnology Risk Perceptions: An Experimental Investigation of Two Hypotheses." Harvard Law School Program on Risk Regulation Research Paper No. 08-24. Available at: http://ssrn.com/abstract=1089230.

Kahan, Dan M., Donald Braman, Paul Slovic, John Gastil, Geoffrey L. Cohen and Douglas Kysar. 2008b. "Cultural Cognition and Nanotechnology Risk Perceptions: An Experimental Investigation of Message Framing." Unpublished paper, Yale University.

Kahan, Dan M., Donald Braman, John Monahan, Lisa Callahan and Ellen Peters. 2009. "Cultural Cognition and Public Policy: The Case of Outpatient Commitment Laws." *Law and Human Behavior*, Online First publication. Available at: http://www.springerlink.com/content/fh377338110h7434/.

Kunda, Ziva. 1990. "The Case for Motivated Reasoning." *Psychological Bulletin* 108(3): 480-498.

Kunda, Ziva. 2001. *Social Cognition: Making Sense of People*. Cambridge, MA: The MIT Press.

Lakoff, George. 2004. *Don't Think Of An Elephant?: Know Your Values and Frame the Debate*. White River Junction, Vermont: Chelsea Green Publishing.

Larrick, Richard P., Richard E. Nisbett, and James N. Morgan. 1993. "Who Uses the Cost-Benefit Rules of Choice?" *Organizational Behavior and Human Decision Processes* 56(December): 331-347.

Lee, Chul-Joo, Dietram A. Scheufele, and Bruce V. Lewenstein. 2005. "Public Attitudes toward Emerging Technologies: Examining the Interactive Effects of Cognitions and Affect on Public Attitudes Toward Nanotechnology." *Science Communication* 27: 240-267.

Lodge, Milton, and Charles S. Taber. 2000. "Three Steps toward a Theory of Motivated Political Reasoning." In Arthur Lupia, Mathew D. McCubbins, and Samuel L. Popkin, (eds.), *Elements of Reason: Cognition, Choice, and the Bounds of Rationality*. Cambridge, UK: Cambridge University Press.

Lodge, Milton, and Charles S. Taber. 2008. "The Rationalizing Voter: Unconscious Thought in Political Information Processing." Unpublished paper, Stony Brook University.

Lord, Charles G., Lee Ross, and Mark R. Leeper. 1979. "Biased Assimilation and Attitude Polarization: The Effects of Prior Theories on Subsequently Considered Evidence." *Journal of Personality and Social Psychology* 37: 2098-2109.

McDermott, Rose. 2002. "Experimental Methodology in Political Science." *Political Analysis* 10: 325-342.

McGraw, Kathleen M., and Thomas Dolan. 2007. "Personifying the State: Consequences for Attitude Formation." *Political Psychology* 28: 299-328.

Mellman Group. 2006. "Public Sentiment About Genetically Modified Foods." http://www.pewtrusts.org/.

Miller, Jon D. 1998. "The Measurement of Civic Scientific Literacy." *Public Understanding of Science* 7: 203-223.

Musham, Catherine, Lillian Trettin, and Richard Jablonski. 1999. "Before the Storm: Informing and Involving Stakeholder Groups in Workplace Biomarker Monitoring." *Journal of Public Health Policy*. 20: 319-334.

Nelson, Thomas E., Zoe M. Oxley, and Rosalee A. Clawson. 1997. "Toward A Psychology of Framing Effects." *Political Behavior* 19(3):221-46.

Nisbet, Matthew C. N.d. "Framing Science: A New Paradigm in Public Engagement." In *Understanding Science: New Agendas in Science Communication*, eds., L. Kahlor, and P. Stout. New York: Taylor & Francis.

Nisbet, Matthew C., and Robert K. Goidel. 2007. "Understanding Citizen Perceptions of Science Controversy: Bridging the Ethnographic-Survey Research Divide." *Public Understanding* *of Science* 16: 421-440.

Nisbet, Matthew C., and Chris Mooney. 2007. "Framing Science." *Science* 316: 56.

O'Keefe, Daniel J. 2002. *Persuasion*. Second Edition. Thousand Oaks: Sage.

Payne, John W., James R. Bettman, and Eric J. Johnson. 1993. *The Adaptive Decision Maker*. New York: Cambridge University Press.

Peter D. Hart Research Associates, Inc. 2008. "Awareness of and Attitudes Toward Nanotechnology and Synthetic Biology." http://www.pewtrusts.org/.

Petty, Richard E., and Duane T. Wegener. 1998. "Attitude Change." In Daniel T. Gilbert, Susan T. Fiske, and Gardner Lindzey (eds.), *Handbook of Social Psychology*. 4th edition, Vol. II. New York: McGraw-Hill.

Petty, Richard E., and Duane T. Wegener. 1999. "The Elaboration Likelihood Model: Current Status and Controversies." In *Dual-Process Theories in Social Psychology*, eds., Shelly Chaiken, and Yaacov Trope. New York: The Guilford Press.

Redlawsk, David. 2002. "Hot Cognition or Cool Consideration: Testing the Effects of Motivated Reasoning on Political Decision Making." *Journal of Politics* 64: 1021-1044.

Rodriguez, Lulu. 2007. "The Impact of Risk Communication on the Acceptance of Irradiated Food." *Science Communication* 28: 476-500.

Rudolph, Thomas J. 2006. "Triangulating Political Responsibility: The Motivated Formation of Responsibility Judgments." *Political Psychology* 27: 99-122.

Savadori, Lucia, Stefania Savio, Eraldo Nicotra, Rino Rumiati, Melissa Finucane and Paul Slovic. 2004. "Expert and Public Perception of Risk From Biotechnology." *Risk Analysis* 24: 1289-1299.

Scheufele, Dietram A. 2006. "Five Lessons in Nano Outreach." *Materials Today* 9: 64.

Scheufele, Dietram A., and Bruce V. Lewenstein. 2005. "The Public and Nanotechnology: How Citizens Make Sense of Emerging Technologies." *Journal of Nanoparticle Research* 7: 659-667.

Sturgis, Patrick, and Nick Allum. 2006. *A Literature Review of Research Conducted on Public Interest, Knowledge, and Attitudes to Biomedical Science*. Report prepared for The Welcome Trust.

Taber, Charles S., and Milton Lodge. 2006. "Motivated Skepticism in the Evaluation of Political Beliefs." *American Journal of Political Science* 50: 755-769.

Taber, Charles S., Amon Cann, and Simona Kucsova. 2009. "The Motivated Processing of Political Arguments." Unpublished paper, Stony Brook University.

Traugott, Michael W., and Paul J. Lavrakas. 2004. *The Voter's Guide to Election Polls*, by Chatham, NJ: Chatham House Publishers, Inc.

Turner, Mark. 2001. *Cognitive Dimensions of Social Science*. Oxford: Oxford University Press.

Table 1: Demographic and Political Profile of Sample

Variable	Scale (Overall Distribution)	Average (std. dev.)
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 (.80)
CNT Knowledge	0 correct = 35% (220) (total N = 620) 1 correct = 50% (307) 2 correct = 15% (93)	.80 (.68)
GM Foods Knowledge	0 correct = 27% (166) (total N = 620) 1 correct = 24% (147) 2 correct = 49% (307)	1.23 (.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
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)

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 twenty three GM producing countries are developing nations that produce virus resistant GM foods with increased iron and vitamins.
Con: Bio Diversity	Most agree that the most important implication of GM foods concerns their impact on bio-diversity and their effect on other crops and animals in the food chain.	A recent study related to bio-diversity 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.

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

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 four to seven 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.

Table 5: Determinants of Support for CNTs

Dependent Variable: Support for CNTs (1 to 7).

Experimental Condition		*Demographic Variable*	
Energy Frame (Pro Frame) (4)	.52*** (.19)	Individualism	.38** (.18)
Energy Fact (Pro Fact) (2)	.62*** (.19)	Hierarchical	.45*** (.18)
Energy Frame/Energy Fact (Pro Frame/Pro Fact) (5)	.37** (.19)	Conservativeness	.21 (.20)
Health Frame (Con Frame) (7)	-.72*** (.19)	Science Credibility	.77*** (.17)
Health Fact (Con Fact) (3)	-.76*** (.19)	Scientific Knowledge	.20* (.14)
Health Frame/Health Fact (Con Frame/Con Fact) (9)	-1.20*** (.20)	CNT Knowledge	-.08 (.15)
Energy Frame/Health Fact (Pro Frame/Con Fact) (6)	-.05 (.19)	Minority	-.28*** (.12)
Health Frame/Energy Fact (Con Frame/Pro Fact) (8)	-.11 (.19)	Female	-.24*** (.10)
		Age	-.22* (.17)
		Education	.12 (.20)
		Newspaper Exposure	-.20* (.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. ***$p \leq .01$; **$p \leq .05$; *$p \leq .10$ for one-tailed tests. The coefficient and standard errors for τ_1 through τ_8 are as follows: -1.69 (.28), -1.27 (.28), -.91 (.27), .45 (.26), .46 (.26), 1.01 (.27), 1.02 (.27), 1.67 (.17). (There are eight cut-points due to two respondents who responded at intermediate values on the 7 point scale.)

Table 6: Determinants of Support for GM Foods

Dependent Variable: Support for GM Foods (1 to 7).			
Experimental Condition		*Demographic Variable*	
Hunger Frame (Pro Frame) (4)	.34** (.19)	Individualism	.35** (.17)
Hunger Fact (Pro Fact) (2)	.30* (.19)	Hierarchical	.56*** (.17)
Hunger Frame/Hunger Fact (Pro Frame/Pro Fact) (5)	.47*** (.19)	Conservativeness	.31* (.19)
Bio Diversity Frame (Con Frame) (7)	-.39** (.19)	Science Credibility	.36** (.16)
Bio Diversity Fact (Con Fact) (3)	-.45*** (.20)	Scientific Knowledge	-.02 (.15)
Bio Div. Frame/ Bio Div. Fact (Con Frame/Con Fact) (9)	-.74*** (.19)	GM Foods Knowledge	.24** (.13)
Hunger Frame/Bio Div. Fact (Pro Frame/Con Fact) (6)	-.12 (.19)	Minority	.14 (.12)
Bio Div. Frame/Hunger Fact (Con Frame/Pro Fact) (8)	-.16 (.19)	Female	-.39*** (.10)
		Age	-.03 (.16)
		Education	-.01 (.20)
		Newspaper Exposure	.05 (.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. ***$p \leq .01$; **$p \leq .05$; *$p \leq .10$ for one-tailed tests. The coefficient and standard errors for τ_1 through τ_6 are as follows: -.91 (.28), -.23 (.27), .21 (.27), .70 (.27), 1.35 (.28), 2.07 (.29).

Table 7: Follow-up 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)

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***
	(.34)	(.33)
Pro Study Support	.71**	.37
	(.39)	(.45)
Con Study Support	.58*	-1.67***
	(.38)	(.53)
Neutral Study Support	.69**	1.13***
	(.38)	(.35)
Pro Study Effectiveness	1.56***	1.75***
	(.31)	(.38)
Con Study Effectiveness	-1.14***	-1.35***
	(.34)	(.32)
Neutral Study Effectiveness	.98***	.30
	(.33)	(.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. ****p*≤.01; ***p*≤.05; **p*≤.10 for one-tailed tests. The coefficient and standard errors for τ_1 through τ_6 are, respectively for CNTs and GM foods are: .48 (.43), .79 (.43), 1.21 (.42). 3.14 (.46), 3.71 (.48), 4.28 (.50), and .68 (.44), 1.48 (.44), 2.09 (.45), 3.27 (.48), 4.05 (.50), 5.11 (.53).

Figure 1: Distribution of Support for CNTs

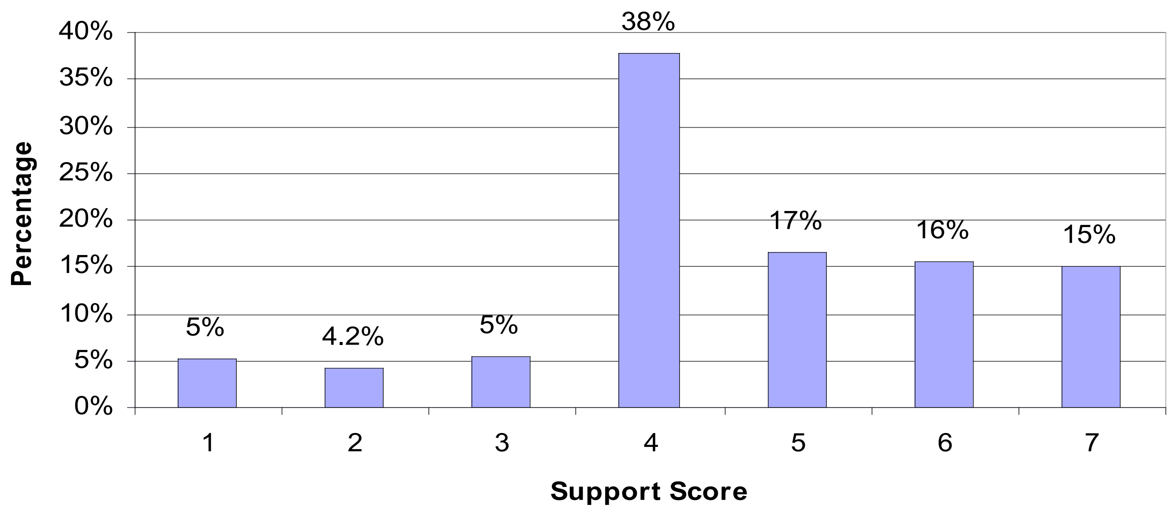

Figure 2: Distribution of Support for GM Foods

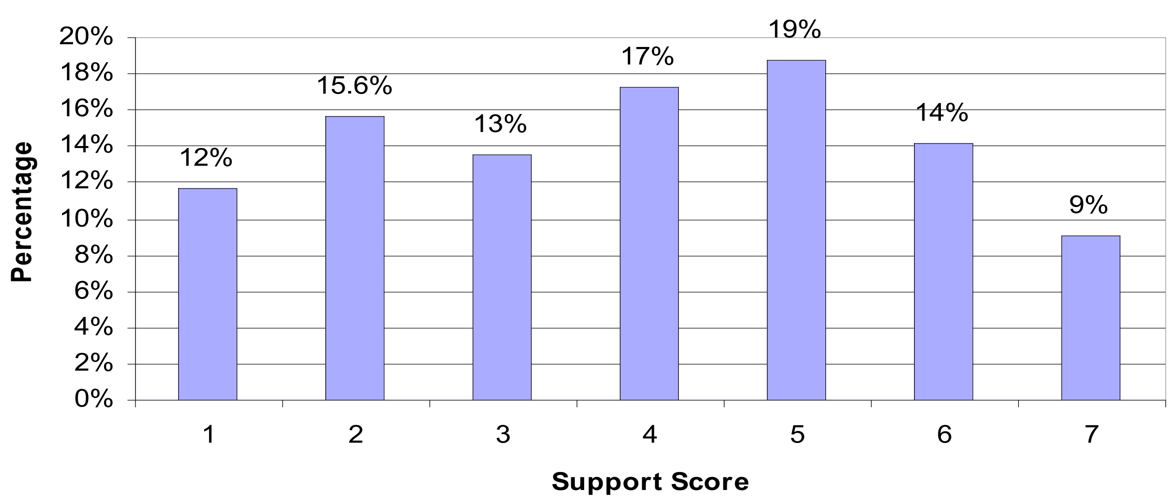

Figure 3: Support for CNTs

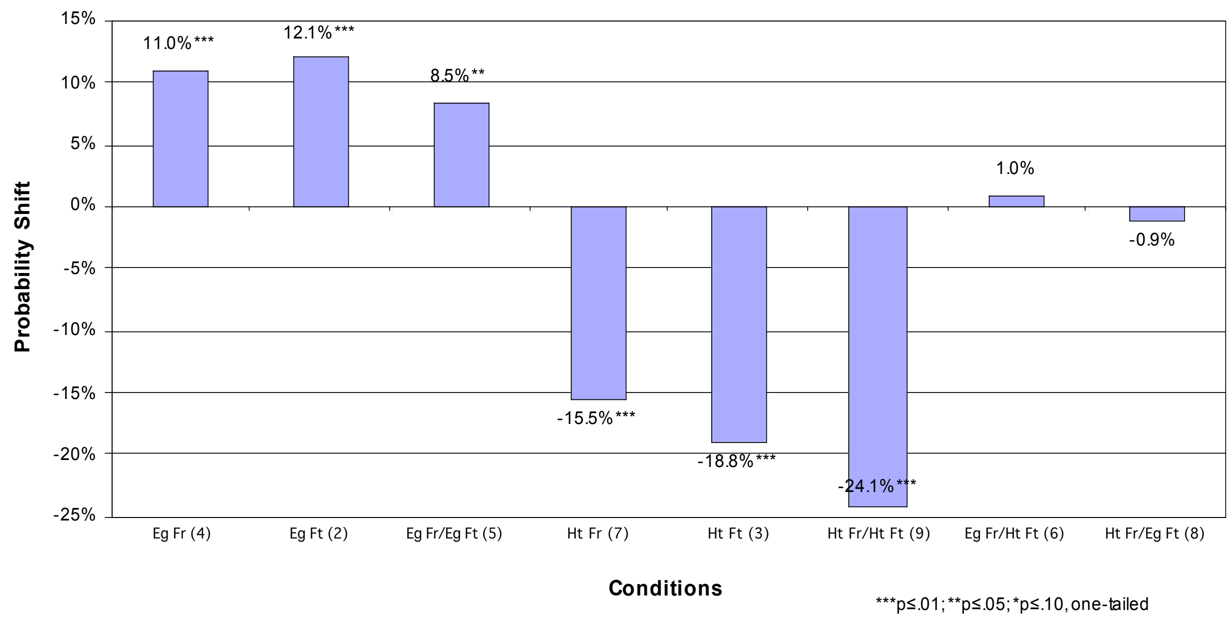

Figure 4: Support for GM Foods

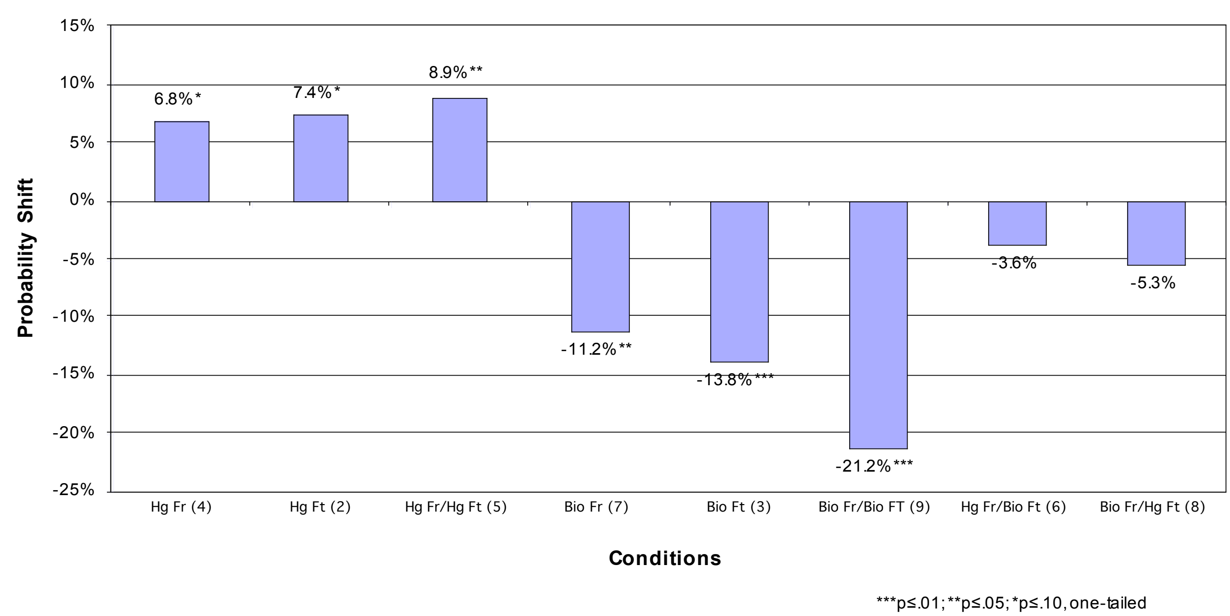

Figure 5: Support for Technologies

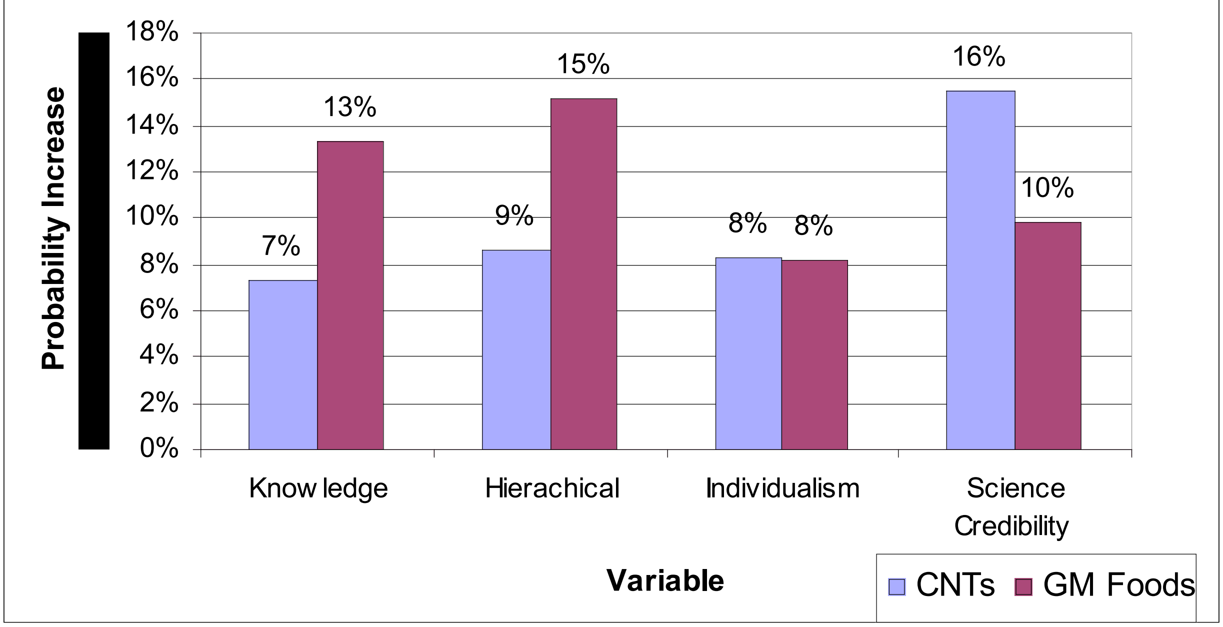

Figure 6: Effect of Initial CNT Support on Follow-Up Effectiveness

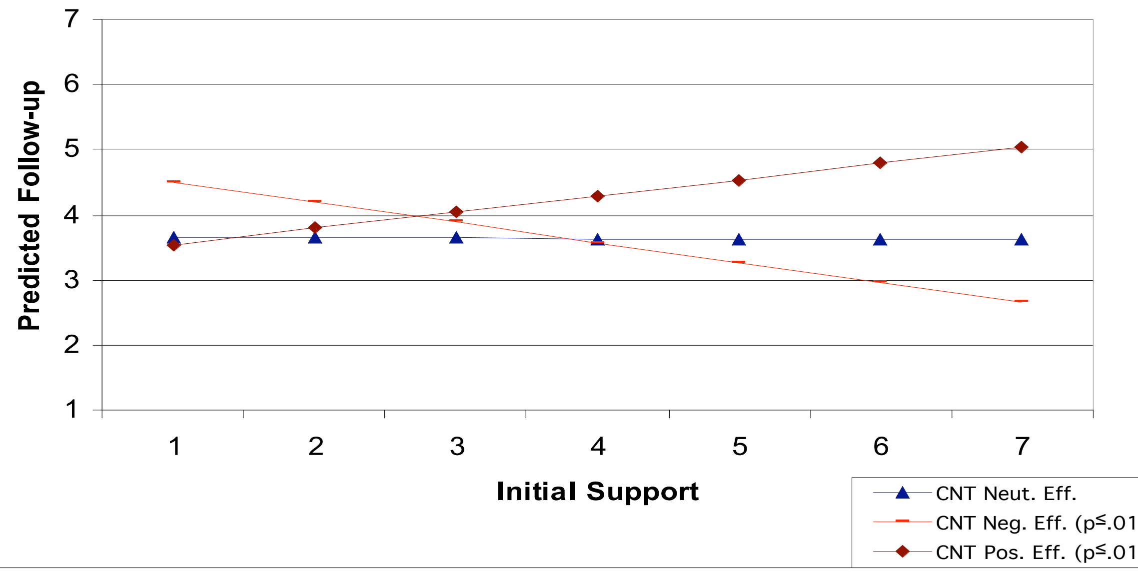

Figure 7: Effect of Initial GM Foods Support on Follow-Up Effectiveness

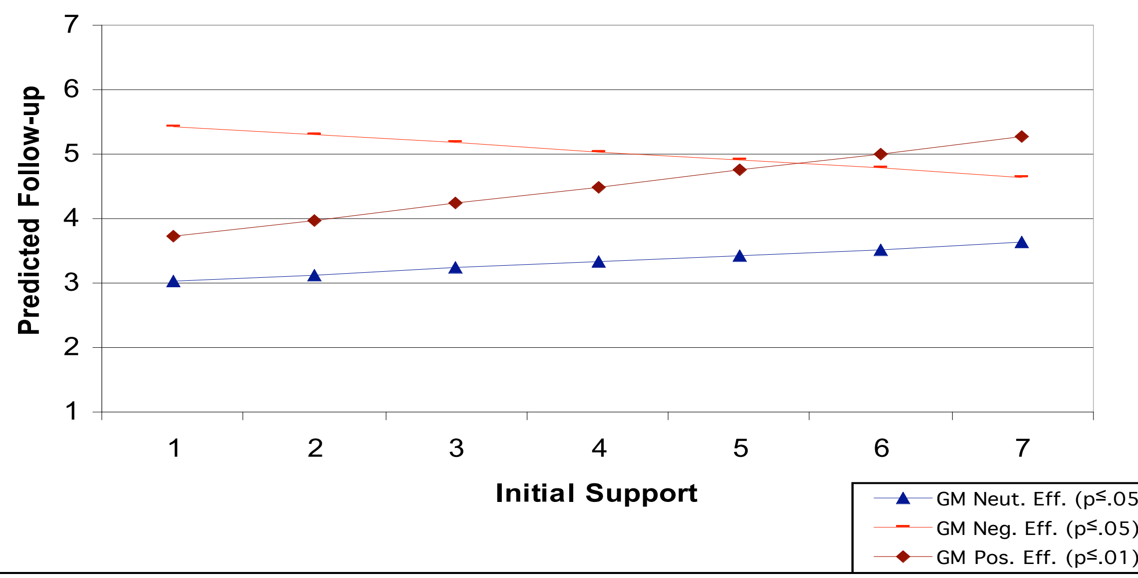

Figure 8: Effect of Initial CNT Support on Follow-Up Support

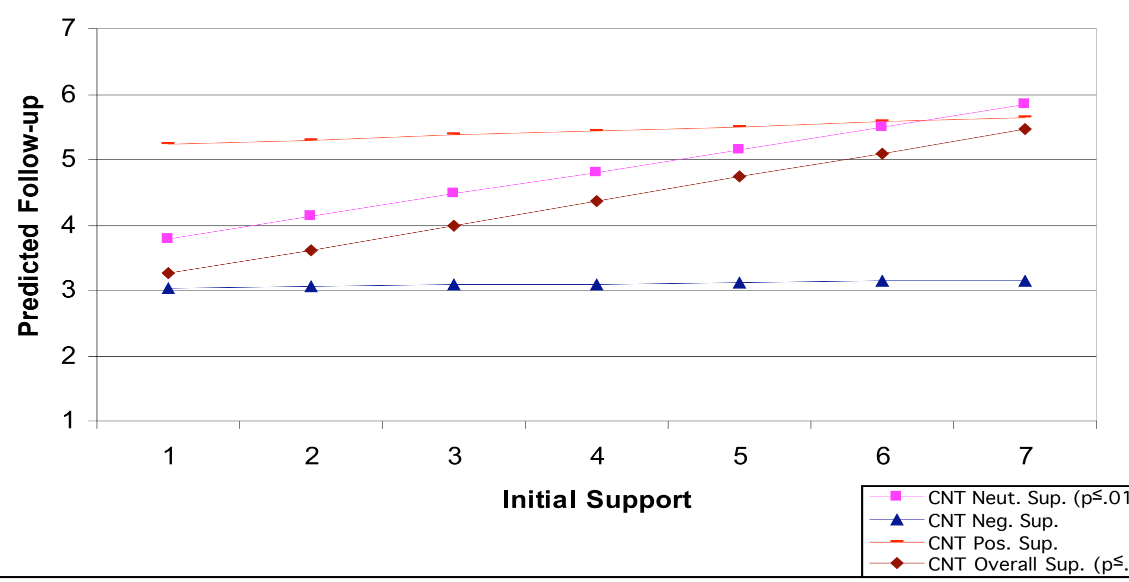

Figure 9: Effect of Initial GM Foods Support on Follow-Up Support