Framing Effects on Public Opinion about Nanotechnology*

Michael D. Cobb

Department of Political Science and Public Administration

North Carolina State University

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Abstract

In this study, I examine whether Americans' emotions and opinions about nanotechnology are influenced by how the issue is framed. Using data collected from an experimental national survey, I find systematic framing effects, but also that attitude change is not usually substantial. Frames based on general beliefs about the merits of science have less effect' frames based on specific nanotechnology risks and benefits are more effective. Surprisingly, I also find that framing nanotechnology as beneficial is nearly as effective as framing it as risky. I conclude by discussing the implication of these framing effects for future mass opinions about nanotechnology.

Despite Americans' initially positive reaction to nanotechnology (Cobb and Macoubrie 2004), it faces an uncertain fate in the future court of public opinion. Future public opinion might shift because Americans do not know much about nanotechnology, and also because experts disagree about the seriousness of the risks that nanotechnology poses to the public. Proponents prefer to talk about its projected benefits, such as medical breakthroughs and cheaper, stronger consumer goods, but critics claim its development could provoke a new arms race and they cite recent studies warn about the toxicity of nanoparticles (Oberdorster 2004; Monteiro-Riviere et al 2005). If critics are able to effectively frame nanotechnology as too risky, supporters might have trouble convincing the mass public otherwise. Thus, whether the mass public embraces or rejects nanotechnology could very well depend on how successful each side is at framing the issue.

This study examines the effects of various ways of framing nanotechnology. In particular, it investigates the effectiveness of framing nanotechnology according to its potential risks and benefits, and the effectiveness of framing it according to fundamental philosophical positions about the merits of science in general. Basic beliefs about the role of science—that it inevitably leads to progress or that it often fails to solve major problems—might shape opinions about nanotechnology. Using philosophical values of science frames in addition to specific risk and benefit frames allows for the study of whether particular kinds of frames are more influential than others.

Why study public opinion about nanotechnology if mass preferences are not thought to dictate scientific policy choices?[1] One reason is that policy makers are responsive to the general policy direction favored by mass opinion (Page and Shapiro 1992). Elites might not choose to implement specific kinds of regulations because of public opinion, but they are more likely to enact regulations in general when strong public preferences exist for greater regulatory activity. A second reason is that public opinion has previously and sometimes dramatically affected the fortunes of new technologies and their products (Priest 2001). For example, public perceptions about genetically modified foods (GMF) were highly influential when they suddenly turned negative (Ferber, 1999; Gaskell, Bauer, Durant, & Allum, 1999; Schurman 2004). Indeed, once GMF were successfully framed in Europe as "Frankenfoods," Americans' perceptions about GMF have at best been ambivalent (Priest 2000, 2002).

Nanotechnology and Public Opinion

Nanotechnology is actually an umbrella term for describing research and technology development that allows for the manipulation and control of materials at the atomic or molecular levels in order to build novel structures and devices. Some scientists and policy makers boldly predict that nanotechnology will become the catalyst of our next industrial revolution (National Science and Technology Council 2000). The annual global impact of nanotechnology based products is expected to surpass $1 trillion within ten years (Roco & Bainbridge 2001). Thus, public perceptions about nanotechnology could have significant social and financial consequences (Roco 2003).

[1] While some scholars question the validity of citizen involvement in science policy (Jasanoff 1990), calls for greater public participation in technology policies are increasing.

Public perceptions about nanotechnology

While government, industry and scientists are investing millions of dollars to better understand what the public thinks about nanotechnology, the mass public is not yet well informed about it (Cobb and Macoubrie 2004; Macoubrie 2005). Most Americans readily admit that they have heard little or nothing about it, and when quizzed about how it works, they do poorly at answering basic factual questions (Cobb and Macbourie 2004). Nevertheless, their first impressions of it are guardedly optimistic.[2] Although the mass public does not predict nanotechnology will be devoid of risks, a solid majority of survey respondents think that benefits will be equal to or greater than these risks. Likewise, Americans reported having positive emotional reactions to nanotechnology, such as feeling significantly more hopeful about it than worried or angry about it. While 83% of respondents reported feeling hopeful, for example, only 26% and 18%, respectively, claimed to feel worried or angry about it.

If most Americans admit to not knowing much about nanotechnology, and yet they are willing to form and report opinions about it, this suggests that perceptions about its risks and benefits must be based on external cues, most likely opinions about the general merits of science (Cobb 2004). Because they lack specific information about nanotechnology, Americans' attitudes about it will be sensitive to new information. According to a vast amount of literature on what influences public opinion, one of the most important qualities about a new issue is how it is initially framed.

[2] A web survey finds similarly held positive opinions toward nanotechnology (Bainbridge 2002).

Framing Effects and their Causes

Framing is ordinarily examined in the context of elites' attempts to influence public opinion about certain issues (Greene 2004).[3] Scholars find that framing is ubiquitous because almost every issue has alternative interpretations. How an issue is defined by framing, therefore, is often crucial to determining who wins in policy disputes. Fames hold particular sway with the mass public because they reduce confusing issues that are remote from most peoples' direct experiences into manageable packages of understandable information (Popkin 1994). Indeed, study after study has reported robust framing effects produced across scores of dissimilar issues (Iyengar 1990, 1991; Iyengar and Kinder 1987; Kinder and Sanders 1990; Sniderman 1993; Chong 1996; Jacoby 2000; Haider-Markel and Joslyn 2001).

Issue framing

There are at least two types of framing effects that are actually disparate phenomenon but are (improperly) identically labeled. In this study, I am referring to *issue framing* effects commonly studied in the political communication literature.[4] Issue framing is when "qualitatively different yet potentially relevant considerations" (Druckman 2005, 672) are used to describe the same issue. Similarly, Entman (1993, 2003) writes that issue framing is the process of selecting and highlighting some facets of

[3] Although most frames originate from self-interested elites, the media is the primary method in which frames are disseminated to the mass public. Some scholars argue that the mass media are biased toward producing stories that frame scientific issues in terms of their prospective risks, often accentuating the highly improbable but potentially catastrophic aspects to uncertain technologies (Singer and Endreny 1993). Others claim the mass media downplay risks in deference to establishment interests or marginalizes critics of industry (Herman and Chomsky 1988).

[4] One of the more widely known research traditions on framing focuses on how different, but logically equivalent words or phrases, can cause individuals to change their preferences, seemingly in violation of an axiom of rational choice theory (Tversky and Kahneman 1981). Druckman (2005) calls these *equivalency framing* effects.

events or issues over their alternatives and making connections among them with the objective of promoting a particular interpretation or evaluation and a preferred solution. Abortion, for example, is typically framed by one side of the debate as "the right to choose" and by the other side as "abortion is murder".

How framing works

Two different cognitive processes, accessibility and salience, are thought to explain how framing effects work. Accessibility refers to the availability of information used to form opinions. Information that is accessible in memory is often used in place of more reliable diagnostic information because people are limited in cognitive ability (Fiske and Taylor 1991) and ordinarily are not motivated to search for more relevant information (Petty and Cacioppo 1986). The expression of opinions is therefore easily manipulated by frames because they provide the most recent or memorable information (Zaller and Feldman 1992). Alternatively, the salience hypothesis, sometimes called the "thoughtful receiver hypothesis" (Brewer 2001), holds that individuals consciously increase the importance they attach to specific considerations (Nelson, Clawson and Oxley 1997). This explains why some of the most successful frames invoke core values: because recipients of these frames already endorse the values in them. When exposed to a frame that says campaign spending is "free speech," for example, people deliberately weight the value of free speech more heavily than they would otherwise when forming opinions about campaign finance reform.[5]

[5] This means that issue framing is not merely argumentation because frames produce a unique kind of opinion change. Whereas persuasion works by actually altering the content of beliefs, successful framing occurs when individuals temporarily place more importance on beliefs or values that they already hold.

Expectations

Some scholars interpret the robust framing effects reported in the literature as worrisome evidence of elite manipulation (Kinder and Herzog 1993). It is now fairly well established, however, that framing effects are more conditional than previously thought (Druckman 2005). The new look at framing suggests when some frames are expected to be more effective than others.

Effective frames

All frames are not equally effective (Chong 2000). Frames that more strongly resonate with existing cultural norms, for example, will be more effective than those that do not (Gamson 1992). Likewise, if the frame is difficult to understand, it will be less influential than an easier to understand one (Cobb and Kuklinki 1997). The source of the frames matters too; some elites are not credible enough to successfully frame an issue (Kuklinski and Hurley 1994; Druckman 2001). Also, since negative information is generally more influential than positive information (Lau 1985), risk frames should be more effective than benefit frames. Finally, past research typically examined frames without considering their logical counter-frames. We now know that when people are exposed to frames on both sides of an issue, framing effects often disappear (Druckman 2005).

Data and Methods

To examine potential framing effects on opinions about nanotechnology, I conducted an experiment embedded within a nationally representative phone survey.[6] This survey of public attitudes about nanotechnology was a random-digit dialed survey of adults eighteen years or older in the continental United States between late March and early April of 2004 (N=1536).[7] Respondents were randomly assigned to one of ten experimental conditions: an over-sampled control group (N=330) or one of nine unique framing conditions about the risks or benefits of nanotechnology (N=134). Respondents in all conditions, even the control group, heard a brief, objective description about nanotechnology. Then, respondents in each of the nine framing conditions heard a distinct way of framing nanotechnology. Respondents in six of the experimental conditions listened to one-sided frames. Three of these one-sided frames were "pro" and the other three were "anti" nanotechnology. The remaining three conditions used two-sided frames that pitted the three pro and the three anti-nanotechnology frames against each other. Substantive questions about nanotechnology were then asked immediately following the frames.

The frames

The baseline frames used in this study represent two opposing philosophical values about the role of science. I label the first kind, "conservative humanism," and the

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[6] Jane Macoubrie and Pat Hamlet, both of whom are co-PI's on the larger NSF grant that funded this study, were heavily involved in the construction of the survey instrument. I alone am responsible for any errors in the data interpretation presented in this paper. The Survey Research unit of the Center for Urban Affairs and Community Services at North Carolina State University conducted the interviews.

[7] Every household in the continental United States with a land phone line had an equal probability of being contacted. The minimum response rate was 38% depending on which particular American Association of Public Opinion Research (AAPOR) standard is used.

other, "cornucopian." A conservative humanistic frame is skeptical that science can solve deficiencies in the human condition. Although humanism has been associated with a preference for the secular over religious, conservative humanists would still posit that science is not a "silver bullet" for our problems. Conversely, a cornucopian frame is optimistic that science inevitably solves all of our problems, such as replacing seemingly finite resources. In other words, science is said to create new resources and propel the advancement of society. Precise wording for the frames is located in Appendix A.

Based on a survey question I asked before starting the framing experiment, I was able to obtain a rough measure of how strongly these values might resonate with Americans. Although the conservative humanist position is only held by a minority (just over 10% thinks that science predominately creates problems), a large percentage (over 40% think that science equally creates and solves problems) is clearly ambivalent about the merits of science (Cobb and Macoubrie 2004).

I anticipated that the frames about the value of science might not be effective, so I also included mention of specific risks and benefits about nanotechnology in six of the nine framing conditions.[8] Thus, the first frame is a conservative humanist one and a second and third frame add mention of different types of potential risks to the values espoused by conservative humanists. Likewise, a fourth frame is a cornucopian one, and a fifth and sixth frame add mention of different kinds of potential benefits to the values promoted by cornucopians. The risks mentioned in the second and third frames are health risks and then multiple dimensions of risks (arms race, weapons, environmental and economic), respectively. Potential benefits identified in the fifth and sixth frames

[8] The specific risks and benefits included in the frames were chosen for their plausibility after consultation with multiple experts familiar with nanotechnology.

are, conversely, health benefits and then multiple dimensions of benefits (energy, consumer goods, health and environmental), respectively.

The final three framing conditions, seven though nine, include both risks and benefits. These two-sided frames match each of the three risk frames with each of their logical opposites among the benefits frames. Thus, respondents in the seventh framing condition hear both the conservative humanist and the cornucopian frames. Respondents in the eighth framing condition listen to the health risks and the health benefits frames.[9] In the final condition, respondents hear both multiple dimensions of risks and benefits frames.

Dependent variables

Following studies about risk perceptions and opinions about GMF, the primary dependent variable in this study is a question asking respondents to predict whether the risks of nanotechnology will be greater than, equal to or less than benefits. A second dependent variable measures how much respondents trust industry officials to minimize risks to humans. I ask this question because trust plays an important role in determining citizens' acceptance of new technologies, like GMF (Frewer, Miles and Marsh 2002). A third, fourth and fifth dependent variable measure three types of emotions that respondents might feel about nanotechnology: hope, anger and worry. According to some psychologists, emotions are independent of cognition (Zajonc 1980).

[9] Although the source of frames often matters (Druckman 2001), I do not attribute these frames to any particular person or group. Source attributions would have created far too many conditions and insufficient numbers of respondents in the sub-samples, or alternatively I would have been forced to significantly reduce the types of frames that I examine. Future studies, though, would clearly benefit from examining the effects of source attribution because there is significant variance in trust of industry officials, scientists and government agencies.

Consequently, emotional reactions to people, events or issues supplement and are often superior to cognition at explaining opinions (Loewenstein and Lerner 2003).[10]

Results

I begin the analysis by comparing respondents' opinions about the risks of nanotechnology versus its benefits across the nine framing conditions and the control group. Then, I examine whether framing affected respondents' trust in industry leaders. Last, I analyze framing effects on respondents' emotions about nanotechnology. I present these results in cross-tabular form, opinions by framing conditions, and use Pearson's Chi-Square to test for significant differences in respondents' opinions compared to the control group.[11]

According to the first cut of the data presented in Table 1, one-sided frames are consistently effective, but only when they identify specific risks or benefits about nanotechnology. Neither frame that promoted a particular version of the merits of science alone—conservative humanism or cornucopian—was influential. All four additional one-sided frames, however, created different perceptions about the balance between risks and benefits. Both frames including health risks and multiple kinds of risks about nanotechnology increased the percentages believing that risks will exceed or be equal to benefits. Similarly, both cornucopian frames that included specific benefits

[10] As part of a larger study, I measured multiple independent variables that theoretically mediate framing effects and are important to understanding Americans opinions about science. I do not report here on their independent or moderating effects on opinions about nanotechnology, but these results will be reported in subsequent published work. The effects of one particular variable, whether respondents had read or discussed Michael Crichton's novel, *Prey,* has been analyzed elsewhere (Cobb 2004).

[11] In additional analyses unreported here, I conduct more rigorous tests for significance, using regression and controlling for numerous independent variables' effects. These results are consistent with what I report in this study.

about nanotechnology resulted in more people expecting the benefits to surpass the risks. Interestingly, risk frames never resulted in a plurality of respondents believing that the risks of nanotechnology would be more likely than its benefits. Instead, respondents in the risk frames conditions were simply more skeptical about potential benefits. Conversely, framing nanotechnology as beneficial resulted in an actual majority of respondents in the health benefits condition saying that benefits would prevail, and a solid plurality in the multiple benefits condition saying the same thing.

==Table 1 about here==

As expected, opinion change was less likely to occur in the two-sided framing conditions. Respondents' perceptions were significantly different in just one of these three conditions. In this one case, perceptions of risks unexpectedly increased when respondents heard both the conservative humanist and cornucopian frames. This seems like a statistical anomaly because neither of these particular frames was associated with significant opinion change when they were one-sided. The general pattern of results for two-sided frames is consistent with the claim that framing affects perceptions because one-sided frames have the advantage of an unequal information environment, which is cancelled out when competing frames are heard.

On the second dependent variable, respondents' trust in industry leaders, I find slightly fewer framing effects. Yet, when framing effects exist, they always result in respondents expressing less trust. These results are presented in Table 2.

==Table 2 about here==

According to these data, trust is remarkably low regardless of condition, and it drops even further in several of the one-sided framing conditions. Just 31% of

respondents in the conservative humanism frame reported having some or a lot of trust, for example, compared to 42% in the control group. A second risk frame about multiple types of risks also caused a significant decline in trust. Strikingly, only 26% of respondents in this condition said they had much trust, a decline of 16% compared to the control group. (Oddly, the health risks frame was ineffective, to which there is no good explanation.)

Several other results stand out. First, all three of the two-sided frames failed to produce significantly different opinions. This finding is in-line with prior research that shows framing effects are eliminated when both frames are heard. Second, benefits framing was ineffective. Overall, then, trust was often but not always affected by risk framing, and these effects do not persist when respondents hear counter framing.[12] Yet, the decline in trust is very interesting because the risks used in these frames do not imply industry leaders are at fault; apparently, respondents simply assume they are responsible. This suggests that opponents of nanotechnology might find it easier to attack it on grounds that you "can't trust business to keep it safe" rather than attack it on some of its own specific characteristics.

For the last set of dependent variables, I find that framing affects feelings of hope, anger and worry. While framing effects on emotions were consistent, their sizes were not especially large and respondents' feelings never completely reversed. Respondents did not report feeling hopeful in the control condition, for example, and then claim they were

[12] Curiously, the only time a benefits condition produced opinion change, which was the cornucopian frame, less trust, not more, was expressed. Either this particular finding is a product of random sampling error or the mere discussion of the merits of science raises the specter of scientific dangers that industry leaders are unable or unwilling to prevent. Since the two-sided framing condition with both the conservative humanist and cornucopian frame did not negatively affect trust, however, it appears that sampling error is the more plausible explanation.

unhopeful in any of the framing conditions. Similarly, feelings of anger and worry never approached majority status. Also, despite the systematic pattern to the framing effects, no specific frame influenced more than one type of emotion. These results are presented in Table 3.

==Table 3 about here==

Framing nanotechnology as risky resulted in respondents reporting more negative feelings. More precisely, risk frames caused respondents to feel less hopeful about nanotechnology and in one case it increased their worry about it. For example, the conservative humanism frame and the health risks frame caused fewer respondents to feel hopeful about nanotechnology, 78% and 73%, respectively, compared to 83% in the control group. Yet, the maximum size of a framing effect on any emotion was +/- 10% compared to the control group. Another important aspect to these effects is that hope overwhelms the negative emotions, and even when it declines in a risk framing condition, at least 73% of respondents remain hopeful about nanotechnology. Likewise, exposure to the multiple risks frame increased respondents' worry about nanotechnology, but even then only about one-third of them felt this way, the highest percentage of worried respondents in any condition.

In contrast to the frames for trust, the benefit frames for emotions produced a similar number of effects as risk frames. When nanotechnology was framed as beneficial, respondents reported feeling less angry about nanotechnology. While 18% of respondents in the control group said they were angry about nanotechnology, for example, the highest percentage of respondents in any benefits condition saying they were angry was 13%, and in two conditions that percentage was just 9%. This result is

impressive considering it is difficult for any stimulus to reduce the already low percentage of respondents angry about nanotechnology in the control group.

One final observation worth noting is that risk frames affected hope while benefits frames affected anger and worry. With one exception, respondents in anti-nanotechnology framing conditions reported less positive feelings about nanotechnology instead of increased negative emotions. Conversely, respondents in the pro-nanotechnology conditions said they felt less negative about nanotechnology rather than more hopeful. Importantly, these patterns do not merely reflect ceiling and floor effects. Feelings of hopefulness were high, for example, so it might appear that risk framing worked only because it would be easier to produce a decline than an increase in feeling hopeful. Yet, negative emotions about nanotechnology were uncommon in the control group and they became even rarer after listening to potential benefits, which should not have happened if floor effects were present.

Discussion

Somewhat expectedly, philosophical frames about the merits of science were only sporadically influential. Successful framing usually required the mention of specific risks and benefits about nanotechnology. In the instances when philosophical frames were effective, the conservative humanism position was more likely to be influential.

As would be expected by the literature, frames including risks of nanotechnology were more successful than ones mentioning benefits; however, the differences were not overwhelming. Hearing about the risks of nanotechnology, for example, lowered respondents' trust in industry leaders and they reported feeling less hopeful about it.

Respondents exposed to risk frames were also less likely to expect benefits. Benefits framing had less impact. For example, framing nanotechnology in terms of its benefits did not increase respondents' trust in industry leaders. However, respondents in benefit framing conditions were somewhat less angry and worried about nanotechnology and more likely to think its benefits would outweigh its costs.

Two additional findings have broad implications for future mass opinion about nanotechnology. One is that two-sided frames generally failed to produce opinion change, and a second is that framing effects in general were not especially large. The inability of two-sided frames to work suggests that opinion change about nanotechnology will be easier to produce in biased information environment where one side of the debate is able to effectively monopolize the framing of the issue to their advantage. Even though risk frames were somewhat more effective than benefit frames, for example, this appears to be the case only when frames are heard in isolation of one another. Assuming media outlets make an effort to cover competing ways of framing nanotechnology, ambivalence rather than opinion change is the most plausible of an outcome.

Another reason to expect restrained opinion change about nanotechnology is that respondents' perceptions were not fundamentally altered in this study. Opinions never completely reversed from support to opposition, for example, or from untrusting to trusting. Likewise, respondents were less hopeful after hearing a risk frame, but they never became unhopeful. In fact, the typical difference between opinions in the control group and a successful framing condition was usually around 10%. To be sure, these differences are meaningful, but they do not portend an immense advantage for either side of the debate. The implication is that unless citizens are exposed to different frames and

information that are qualitatively different than those used in this study, we should not expect a sudden or massive shift in public opinion about nanotechnology.

From another perspective, these findings are somewhat puzzling. When citizens lack information and hardened opinions about an issue, these conditions are thought to facilitate framing effects. So why were the framing effects in this study rather small? I conclude by exploring four possible answers to this puzzle and their implications for future opinions.

Hard Issues

One explanation for the limited magnitude of the framing effects is that nanotechnology is the kind of issue that Carmines and Stimson (1980) labeled "hard." By this, they mean that the issue is new, complicated and unfamiliar to most people. People have a difficult time forming consequential opinions on hard issues. Nanotechnology is incredibly complex and most Americans do not think very often or deeply about scientific issues (National Science Board, Science and Engineering Indicators 2002). Thus, framing is arguably less effective on these kinds of issues because people are unable to connect the frame to the issue, and since the issue is a hard one they are not motivated to do so. In turn this suggests that until more Americans become familiar with nanotechnology, different ways of framing the issue are probably limited to creating modest effects. The likely reason that frames about nanotechnology were effective at all is because some frames can be easy to understand even if the issue is a hard one (Cobb and Kuklinski 1997). Anyone can appreciate framing about nanotechnology that talks about protecting human health (i.e., "nanotechnology is

dangerous to human health because nanoparticles cause cancer"), even if most people fail to grasp the intricacies of nanomanufacturing.

Forms of communication

Although I am unaware of the existence of a formal study comparing framing effect sizes by the method of survey administration, it seems likely that effects are smaller when studies are conducted by phone rather than in-person and when they are self-administered. The reason is that it is harder to follow and remember question wording over the phone. In addition, the frames used in this study, although brief by extant standards, might be too long to fully remember over the phone. This would imply that framing effects on nanotechnology could be more robust than I find here because frames are easier to comprehend during other more common forms of real world information dissemination, such as watching television, reading newspapers or talking with friends face-to-face. Thus, repeated exposure to framing via different forms of communication might increase the size of framing effects, and reveal greater instability of opinions about nanotechnology than found here.

Sources of frames and elite polarization

Another plausible explanation is that the frames in this study were not sourced. I intentionally avoided identifying sources of frames because the additional variable would have overburdened an already complex experimental design. In the real world, however, frames are rarely read or heard without attribution. Usually the source of a frame is a social, political or economic elite, which is important because citizens rely on elites as a

primary heuristics when forming opinions about issues (Zaller 1992). Credible elites will undoubtedly enhance the effectiveness of framing. In Britain, for example, Prince Charles' criticisms of nanotechnology probably gave credence to critics' complaints, whereas opposition elites in the U.S. are unknown to most people. When elites are unified on an issue, public opinion is expected to follow along. If elites disagree, however, public consensus can disappear too.

Kinds of risks

A final possible cause of limited framing effects is suggested by studies of risk perceptions. Risk perception research reveals that citizens, in contrast to experts, place potential hazards on a two dimensional space, one end anchored by the magnitude of the risk ("dread") and the other by its controllability (Slovic 1987). Researchers consistently find that the social response to risk maps onto the placement of hazards in this two dimensional space. The more catastrophic and the less controllable a hazard is perceived to be, the more fearful people will be about it. Thus, at least for the risk framing conditions, small effects might have occurred because the specific risks identified in this study were not perceived as being catastrophic and they were seen as controllable. This might explain why 12% of respondents in this survey named self-replicating nanorobots, which is an often ridiculed scenario, as the risk of nanotechnology they most wanted to avoid (Cobb and Macoubrie 2004). Regardless of the actual possibility of a "grey-goo" scenario, it conjures up images of both dread and a lack of control.

Risk perception studies, however, are less helpful for understanding how certain issue like nanotechnology will move from one location to another in this two-dimensional

space. Arguably, framing of an issue will contribute to its placement in this space. Framing nanotechnology as facilitating the invasion of one's privacy, for example, might be an especially powerful frame because it implies a lack of controllability. Most likely, nanotechnology will be considered more risky only if credible new information emerges that it poses unmanageable catastrophic risks. Of course, the difficulty is predicting what kinds if information will be seen as credible. It will probably require real-world negative outcomes before mass opinion about nanotechnology would turn solidly negative.

Conclusion

The results presented here suggest that opinions about nanotechnology are malleable but that there are limits to changing opinions. Americans begin with a basically positive view of nanotechnology and that—despite its weak factual basis—this view remains surprisingly constant even when exposed to negative frames. Other main findings include: (1) even in an area with opinions based on little specific knowledge, general frames (overall attitudes towards science) produced less effect; (2) positive frames were sometimes almost as efficacious as negative eons, in contrast to past findings; and (3) trust of elites was low and easily driven lower by negative frames.

Studies like this one provide important insights into the effect of framing on a broad category of public policy—complex issues where the public is ill-informed and knows it. Thus, the findings here may well have implications for framing in other areas, including medical issues, tax policy, weapons policy and complex social programs.

Appendix A: Wording for Framing Conditions

Condition 1: Control group

"Nanotechnology is the process of manipulating materials at the minuscule level of atoms and molecules. Another way to say this is that nanotechnology refers to the manipulation of living and non-living matter at the level of the nanometer, one billionth of a meter."

Condition 2: Conservative Humanist

Control group statement plus: "Some scientists warn that nanotechnology will not be a "silver bullet" for resolving the wants and needs of mankind. They say we have to avoid the seduction of technology as a cure for everything because the human condition cannot be conquered by modern technology."

Condition 3. Conservative Humanist/Health Risks

Control group statement plus Conservative Humanist Frame plus: "They say nanotechnology might be dangerous to humans. Researchers have discovered that nanoparticles are showing up in the livers of research animals, they can seep into living cells, and perhaps piggyback on bacteria to enter the food chain."

Condition 4. Conservative Humanist/Multiple Risks

Control group statement plus Conservative Humanist frame plus: "They say nanotechnology might cause competing nations to enter a disruptive and unstable arms race. Sinister weapons and surveillance devices could be made small, cheap, powerful, and very numerous. Cheap manufacturing and duplication of designs could lead to economic upheaval. And overuse of inexpensive products could cause widespread environmental damage."

Condition 5. Cornucopian

Control group statement plus: "Some scientists say that we are not optimistic enough about nanotechnology. They say it is not possible to project the fantastic worlds which nanotechnology will continue to open up to us in the coming years. Science inevitably leads to human progress and the Earth is inexhaustible because new technologies create new resources."

Condition 6. Cornucopian/Health Benefits

Control group statement plus Cornucopian frame plus: "They say nanotechnology will improve human health, physical and mental abilities. Researchers expect to create new medical tools to detect diseases earlier and treat them more effectively; such as implanting tiny drug delivery systems that automatically administer drugs that go where they are needed most."

Condition 7. Cornucopian/Multiple Benefits

Control group statement plus Cornucopian frame plus: "They say nanotechnology can make solar power a primary and abundant energy source; greatly reduce infectious diseases; make computers and display devices stunningly cheap; make stronger fabrics and safer bumpers on cars; and even make products with far less waste to protect the environment."

Condition 8. Conservative Humanist vs. Cornucopian

Control Group statement plus: "Some scientists warn that nanotechnology will not be a "silver bullet" for resolving the wants and needs of mankind. They say we have to avoid the seduction of technology as a cure for everything because the human condition cannot be conquered by modern technology. Other scientists say that we are not optimistic enough about nanotechnology. They say it is not possible to project the fantastic worlds which nanotechnology will continue to open up to us in the coming years. Science inevitably leads to human progress and the Earth is inexhaustible because new technologies create new resources."

Condition 9. Health Risk vs Health Benefit

Control group statement plus: "Some scientists say nanotechnology might be dangerous to humans. Researchers have discovered that nanoparticles are showing up in the livers of research animals, they can seep into living cells, and perhaps piggyback on bacteria to enter the food chain. Other scientists say nanotechnology will improve human health, physical and mental abilities. Researchers expect to create new medical tools to detect diseases earlier and treat them more effectively; such as implanting tiny drug delivery systems that automatically administer drugs that go where they are needed most."

Condition 10. Multiple Risks vs Multiple Benefits

Control group statement plus: "Some scientists say nanotechnology can make solar power a primary and abundant energy source; greatly reduce infectious diseases; make computers and display devices stunningly cheap; make stronger fabrics and safer bumpers on cars; and even make products with far less waste to protect the environment. Other scientists say nanotechnology might cause competing nations to enter a disruptive and unstable arms race. Sinister weapons and surveillance devices could be made small, cheap, powerful, and very numerous. Cheap manufacturing and duplication of designs could lead to economic upheaval. And overuse of inexpensive products could cause widespread environmental damage."

Appendix B: Question wording, Variables and Original Coding

RISKS vs. BENEFITS: "There is a lot of talk about the potential risks and benefits of nanotechnology. What do you think? Do you think the benefits of nanotechnology will outweigh the risks, the risks will outweigh the benefits, or will the risks and benefits be about equal?"

1 = risks > benefits
2 = risks = benefits
3 = benefits > risks

TRUST: "How much do you trust business leaders within the nanotechnology industry to minimize potential risks to humans? Do you trust them a lot, some or not that much?"

1 = A lot
2 = Some
3 = Not that much

EMOTIONS (WORRY, HOPE, ANGER): "The next set of questions asks about emotions you might feel. Are you [worried/hopeful/angry] about nanotechnology? How [worried/hopeful/angry] are you?

0 = No, not [worried, angry, hopeful]
1 = Yes, a little [worried, angry, hopeful]
2 = Yes, somewhat [worried, angry, hopeful]
3 = Yes, very [worried, angry, hopeful]

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Table 1. Respondents' Perceptions of Risks and Benefits of Nanotechnology, by Framing Condition

Condition	Risks > Benefits	Risks = Benefits	Risks < Benefits
Control Group	20% (64)	40% (125)	40% (126)
Conservative Humanism	23% (30)	35% (46)	42% (54)
Cornucopian	14% (18)	46% (80)	41% (53)
Health risks***	32% (42)	37% (48)	31% (40)
Health Benefits***	18% (23)	28% (36)	54% (69)
Multiple Risks***	32% (42)	35% (46)	33% (43)
Multiple Benefits**	12% (15)	41% (53)	48% (63)
Conservative Humanism versus Cornucopian*	29% (38)	37% (49)	34% (45)
Health Risks versus Health Benefits	22% (28)	39% (51)	39% (51)
Multiple Risks versus Multiple Benefits	20% (27)	43% (57)	37% (50)

Note: Entries are percentages; number of respondents is in parentheses.
***p<.05; **p<10; *p<.15, Pearson Chi-Square Tests (responses in each of the framing conditions are compared to the control group).

Table 2. Respondents' Trust in Business Leaders Minimizing Risks to Humans, by Framing Condition

Condition	Not Much Trust	Some or A lot of Trust
Control Group	58% (190)	42% (140)
Conservative Humanism	69%*** (92)	31% (42)
Cornucopian	67%** (90)	33% (44)
Health risks	62% (83)	38% (51)
Health Benefits	58% (78)	42% (56)
Multiple Risks	74%*** (98)	26% (35)
Multiple Benefits	56% (75)	44% (58)
Conservative Humanism versus Cornucopian	58% (78)	42% (56)
Health Risks versus Health Benefits	52% (70)	48% (64)
Multiple Risks versus Multiple Benefits	55% (73)	45% (61)

Note: Entries are percentages; number of respondents is in parentheses.
***p<.05; **p<10; *p<.15, Pearson Chi-Square Tests (responses in each of the framing conditions are compared to the control group).

Table 3. Respondents' Emotions about Nanotechnology, by Framing Condition

Condition	Hope	Anger	Worry
Control Group	83% (275)	18% (59)	26% (84)
Conservative Humanism	78%* (104)	17% (23)	25% (33)
Cornucopian	81% (109)	13% (17)	23% (31)
Health risks	73%*** (98)	13% (17)	31% (41)
Health Benefits	88% (118)	9%*** (12)	25% (34)
Multiple Risks	81% (108)	17% (23)	34%** (46)
Multiple Benefits	87% (117)	9%*** (12)	27% (36)
Conservative Humanism versus Cornucopian	79% (106)	13% (18)	25% (34)
Health Risks versus Health Benefits	84% (112)	10%*** (14)	31% (41)
Multiple Risks versus Multiple Benefits	84% (112)	13% (18)	31% (41)

Note: Entries are percentages; number of respondents is in parentheses.
***p<.05; **p<10; *p<.15, Pearson Chi-Square Tests (responses in each of the framing conditions are compared to the control group).