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Technology and applications

Public perceptions about nanotechnology: Risks, benefits and trust

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Abstract

We report data from the first representative national phone survey of Americans' perceptions about nanotechnology ($N = 1536$). Public opinion about nanotechnology is in its infancy, and knowledge about it is quite limited. Yet, Americans' initial reaction to nanotechnology is thus far generally positive, probably rooted in a generally positive view of science overall. Survey respondents expected benefits of nanotechnology to be more prevalent than risks, and they reported feeling hopeful about nanotechnology rather than worried. Their most preferred potential benefit of nanotechnology is "new and better ways to detect and treat human diseases," and they identified "losing personal privacy to tiny new surveillance devices" as the most important potential risk to avoid. The most discouraging aspect to the data is respondents' lack of trust in business leaders to minimize nanotechnology risks to human health. Overall, these data indicate that while Americans do not necessarily presume benefits and the absence of risks, their outlook is much more positive than not.

Introduction

Perception and knowledge are important parts of public understanding of science. Public perceptions about science can be influential, for example, such as when worldwide perceptions about genetically modified foods adversely affected their sales (Ferber, 1999; Gaskell et al., 1999; National Academy of Sciences, 2000). According to recent studies in several countries, however, governments' and scientists' misunderstanding the source of public concerns is an additional problem affecting public perceptions of science and technology (Priest, 1995; Leggett & Finlay, 2001; Robins, 2001; Tytler et al., 2001). Contrary to what scientists tend to worry about, public fears about technology risks are less about risks directly attributable to a technology than the social and regulatory context in which they are embedded. Consequently, these authors warn that misinterpreting public concerns is leading to an increasingly dissatisfied public, and one even less inclined to trust corporate scientists and regulators.

We believe experts will benefit from understanding the underpinnings of public perceptions about science, and learning about the topics the public most wants to be informed about (Roco, 2003). When citizens perceive that scientists take their concerns into account, this promotes greater public trust in the relevant actors and institutions. As the study to be discussed here will show, trust plays an important part in public opinion about nanotechnology. Thus, our point seems especially salient for nanotechnology scientists and regulators, since nanotechnology is presumed to become a very significant force in science and economics world wide. In fact, the National Science Foundation (NSF) has already increased their funding

of research that studies the social implications of nanotechnology (Roco & Bainbridge, 2001), and is presently promoting new methodologies for early public involvement in nanotechnology policy.

To discover the status of US public concern or interest in nanotechnology, we recently conducted a national survey of nanotechnology attitudes and knowledge. Prior to our study, only one large survey had been conducted, but it was based on a non-random sample that took place over the Internet in 2001 (Bainbridge, 2002). Although the sample size of the earlier web survey was impressive ($N = 3909$), there are enough questions about the validity of web samples to warrant further examination of public perceptions (Couper, 2000). In addition, while the information provided by the web survey is valuable for establishing a benchmark of some basic perceptions about nanotechnology, only a few questions about it were included in the survey. Last, as Bainbridge acknowledges, respondents in the web survey were intentionally selected for their greater interest in and knowledge of science. A more broadly representative survey of public perceptions of nanotechnology is therefore desirable because we simply do not know what the general public believes.

We expected a nationally representative sample would include a large percentage of "uninformed opinions" about nanotechnology. Not only is nanotechnology a new science, but also Americans rank following science in general as a low priority (NSF 2002: 7–9; appendix, Table 7-7). Even uninformed opinion is worth examining, however, because mass opinion affects policy direction and yet it is routinely ill-informed (Page & Shapiro, 1992). While mass preferences do not usually dictate scientific policy choices, and to some skeptics they should not, public opinion can affect success or failure of new technologies and their products.

Although we are justifiably interested in mass opinion, an additional research goal was to investigate whether the variance in individuals' level of information about nanotechnology affects their perceptions and recommendations for nanotechnology policy. In politics, for example, knowledge is strongly associated with citizens' preferences, and citizen knowledge levels are thought to affect the quality of governance (Delli Carpini & Keeter, 1989). The relationship between knowledge and preferences might not be perfectly understood with these data because we find a rather small number of highly knowledgeable individuals in our sample. The national survey we report here is also part of a larger project designed to methodically answer this and other questions by comparing public perceptions across: (1) an uninformed condition (the national survey), (2) a moderately informed condition (quasi-experimental discussion groups around the country), and (3) a fully informed condition (two three-month long Citizens Technology Forums, based on the Danish-model Citizens Consensus Conference). These comparisons cannot be made at this time, however, because data collection for one of these studies is still underway.

Methodology

The national survey of public attitudes about nanotechnology was a random-digit dialed survey of adults 18 years or older in the continental US between late March and early April of 2004 ($N = 1536$).[1] Every household in the continental US with a land phone line had an equal probability of being contacted. The response rate was between 38% and 48%, depending on which particular American Association of Public Opinion Research (AAPOR) standard is used. Estimates for the entire sample have a margin of error of plus or minus 2.5%; however, the error will be larger for responses of sub-groups within the sample.

Our survey research investigates a number of theoretical and practical concerns. We ask: What does the public currently know about nanotechnology? How does knowledge about nanotechnology affect attitudes towards it? Do risks dominate public perceptions, or is there a balanced view of risks and benefits? Are more informed citizens more positive in their assessments, or more skeptical? How much have science fiction portrayals of nanotechnology (such as Michael Crichton's novel *Prey*) affected public perceptions?

[1] An experiment was embedded within the survey so that 330 respondents were in a control group and the rest were divided equally into nine conditions ($N = 134$). Except for the control group, each of the other conditions was exposed to a unique frame, otherwise known as an argument, about the risks or benefits of nanotechnology. We do not report the framing experiment results in this study.

There are many more questions we have asked, and the data set is extensive, so it is feasible to only report a portion of the total survey results here.

Measures

Unlike Bainbridge's (2002) web survey, we were able to include a large number of questions about nanotechnology because the measurement of these attitudes was the sole purpose for conducting this study (the survey questions and our coding of answers are reproduced in the Appendix). To measure respondents' knowledge, we included an item measuring respondents' familiarity with nanotechnology ("how much have you heard") and three additional "true or false" factual questions that include self-assessments of confidence and admissions of guessing. We also measured respondents' perceptions of nanotechno1ogy risks and benefits, the salience of specific kinds of risks and benefits, emotional reactions to the concept of nanotechnology, and levels of trust in technology business leaders. A final substantive question we asked was not directly about nanotechnology, but instead one about respondents' views of science in general.

Important demographic characteristics about our sample were also recorded, such as age, sex, educational background, race and political ideology. We also asked respondents whether they liked to read science fiction books and specifically if they had read or discussed with anyone Michael Crichton's novel, *Prey*. For many Americans, *Prey* is potentially an important source of information about nanotechnology. Given its ominous if implausible portrayal of nanotechnology, we hypothesized that it might have negatively affected public perceptions.

Results

Most of the analysis we present is simply descriptive survey data, though sometimes we examine relationships between variables using cross-tabs and regression models to more rigorously control for the effects of demographics. We pay particular attention to the relationship between knowledge about nanotechnology and other attitudes, and having read or discussed *Prey* of relationships with these attitudes. To make the presentation easy to follow, we collapsed the four-point knowledge scale into a dichotomous variable, measuring knowledge about nanotechnology as high or low.

Knowledge

We start by presenting data on respondents' familiarity and knowledge about nanotechnology. Clearly, and as expected, most Americans are unfamiliar with nanotechnology. More than 80% of survey respondents indicated that they had heard "little" or "nothing" about nanotechnology (Table 1). Unsurprisingly, most Americans also possessed minimal factual knowledge about it. On average, respondents could answer just one of three factual "true or false" questions correctly (Table 2).[2]

Table 1. Americans' familiarity with nanotechnology

Answer	*N*	%
"Heard nothing"	796	51.8
"Heard a little"	488	31.8
"Heard some" or "A lot"	252	16.4
Total	1536	100

Table 2. Content knowledge: Number of correct "True or False" answers

Number of correct answers	*N*	%
Zero	453	29.5
One	508	33.1
Two	528	34.4
Three	47	3.1
Total	1536	100

[2] To control for guessing, we asked respondents how confident they were in each answer, and to self-report guessing. If a respondent answered correctly but reported guessing, their answer was recoded as false. We were therefore able to create a four-point knowledge scale; correct answers received a "1" and incorrect and "no answers" received a "0". The mean of the four-point scale is just 1.1.

Risks versus benefits

Even though Americans possess little knowledge about nanotechnology, a plurality predicted the greater probability of beliefits than risks. Table 3 presents these results. For the entire sample, a sizeable percentage (38%) thought risks and benefits would be about equal, and slightly more (40%) predicted that nanotechnology would produce more benefits than risks, while only half that many (22%) said risks would outweigh the benefits.

When the risks versus benefits data are examined by respondents' level of knowledge about nanotechnology, it is clear that greater knowledge is associated with more positive perceptions of risks and benefits. Respondents who scored "high" on knowledge were much more likely to predict that benefits would exceed the risks, and less likely to think that risks would surpass benefits. Half (50%) of the high knowledge respondents predicted greater benefits while just 34% of the low knowledge respondents make the same forecast.

Like knowledge, a simple but powerful relationship exists between respondents' view of science and their predictions of benefits versus risks of nanotechnology (Table 4), Apparently, respondents to some degree use their views of science in general as a "heuristic" to construct their perceptions of risks and benefits of nanotechnology. About the same percentages of respondents who expect balanced benefits and risks, or largely benefits, believe science equally solves and creates problems (41%) and largely overcomes problems (47%). Respondents who perceive that science largely creates problems (11%) also predict that risks will be greater.

Which risks and benefits?

The scientific literature describes nanotechnology as being predicted to produce a large number of benefits to society, and less frequently discusses possible risks (Colvin, 2004). Some public media, however, focus more on the risks of nanotechnology. For the public, are particular hypothesized risks or benefits seen as more important to avoid or achieve than others? We try to answer this question by asking respondents to pick one (and only one) of five potential risks and benefits as the most important to avoid or obtain. (Tables 5 and 6). The choice of which risks and benefits to include in the list was made by reviewing the literature on nanotechnology and consulting with scientists who work in the field to identify the more popularly discussed possibilities.

For benefits, one choice commanded a majority preference: "new ways to detect and treat human diseases." While consumer products might be the engines of nanotechnology commerce in the

Table 3. Perceptions of risks and benefits of nanotechnology, by respondent's knowledge

	Risks > Benefits	Risks = Benefits	Risks < Benefits
Low knowledge (zero or one correct)	N = 225 24.2%	N = 388 41.8%	N = 315 33.9%
High knowledge (two or three correct)	N = 102 18.1%	N = 183 32.4%	N = 279 49.5%
Entire sample	N = 327 21.9%	N = 571 38.3%	N = 593 39.8%

Table 4. Perceptions of risks and benefits of nanotechnology, by respondents' views of science

	Risks > Benefits	Risks = Benefits	Risks < Benefits
Science creates problems	N = 104 61.2%	N = 49 28.8%	N = 17 1.0%
Science equally creates/overcomes	N = 126 20.7%	N = 317 52.1%	N = 165 27.1%
Science overcomes problems	N = 97 13.6%	N = 205 28.8%	N = 411 57.6%

Table 5. Most important potential benefit of nanotechnology to achieve

Choice of benefit to achieve	*N*	%
Cheaper, better consumer products	58	3.8
New ways to detect and treat human diseases	878	57.2
Increased national security and defense	180	11.7
New ways to clean the environment	243	15.8
Physical and mental improvements for humans	177	11.5
Total	1536	100

Table 6. Most important potential risk of nanotechnology to avoid

Choice of risk to avoid	*N*	%
Economic disruption	212	13.8
Losing personal privacy	490	31.9
Arms race	365	23.8
Breathing nano-particles that accumulate in body	282	18.6
Uncontrollable spread of nano-robots	184	12
Total	1536	100

immediate future, other potential benefits appear to be more important to respondents. Most interestingly, even after 9/11 and the war in Iraq, increased national security benefits of nanotechnology still ranked less highly than environmental benefits.

Unlike answers about benefits, there was no consensus as to which risk is perceived to be the most important one to avoid. The plurality opinion is that "losing personal privacy" is the most important to avoid (31.9%). Although the scenario of self-replicating nano-organisms ("grey goo") was identified by the smallest percentage of respondents as the most important risk to avoid, another way to view this result is to be surprised that as many as 12% picked it as the highest risk even though many highly respected scientists consider it an improbable outcome.

Interestingly, respondents' level of knowledge about nanotechnology is minimally related to the choices they make about risks and benefits to avoid or achieve. We do not report these data in tabular form because of the lack of an obvious relationship. Knowledge generally has no relationship to specific types of benefits, except that it affects the percentage choosing an arms race as the most important risk to avoid. Whereas 20% of low knowledge respondents pick this risk, 31% of high knowledge respondents choose this one. Otherwise, the distribution of choices was nearly identical.

Emotions

Many social scientists accept that emotions serve an important, if not primary, role in the construction of attitudes (Marcus et al., 2000; Marcus, 2002). Anticipating that Americans' factual knowledge about nanotechnology would be limited, measures of emotional reactions to nanotechnology were included in the survey. We hypothesized that emotions might be more strongly related to perceptions about nanotechnology than cognitive measures.

The data presented in Tables 7–9 indicate that most Americans hold positive and not negative emotions when asked how they feel about nanotechnology. Very few Americans report being angry about nanotechnology, and a solid minority reports feeling worried. Indeed, about four out of every five respondents claim not to be worried at all. Conversely, about 70% said they are very or somewhat hopeful about nanotechnology. Although the presence of positive emotions is not as strong as the absence of negative emotions, the

Table 7. Feeling hopeful about nanotechnology

Answer	*N*	%
Not hopeful	277	21.2
Only a little hopeful	114	8.7
Somewhat hopeful	475	36.3
Very hopeful	443	33.8
Total	1309	100

Table 8. Feeling worried about nanotechnology

Answer	*N*	%
Not worried	1115	80.3
Only a little worried	59	4.2
Somewhat worried	133	9.6
Very worried	82	5.9
Total	1389	100

Table 9. Feeling angry about nanotechnology

Answer	*N*	%
Not angry	1323	94.8
Only a little angry	11	0.8
Somewhat angry	27	1.9
Very angry	35	2.5
Total	1396	100

overall picture of emotional responses is very favorable toward nanotechnology. In results not shown here, even respondents who are worried about nanotechnology, except for those who are ''very worried,'' also express their hopefulness about nanotechnology.

Positive emotions, however, are not distributed evenly by respondents' level of knowledge. While knowledge does not affect feeling angry or worried, it strongly shapes feeling hopeful (Table 10). Less knowledge about nanotechnology is associated with far less hopefulness than more knowledge. Almost 27% of low knowledge respondents reported not feeling hopeful about nanotechnology, but just half that percentage (13%) of high knowledge respondents said they feel that way. Conversely, while just 27% of low knowledge respondents claim to be very hopeful, 44% of high knowledge respondents say the same thing.

Trust

A majority of Americans report low trust in business leaders within the nanotechnology industry to protect them from potential risks (Table 11). Slightly more than 60% of respondents said they had ''not much trust'' in business leaders' ability or willingness to minimize risks to humans. Although a sizeable percentage claimed to have ''some'' or ''a lot'' of trust (40%), fewer than 5% of the sample said they had ''a lot'' of trust. The amount of trust respondents have is not significantly related to knowledge about nanotechnology, but it is strongly associated with perceptions of specific potential risks and benefits (Table 12). Less trust also results in more respondents claiming that risks will outweigh benefits.

Table 10. Feeling hopeful by level of knowledge

	Not hopeful	Only a little hopeful	Somewhat hopeful	Very hopeful
Low knowledge	26.5% (206)	10.7% (83)	36.2% (282)	26.6% (207)
High knowledge	13.4 (7.1.)	5.8% (31)	36.3% (193)	44.4% (236)

Note: Entries are percentages and the number of respondents is in parentheses.

Prey

Our last set of basic survey results presents the associations between reading or discussing the novel *Prey* and holding particular attitudes about nanotechnology. We find evidence that being exposed to *Prey* significantly affects respondents' perceptions of risks versus benefits (Table 13), although not in the expected direction, as well as their choice of the specific risk to avoid and the benefit to achieve (Tables 14 and 15). In the next section, though, we show that some of these effects

Table 11. Trust that business leaders will minimize risks of nanotechnology

Answer	*N*	%
''Not much''	927	60.4
''Some what'' or ''A lot''	607	39.6
Total	1534	100

Table 12. The relationship between trust and perceptions of risks and benefits of nanotechnology

	Risks > Benefits	Risks = Benefits	Risks < Benefits
''Not much''	$N = 250$ 27.8%	$N = 338$ 37.6%	$N = 312$ 34.7%
''Some what'' or ''A lot''	$N = 77$ 13.1%	$N = 231$ 39.2%	$N = 282$ 47.8%
Total	$N = 327$ 21.9%	$N = 569$ 38.2%	$N = 594$ 39.9%

Table 13. Exposure to *prey* and perceptions of the risks and benefits of nanotechnology

Read or talked about Prey?	Risks > Benefits	Risks = Benefits	Risks < Benefits
No	$N = 311$ 23%	$N = 541$ 40%	$N = 517$ 38%
Yes	$N = 16$ 13%	$N = 30$ 24%	$N = 77$ 63%

Table 14. Exposure to prey and the most important potential benefit to achieve

Read or talked about Prey?	Cheaper, better consumer products	New ways to detect and treat human diseases	Increased national security and defense	New ways to clean the environment	Physical and mental improvements for humans
No	$N = 56$ 4%	$N = 790$ 56%	$N = 169$ 12%	$N = 232$ 17%	$N = 163$ 12%
Yes	$N = 2$ 4%	$N = 88$ 70%	$N = 11$ 9%	$N = 11$ 9%	$N = 14$ 11%

Table 15. Exposure to prey and the most important potential risk to avoid

Read or talked about *Prey*?	Economic disruption	Losing personal privacy	Nanotechnology inspired arms race	Breathing nano-particles that accumulate in body	Uncontrollable spread of nano-robots
No	$N = 198$ 1%	$N = 463$ 33%	$N = 313\%$ 22%	$N = 270$ 19%	$N = 166$ 12%
Yes	$N = 14$ 11%	$N = 27$ 21%	$N = 52$ 41%	$N = 15$ 12%	$N = 18$ 14%

might be spurious and a product of the demographics associated with the kind of person who would read or discuss *Prey*.

According to the data in Table 13, *Prey* has a counter-intuitive effect on perceptions of risks *versus* benefits. A whopping 63% predicted that benefits of nanotechnology would exceed the risks if they were exposed to *Prey,* compared to just 38% is they weren't exposed to it.[3] Likewise, just 13% thought risks would surpass the benefits if they were exposed to *Prey,* while 23% said this if they weren't, Although the effects were far less dramatic, reading or discussing *Prey* also affects the salience of particular risks and benefits. Compared to those who did not hear about *Prey,* a greater percentage of respondents identified "new ways to treat and detect human diseases" as the most important benefit and a smaller percentage chose "new ways to clean the environment," Similar findings existed for risks. Those who heard about *Prey* were less likely to identify "losing personal privacy" as the most important risk to avoid, but they were much more likely to name a "nanotechnology inspired arms race" as that risk.

Risk versus benefits: A multivariate OLS regression model

Thus far, we have largely presented basic descriptive data. We have also identified several suggestive relationships between attitudes, but since we have not controlled for the influence of respondents' demographics, it is possible that the relationships we highlighted are spurious. To test this possibility, we conduct several regression analyses to more rigorously examine the potential correlates of nanotechnology attitudes. Two of the four nanotechnology items we considered to be dependent variables, however, the specific risk or benefit respondents preferred to avoid or obtain, have responses that are not coded in a way that permits regression analyses to be conducted.[4] We therefore limit these types of analyses to the questions of

[3]Although we report results later in the paper that rigorously control for the effects of other variables, one obvious possibility was ruled out here: this finding does not appear to just be the product of liking to read, science fiction, While most respondents who read or discussed *Prey* also like to read science fiction, there are hundreds more respondents who like science fiction but have not been exposed to *Prey*. A simple cross-tab analysis suggests that the effect of liking science fiction on perceptions of risks versus benefits is far more muted than that for *Prey*.

[4] The answer options to each of these questions are not linear or dichotomous, so regression is inappropriate. We recoded both variables as a series of dichotomous comparisons between the items respondents chose versus all other possibilities, but this creates 10 dependent variables and makes the presentation of our results far more complex than it needs to be. Results of these analyses, however, are available upon request.

trust in business leaders and whether risks or benefits are expected to be more prevalent.

Table 16 presents the OLS regression results for respondents' perceptions of whether risks or benefits will prevail. Independent variables included in the model are respondent demographics and measures of reading science fiction, exposure to *Prey,* trust in business leaders, familiarity and knowledge about nanotechnology, emotions about nanotechnology and views about science in general. Respondents' perceptions of risks *versus* benefits are coded as a three-point variable; −1 if risks are thought to outweigh benefits, 0 if they are thought to be equal, and 1 if benefits are thought to outweigh risks.

Only two demographic variables explain perceptions of risks *versus* benefits: race and education. We find that whites and more educated respondents are more likely to perceive benefits exceeding risks. Other significant variables include trust, feeling worried or hopeful, views on science, and familiarity with nanotechnology. The more that respondents' trust business leaders, the more likely they think benefits will outweigh risks. Feeling hopeful has the same effect, while feeling worried is correlated with a greater perception of risks. If respondents have a positive view of science in general, they also are more likely to say benefits will be greater, Likewise, the more respondents say they have heard about nanotechnology, the more they see benefits outweighing the risks. We do not find, however, an effect for knowledge about nanotechnology or exposure to *Prey*. The effects we reported earlier for *Prey* and know1edge are apparently caused by different respondent characteristics and attitudes.

Table 17 presents logistic regression results for respondents' trust in business leaders. We use logistic regression because the dependent variable, trust, is coded as a dichotomous variable; 0 for "not much" trust and 1 for "some" and "a lot" of trust, The same independent variables are included in this regression mode1 as before, except trust is obviously moved from the "right-hand" side of the equation to the "left-hand" side. Although the variance in respondents' trust in business leaders is not as wel1 explained as perceptions of risks *versus* benefits (the Nagelkerke R^2 is only 0.09), some interesting findings emerge. First, even though the descriptive data made it appear that *Prey* did not influence trust, the regression analysis indicates that exposure to the novel significantly correlates with less trust. Those exposed to *Prey* are less trusting of business leaders. Second, feeling angry is also associated with reduced trust, but feeling worried is not (it does not quite meet conventional criteria for statistical significance). Feeling hopeful, however, is strongly linked to greater trust, as is greater familiarity with nanotechnology, a conservative political ideology and a more positive view of science overall. Noticeably, familiarity with nanotechnology, a very general and ambiguous measure, is once again more impor-

Table 16. OLS regression estimates of respondents' of perceptions of risks *versus* benefits

Variable	Unstandardized beta	Standard error	*T* value	*P* value
R is white	0.09	0.05	2.00	0.05**
R's gender	0.04	0.04	0.92	0.36
R's age	−0.002	−0.001	−1.45	0.15
R's education	0.03	0.01	2.38	0.02**
R's political ideology	−0.00	0.02	−0.05	0.95
Prey	−0.01	0.07	−0.11	0.91
Science fiction	0.06	0.04	1.41	1.6
Knowledge	−0.02	0.02	−0.77	0.44
Familiarity	0.09	0.03	3.02	0.00***
Trust	0.06	0.04	1.66	0.10*
Hopeful	0.21	0.02	11.02	0.00***
Worried	−0.18	0.03	−7.33	0.00***
Angry	0.02	0.04	0.39	0.69
View of science	0.26	0.03	8.92	0.00***
Constant	−0.33	0.10	−3.44	0.00***

Note: $N = 1152$; adjusted $R^2 = 0.34$; two-tailed test ***$P < 0.01$; **$P < 0.05$; *$P < 0.10$.

Table 17. Logistic regression estimates of respondents' trust in business leaders

Variable	Unstandardized beta	Standard error	Wald statistic	*P* value
R is white	0.13	0.16	0.71	0.40
R's gender	−0.02	0.13	0.01	0.91
R's age	0.002	0.004	0.25	0.62
R's education	−0.03	0.04	0.46	0.50
R's political ideology	0.26	0.07	14.67	0.00***
Prey	−0.43	0.23	3.49	0.06*
Science fiction	0.09	1.4	0.42	0.51
Knowledge	0.004	0.08	0.002	0.96
Familiarity	0.20	0.09	4.48	0.04**
Hopeful	0.22	0.06	12.31	0.00***
Worried	−0.14	0.09	2.48	0.12
Angry	−0.47	0.19	6.21	0.01***
View of science	0.24	0.10	5.70	0.02**
Constant	−0.33	0.10	−3.44	0.00***

Note: $N = 1176$; nagelkerke $R^2 = 0.09$; 62% predicted correctly.
Two-tailed test ***$P < 0.01$; **$P < 0.05$; *$P < 0.10$.

tant for understanding nanotechnology attitudes than is specific content knowledge about nanotechnology.

Conclusions and implications

This analysis is one part of a multifaceted study and it represents only a portion of what will eventually be reported from the survey. Here, we demonstrate that public opinion about nanotechnology in some ways fit what many might expect, and in other ways that it is surprising. To start with the potentially obvious, most Americans have heard little or nothing about nanotechnology. Scientists working in technology-driven local economies or large cities where nanotechnology is a salient business issue might be surprised by this, but they shouldn't be: Americans pay scant attention to science in general and nanotechnology is new and complex in particular. Just as the public is minimally aware of nanotechnology, they are also minimally knowledgeable about it. A large percentage of respondents could not surpass answering just one true or false question correctly when we asked a total of three. Almost a third of the sample could not manage to answer one question correctly.

The American public does not appear to simply presume benefits, but they do think benefits are more likely. In some of our analyses it appeared that knowing little or nothing strongly affected this perception. Instead, our regression results show that what really matters is how much respondents say they have heard about nanotechnology, not what they know specifically about it, at least not the kinds of knowledge we queried them about. This finding actually fits well with social psychologists' models of public opinion that note specific information is typically discarded after it is encountered and the emotional response to it is what is stored in memory and retrieved later when judgments are called for (Marcus et al., 2000). In turn, this suggests that the majority of information about nanotechnology that has been disseminated is positive news. Our finding that emotions consistently explain respondents' attitudes about nanotechnology, especially the emotion of feelling hopeful, also supports this position.

Knowledge does influence perceptions that another arms race is the most important risk to avoid. A nanotechnology arms race was also the risk of most concern to those who had read *Prey* or discussed it with someone who had. Given the events of 911 and wars in Iraq and Afghanistan, we expected defense benefits might rank higher than they did. We were also surprised that knowledge did not condition trust in business leaders. While trust is low in general, familiarity led to greater trust, while exposure to *Prey* lowered it. Also of interest, those who reported having less trust also reported feeling more angry about nanotechnology.

We close by giving some additional perspective on these data, by noting some preliminary observations on risks and benefits coming from a different part of our project. Important differences seem to be emerging between the public data we report here and the opinions of ordinary citizens' after discussing nanotechnology in the quasi-experimental issue groups we have been conducting. In contrast to the survey data, we observe that when citizens in those small groups are explicitly given information on the hypothetical 'grey goo' scenario, including the arguments scientists themselves make on its likelihood (and agree on), citizens largely agreed with scientists who consider it implausible. While survey data show that public opinion is negatively affected by knowing the details of *Prey*, this result might only arise because balanced information is not available. When we present citizens with scientists' arguments (in ordinary language form), for example, this information seems to negate the *Prey* effect. This finding is further reinforced by the observation that groups instructed not to digress and discuss "grey goo" sometimes insisted on raising the *Prey* scenario, and those who advanced it unanimously expressed fear. Thus, the bottom line seems to be that openly discussing the critical issues by giving accessible balanced information (not presently competing beliefs, but the agreed-upon principles relied upon by scientists), is probably the best way to prevent uninformed opinion from coalescing around negative perceptions based on improbable events.

Appendix: Survey instrument and coding

(1) The first question is about your view of science. Some say that we can overcome almost any problem using scientific and technological solutions, while others say that science creates unintended consequences and largely replaces older problems with newer ones. Which point of view do you agree most with?

1 = science overcomes problems,
0 = both,
−1 = science creates new problems.

(2) Our focus today will be on nanotechnology. How much have you heard, about nanotechnology_before today? Have you heard a lot, some, just a little, or nothing at all?

4 = A lot,
3 = Some,
2 = Just a little,
1 = Nothing at all.

(3) 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 = benefits > risks,
0 = risks > benefits,
1 = risks = benefits.

(4a,b,c) The next set of questions asks about emotions you might feel. First, are you [worried/hopeful/angry] about nanotechnology?

0 = No,
1 = Yes.

(5a,b,c) How [worried/hopeful/angry] are you?

3 = very worried,
2 = somewhat worried,
1 = only worried a little.

(6) Next, I will read five potential benefits of nanotechnology. After I read the list, please tell me which item is most important to achieve?

1 = Cheaper, longer lasting consumer products,
2 = New and better ways to treat and detect human diseases,
3 = Increased national security and defense capabilities,
4 = New and better ways to clean up the environment,
5 = The ability to improve human physical and mental abilities.

(7) Next, I will read five potential risks of nanotechnology. After I read the list, please tell me which item is most important to avoid?

1 = Economic disruption caused by the loss of traditional jobs,
2 = Losing your personal privacy to tiny new surveillance devices,
3 = A nanotechnology inspired arms race between the US and other countries,

4 = Breathing tiny nano-sized particles that accumulate in your body,
5 = The uncontrollable spread of self-replicating nano-sized robots.

(8) How much do you trust business leaders within nanotechnology industry to minimize potential risks to humans? Do you trust them a lot, some or not that much?

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

(9 a, b, c) Next, I am going read a couple of statements about nanotechnology. After I read each one, please tell me if you think the statement is true or false.

(9A) Here's the first one: Nanotechnology involves materials that are barely visible to the naked eyes. Is this true or false?

Correct answer = (FALSE).

(9B) The next one is: Industry is already using nanotechnology to make products sold today.

Correct answer = (TRUE).

(9C) Next, Nanotechnology is predicted to be the next industrial revolution of the U.S. economy.

Correct answer = (TRUE).

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