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Nanotechnology as an experiment in democracy: how do citizens form opinions about technology and policy?

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Abstract This article analyzes nanotechnology as an experiment in democratic deliberation, one that seems motivated both by a desire to improve deliberative democracy and to protect the technology from undue public interference. However, rather than involving amplified (overstated) risks, nanotechnology appears to involve attenuated (understated) risks. Results from a 3-year panel study are presented to illustrate the ways in which citizens form opinions about nanotechnology, supporting the assertion that public opinion about complex technology can be both reasonable and stable. Nevertheless, the authors also voice concern that, in the absence of public pressure, risk regulation may not evolve as swiftly as it should to protect both society and industry.

Keywords Public opinion · Public policy · Panel study · Deliberative democracy · Regulating risks · Governance

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Introduction

Nanotechnology has become the occasion for considerable experimentation on how best to unroll an entirely new class of technology within a democratic context (Toumey 2006). Deliberative democracy theorists have argued in favor of more opportunity for public discussion of scientific and technological alternatives facing society (Smith 2010). The U.S. Congress provided for the integration of mechanisms for public input and outreach with respect to nanotechnology policy-making in its 21st Century Nanotechnology Research and Development Act, signed into law in 2003. Recent reports from the U.S. National Academy of Engineering (NAE) and the National Research Council (NRC) have identified public participation in decisions about the development and use of technology as a key component of critical thinking (Garmire and Pearson 2006). Similar philosophies have influenced public engagement activities elsewhere, particularly in Europe.

As a result of this interest in public participation, a variety of novel approaches to public involvement have been pioneered with funding from the U.S. National Science Foundation's (NSF) nanotechnology budget. For example, the University of South Carolina created an informal "citizen's school" that gave interested community members opportunities to interact with nanotechnology experts. The University of Wisconsin-Madison sponsored a "science café" program with a somewhat similar mission (Powell and Colin 2008). The most concentrated such effort has been the one at Arizona State University, which received $13 million in NSF funding for a Center for Nanotechnology in Society that has supported (among many other outreach and assessment activities) research on whether "structured public deliberations" could take place without the strong opinion polarization some political scientists have predicted (Hamlett and Cobb 2006). These and other efforts are all predicated on the notion that some form of deliberative or participatory democracy would be a useful and constructive way to introduce ordinary (that is, non-expert) citizens to nanotechnology and related policy issues, including allowing them a voice in the development of nanotechnology policy. The problem has been conceptualized primarily as one of finding the right format.

This move to experimentation with public engagement strategies was likely motivated in part by the perceived failures of biotechnology to readily win public support. The scientific and science policy communities seemed genuinely surprised by objections raised to various agricultural applications of genetic engineering on a host of economic, environmental, animal welfare, and human health grounds. Ethical debates and legal struggles continue to attach to the development of medical biotechnology ranging from embryonic stem cell research to gene therapy. Historically, other major technologies, notably nuclear power generation, have met with a similarly mixed (and polarized) public reaction. While the U.S. remains a highly pro-technology democracy, the recent history of popular reactions to new biotechnologies, in particular, has provided abundant evidence that public opinion is not always going to embrace each new development (particularly if non-expert publics are not taken into account in early phases; see, e.g., Priest 2001). If this resistance was the disease, then perhaps early public engagement would be the cure.

Thus was born an implicit and somewhat ironic confluence of interests between those who wanted to promote both public awareness and participatory democracy for science and technology, primarily in the interests of good democratic practice, on the one hand, and those who wanted to protect science and technology from public disapproval, especially disapproval that might, in some cases, be perceived as unfounded or "irrational," on the other. As it turns out, from a public opinion point of view, nanotechnology is not unfolding in a way that parallels the history of biotechnology. Public opinion about nanotechnology remains positive and is not showing evidence of early polarization, even though biotechnology can nevertheless provide a useful basis for comparison in terms of the dynamics of the policy-making process (Kuzma and Priest 2010).

A philosophy of public participation

Philosophers interested in the nature of democratic deliberation and discussion—notably Jurgen Habermas and John Rawls—have developed extensive bodies of study analyzing the appropriate role and nature of public deliberation and public political discourse in democratic societies. It is well beyond the scope of this article to review this study, except to note that the role of discussion and debate in both public opinion formation and the conduct of democracy remain ongoing subjects of academic discussion, and have influenced the turn toward public engagement in science and technology policy. One essential tension within these discussions, however, is worth further consideration here. That tension is whether the notion that ordinary people can participate in meaningful discussion and debate remains valid as societies themselves and the issues and policies with which they are concerned become more complex. The societal role of information and news is different, depending on which position on this question is adopted.

At one pole of this influential debate, American educational philosopher and psychologist John Dewey saw democracy not merely as a means, but as an end in itself—something he valued as "a form of moral and spiritual association" (Boydston 1967, p. 240). Dewey argued that participatory democracy creates the conditions for self-realization and introspection, as well as making publics aware of their collective capabilities. Through communicating about issues, people enhance their ability to interact within the greater public arena, as well as to reflect on and modify their personal behavior (Dewey 1922). For Dewey, communication allows the public to think more critically about issues and about themselves, to be more thoughtful in their deliberations, and to be better problem-solvers, gaining the ability to control their own behaviors and beliefs (Dewey 1922). This heightened human agency by means of democracy allows people to learn from the past and to take charge of their future. The acts of speaking and hearing make people active participants in policy debates, rather than the passive audience members that others (see later) presume them to be (Dewey 1927).

Dewey extended these ideas into his analysis of education, arguing that it was the role of education to equip citizens to fully participate in democratic life. His views of the public and public opinion continue to be contrasted with those of Walter Lippmann, whose book *Public Opinion* (1922) Dewey reviewed critically in print, touching off a longstanding, well-known, and oft-cited debate between the two. Lippmann, a former journalist, characterized most people as passive consumers of media images and information, with little real understanding of the complicated issues of the day. From this point of view, it stands to reason that complex societies must be governed primarily by elites, rather than controlled by the opinions of "the masses." In Lippmann's worldview, news and information is disseminated largely for the purpose of persuading people that policies decided on by elites are correct. In Dewey's view, the goal of democracy is to empower people to participate in deciding on those policies. This implies a news and information system that supports this rather different goal.

The present trend toward encouraging public engagement in discussions about science and technology policy clearly has more in common with Dewey's philosophy than Lippmann's. However, some supporters of public engagement are likely hoping, following Lippmann, that public engagement will generate support for existing science and technology policy. This will not necessarily happen in every case, of course, especially if true empowerment is the goal. Some technologies will be seen as serving the needs of ordinary people more than others, and some may challenge their underlying values more than others and meet with organized resistance as a result.

Empirical studies of public engagement processes may do little to resolve this distinction between persuasion and empowerment. For example, recent research exploring popular reactions to nuclear energy scenarios in a public engagement process confirms that the perception that decision outcomes derived from such a process are "fair" makes people more supportive of a technology-related decision overall (Besley 2010). In other words, process matters—an important conclusion of this study. However, it is easy to see that making people more supportive by following a particular process can as readily serve the interests of elitist or "top-down" government as those of participatory or "bottom-up" democracy.

As a practical matter, most citizens are unlikely to take time out of their lives to participate in consensus conferences or other organized public discussions, especially of less well-known and largely uncontroversial new technologies such as nanotechnology, without special motivation, e.g., a personal interest, a stake in the outcome, or a financial incentive (Kleinman et al. 2009).

Despite the proliferation of research on new mechanisms for "upstream" public engagement, it still makes sense to be concerned with the opinions and reactions of citizens who are *not* participants in activities specially designed to encourage public engagement, as well as those who are. Their participation in actual debate may remain vicarious, mediated in the sense that it is nourished by their consumption of news and information, and may never go further than their own living rooms. Experiments with novel public engagement events are intriguing, but currently may have limited practical utility, especially in the United States, a country that is geographically large, ethnically and politically diverse, and lacking a tradition of public discussion directly influencing the federal-level policy process (as compared to Scandinavian countries, Denmark in particular, that boast of their long traditions of populist democracy).[1]

Since most citizens are *not* likely to have occasion to participate in any kind of special public engagement or outreach event (either due to a lack of

[1] Public input provisions are common in the U.S. Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) policy making, and other agencies are moving in this direction. However, the emphasis in these efforts is usually more narrowly on *stakeholder* involvement in the development of specific regulatory policies, rather than broader *citizen* involvement in the discussion of more general and more prospective policy issues—an approach to policy sometimes referred to as "public consultation."

opportunity or to a lack of motivation) on an arguably obscure national issue like nanotechnology policy, other means of developing and assessing citizens' opinions are important and remain understudied. How people might take up and be influenced by information from the news media, for example, is reasonably well documented for controversial topics receiving wide publicity, but these dynamics may not apply to the topic of nanotechnology that has received very little conflict coverage (Weaver et al. 2009) and for which specific information about risks has been quite slow to develop as a news topic (Friedman and Egolf 2005). The influence of media framing of nanotechnology may, under these circumstances, be much weaker than the influence of pre-existing attitudes toward technology (Priest and Greenhalgh, under review). These considerations have influenced our present project.

Polling and public opinion

In terms of assessing the drift of public opinion, conventional opinion polls can reach more people than public engagement exercises are ever likely to, and they do so efficiently. Opinion polls do little, however, to elucidate the dynamics of the *process* through which ordinary citizens form their opinions, nor to encourage them to do so. Furthermore, poll data are of especially questionable value for a complex, technical issue to which few people have given much thought. Issues of science literacy aside, interpreting the meaning of answers to survey questions offered under these circumstances is a task fraught with substantial ambiguity. Following Dewey, debate and discussion are what allow people to form opinions, and, for nanotechnology, little real public discussion (despite extensive effort, in some cases) has yet taken place outside academic experiments.

Some commentators have gone so far as to describe public opinion on emerging technology as "fickle," but still too little is known about the actual dynamics of public opinion formation in early consideration of emerging technologies to reach this conclusion. It is also possible that the technology of polling is itself to blame for this phenomenon, that is, for the construction among opinion experts of the idea that public opinion is based on transitory and superficial (often called "heuristic") considerations. When one does not understand a social process, then one may view it as without structure, but this is not necessarily accurate.

The argument that people simply do not have pre-formed attitudes about many of the topics on which polls routinely propose questions, though they answer the questions anyway, has been put forth by Zaller and Feldman (1992), among others, and numerous examples of the influences of question wording and timing on poll data have been extensively described by Bishop (2005) and many others. Unfortunately, these dynamics could be taken to imply that, contrary to the assumptions of deliberative democracy, one should not take public opinion into account at all, especially the public opinion about novel and complex or technical issues (supported by Lippmann's contention that ordinary people cannot have enough knowledge of complicated public affairs to have meaningful opinions). Instead, arguments about the problems with opinion polling should not lead to discounting public opinion, but rather to discounting, or at least more cautiously interpreting, public opinion *polls* under these circumstances.

The idea that the opinions of members of non-expert publics on complicated subjects are somehow "random" (in the lay sense that they are the result of a process much like throwing darts or flipping a coin), "irrational," or wrong-headed is certainly problematic, especially if one takes as a premise the proposition that public engagement in policy discussions regarding science and technology has inherent value in a technology-dependent democracy. However, both risks and benefits are associated with new technology (Garmire and Pearson 2006), leading individuals to weigh both sides when responding to opinion questions and, thus, sometimes to appear to hold contradictory opinions. This can be a highly rational process and not necessarily evidence of their holding superficial, ephemeral, or "fickle" opinions.

The authors therefore sought, through the research presented below, to provide a more nuanced understanding of the dynamics of opinion development regarding a set of new technologies than public opinion polls by themselves seem likely to yield. However, the example at hand—the development of public opinion about nanotechnology—turned out to be quite different than what some might have predicted in advance, including the authors.

Certain developments in science and technology have emerged as controversies through a process that Kasperson and Kasperson (1996) have called "social amplification of risk," a process by which social institutions, including the mass media, tend to overemphasize certain technological risks, producing magnified risk responses among members of the public. These cases involving social amplification tend to be the ones that generate the most publicity and the most political concern, creating a feedback loop leading to further amplification. However, nanotechnology has turned out to be an "attenuated" risk instead, one in which institutional inertia and media indifference seem to have quite possibly dampened public concern rather than magnified it.

The reasons for this seem likely to have to do with underlying cultural values and orientations that this study was not designed to capture, as well as accidents of circumstance (i.e., nothing really bad has happened yet, and some of the risks of nanotechnology may well be longer term ones) and traditions of professional practice (i.e., the traditions of professional practice among journalists, politicians, and regulators), alongside the actual levels of hazard and risk involved; however, these might be judged later. Unpredictably and serendipitously, therefore, our study has also provided an opportunity to observe what happens to public opinion over time *in the absence of* a pattern of social (e.g., media) amplification of risk. Our fundamental conclusion is that public opinion about nanotechnology, at least among the small number of participants who stayed with us throughout the full three years of the project, *is remarkably stable*. Of course, only future research on other cases will be sufficient to establish this as a general principle.

Results of a panel study

Understanding and accommodating public opinion under circumstances involving limited media coverage of risk or controversy, which present few compelling motivations for citizens to seek information or form opinions, are challenging. In an effort to increase our understanding of the process through which ordinary citizens make up their minds on technology-related issues like those associated with nanotechnology, a strategy that did not depend on opinion polls was chosen (but was originally conceptualized as supplementing them). A panel study of 76 South Carolina citizens was conducted between early summer of 2007 and late fall of 2009.[2]

This study was designed to investigate how the broadest possible range of individuals might make up their minds about nanotechnology over time. Selection of participants was not random, but purposive, targeting a variety of specific social groups. The goal of the study was to include people from different walks of life, given that truly random recruitment for a study of this type is impractical. The study involved four waves of survey data and began with extended baseline interviews that demonstrated how study participants applied "templates" of expectations concerning technology generally (largely, but not exclusively, positive ones, including a range of risk and benefit considerations) to consideration of this new class of technology with which they were largely unfamiliar (Priest et al., under review). The first of these four surveys was administered part-way through the initial interviews, so that the authors were able to collect initial participant impressions before exposure to the survey questions. However, a neutral, basic definition of nanotechnology was provided just before the administration of that initial survey.

These largely qualitative baseline interview results (Priest et al., under review) showed that most panel members (about two-thirds) initially had a positive impression of nanotechnology, even if they were not quite sure what it was, and that most had heard of the term before the study. Not surprisingly, the majority (over 80%) also felt that the potential benefits of nanotechnology outweighed the risks, although a smaller majority (about two-thirds) of the panel had ethical concerns, primarily about privacy issues. Most of the future benefits anticipated by the panel were projected in the areas of medical and technological advances, while the biggest risks seen pertained to uncertain or unexpected possible side effects. Most panelists (about two-thirds) felt that active government and marketplace controls should be implemented to prevent these side effects. The panel was split on whether they had enough say in the policy decisions regarding nanotechnology and also on

[2] Data were subsequently analyzed at the University of Nevada, Las Vegas.

whether the government was doing a good enough job at regulation of new technology.

Our participants manifested awareness that new technology offers both risks and benefits and gave thoughtful responses to our questions about nanotechnology's likely societal impacts. These qualitative data proved a rich source of insight as to the ability of our citizen panel participants to talk meaningfully about an unfamiliar technology and to consider that technology thoughtfully with minimal input from the research team. Participants drew from their experiences with other technologies, their generalized expectations about technology, and, in some cases, recall of media material (sometimes including fiction, as well as news). The authors then turned to the question of how these initial impressions changed over time, following as many of these initial participants as possible through three more surveys and a brief exit interview over the subsequent 30–32 months.

Initial panel participant recruitment

The target area for this study included metropolitan Columbia, South Carolina, and other rural and urban areas in the northwest quadrant of South Carolina. Panelists were recruited from a variety of groups. The goal was not to provide a statistically representative sample, but to sample a broad range of social groups in an attempt to include the broadest possible range of opinions and opinion-formation considerations. As community leaders, the panel included members of the local Kiwanis Club and the local Chamber of Commerce in Columbia. To assure inclusion of religion-affiliated panelists, individuals from two African-American churches and a relatively mainstream Baptist church were recruited. As representatives of the population with special interests in the environment, members of the regional Sierra Club chapter were recruited. And, as non-affiliated citizens, staff members from a day care facility and American Cancer Society volunteers were included.

As an incentive, participants were offered a \$25 initial payment in the form of a donation to the organization through which they were recruited. A second \$25 payment would be donated in a similar fashion for those participants who continued for the life of the study. The rationale for this incentive is that persons who might not participate in exchange for a small cash payment to themselves could be motivated to participate on behalf of an organization to which they belong and whose goals they support, resulting in a more substantial collective donation. In addition, this approach assisted us in recruiting and retaining the broadest possible range of views as the study moved forward. The goal was not random sampling, but inclusion of this broad range of views.

The initial survey of all 76 panelists occurred in summer of 2007 (referred to as T1 throughout this article). The three follow-up surveys were conducted in spring 2008, winter of 2008, and fall of 2009 (referred to here as T2, T3, and T4, respectively), to provide a sense of the opinion trajectory. While designed in part to explore the issue of media use by the general public, this study was not an attempt to directly measure the "effects" of media use. Instead, the study sought to show how citizens from diverse backgrounds actually come to grips with newly emerging technologies, given their varied communication influences and backgrounds. A total of 34 participants stayed with the project through T4; quantitative results from this subset of participants are the focus of our discussion here.

Analytic and measurement approaches

The emphasis in this article is on opinion formation, and the primary data of concern reflect opinion development over time. Time series analysis was carried out by using the survey sequence indicator (T1, T2, T3, or T4) as the independent variable and 22 survey response variables (eight-benefit perceptions, eight risk perceptions, and six need for regulation perceptions concerning nanotechnology) as the dependent variables in a series of one-way analyses of variance (ANOVAs).

The eight-benefit perception questions asked respondents to rate "How beneficial do you believe nanotechnology will be for society over the next 20 years in each of the following areas: medicine and health, agriculture and food, new material development, improved electronics and computing capability, environmental clean-up, natural resource conservation, energy production, and general economic growth and job creation," assessed using a 5-point scale with one being "not important" and five being "very important."

The eight-risk perception questions asked respondents to rate "How risky do you believe nanotechnology will be for society over the next 20 years with respect to each of the following areas: human health, animal health, environmental pollution, increased expense of health care, food, energy, goods, etc., rich/poor country divide getting worse, increased privacy issues, access to benefits limited to a few, and economic insecurity (loss of jobs, for example)," again using a 5-point scale with one being "not important" and five being "very important."

The six need-for-regulation perception questions asked respondents to rate "How important do you believe it is to have regulations to control nanotechnology's risks in each of the following areas: human health, animal health, environmental pollution, increased expense of health care, food, energy, goods, etc., privacy issues, and distribution of benefits," again using a 5-point scale with one being "not important" and five being "very important."

Findings

Based on quantitative measures at four points in time, initial attitudes remained relatively constant, on average, over the course of the 3-year study. Analysis of changes between the first and second surveys, roughly 10 months apart, had indicated that heavy media consumers initially perceived more risk to be associated with nanotechnology than lighter media consumers, and also showed that risk perceptions increased modestly for both groups of participants between these first and second survey events (Priest et al. 2010). Among participants who continued across all four surveys—who are the subject of consideration here—this pattern was not persistent, however. This group was smaller and somewhat less diverse (furthermore, those who remained in the study tended to be more educated and have higher incomes than those who did not), also making subgroup analysis less robust.

For those 34 individuals who remained in the study for the full three years, no overall statistically significant changes in risk, benefit, or need-for-regulation ratings were revealed across the full study period (Tables 1, 2, 3). The largest change was in perceptions of the need for regulation with respect to human health, which rose .41 points over the study period, but even this was still not a statistically significant change, presumably because of the small sample size. The mildly elevated risk perceptions observed at T2 had actually modestly receded, overall, by T4 (at least for the smaller group of participants finishing the entire study). While this was a disappointing finding from the point of view of the original goal of the study—that is, the goal of observing opinion formation over time—since there was relatively little change to observe, it did force us

Table 1 Changes in benefits perception for eight nanotechnology-related areas as a function of time

Variable	Means at						
	T1	T2	T3	T4	Avg	F	Sig.
Medicine and health	4.45	4.67	4.42	4.44	4.50	.617	.605
Agriculture and food	3.53	3.82	3.76	4.03	3.79	1.385	.250
New material development	4.33	4.19	4.27	4.29	4.27	.152	.928
Improved electronics	4.44	4.56	4.48	4.26	4.44	.668	.573
Environmental clean-up	3.58	3.70	3.67	3.68	3.65	.080	.971
Resource conservation	3.28	3.39	3.15	3.50	3.33	.678	.567
Energy production	3.91	3.97	3.58	3.88	3.83	.850	.469
Economic growth	3.66	3.58	3.42	3.79	3.61	.696	.556
Average	3.85	3.99	3.85	3.99	3.92	.447	.770

Responses based on a five point scale (1 = not important, 5 = very important) to the following question: "How beneficial do you believe nanotechnology will be for society over the next 20 years in each of the following areas?" ($N = 34$)

Survey T1 taken summer 2007

Survey T2 taken spring 2008

Survey T3 taken winter 2008

Survey T4 taken fall 2009

Table 2 Changes in risk perception for eight nanotechnology-related areas as a function of time

Variable	Means at						
	T1	T2	T3	T4	Avg	F	Sig.
Human health	3.09	3.48	3.24	3.35	3.30	.723	.540
Animal health	2.88	3.00	2.76	3.00	2.91	.481	.696
Environmental pollution	2.79	3.00	3.00	3.06	2.96	.388	.762
Increased expense for items	2.79	3.33	3.09	3.27	3.12	1.530	.210
Rich/poor divide gets worse	3.21	3.42	3.06	3.52	3.30	1.103	.350
Increased privacy issues	3.24	3.67	3.24	3.44	3.40	.845	.472
Access limited to a few	3.03	3.18	2.88	3.06	3.04	.452	.717
Economic insecurity	2.48	2.76	2.55	2.74	2.63	.458	.712
Average	2.98	3.23	2.99	3.16	3.09	.985	.402

Responses based on a five point scale (1 = not important, 5 = very important) to the following question: "How risky do you believe nanotechnology will be for society over the next 20 years with respect to each of the following areas?" ($N = 34$)

Survey T1 taken summer 2007

Survey T2 taken spring 2008

Survey T3 taken winter 2008

Survey T4 taken fall 2009

Table 3 Changes in perception of the need to regulate for six nanotechnology-related areas as a function of time

Variable	Means at						
	T1	T2	T3	T4	Avg	F	Sig.
Human health	4.29	4.59	4.36	4.70	4.48	1.674	.176
Animal health	3.92	4.00	3.64	4.15	3.92	1.157	.329
Environmental pollution	4.26	4.25	3.88	4.09	4.12	.969	.409
Increased expense for items	3.53	3.66	3.72	3.91	3.70	.544	.653
Increased privacy issues	4.06	4.25	4.15	4.18	4.16	.156	.926
Access limited to a few	3.50	3.63	3.33	3.73	3.55	.602	.615
Average	3.93	4.06	3.82	4.13	3.98	.831	.479

Responses based on a five point scale (1 = not important, 5 = very important) to the following question: "How important do you believe it is to have regulations to control nanotechnology's risks in each of the following areas?" ($N = 34$)

Survey T1 taken summer 2007

Survey T2 taken spring 2008

Survey T3 taken winter 2008

Survey T4 taken fall 2009

to rethink the dynamics of popular thinking about emerging technologies.

Of course, some of the modest shifts that were observed might have achieved statistical significance with a larger sample; the study lacks the statistical power that would have been provided by further observations, as it had been designed all along to study a smaller group in more depth instead. Further, it may be that the act of initially being interviewed for the study served the same purpose as other public engagement activities, even though these interviews took place individually. By asking participants to talk out loud about their views, these views may have crystallized in a way that would not have happened without the baseline interviews. Finally, our participants were not randomly chosen, and there is likely a bias in the group toward those interested in technology, especially among those who completed the entire study.

Small differences in perception trends were observed in our study between respondents who had been recruited from different groups, suggesting some opinion adjustment was taking place (even though none of these differences was statistically significant). For example, those recruited from the environmental group initially saw somewhat less benefit across all eight-benefit items taken together than either business and civic leaders or those recruited from other groups, but by the end of the study the benefit assessments of all three groups were nearly identical. Members of the business/civic leaders groups were noticeably less supportive of regulation across all six regulation items than the other groups at the beginning of the study, although this difference was much smaller (intriguingly) by the end of the study.

Finally, participants who were neither members of the environmental group nor of the business/civic leaders groups ($n = 14$) did end the study perceiving slightly higher risks across all eight-risk items than other participants, even though all groups had begun the study with about the same average perceptions overall. Again, this contrast was not statistically significant; however, change took place in the same direction in every one of the eight separate risk items for this group (the greatest increase within this group was in the perceived risk of rising expenses, followed by the perceived risk of environmental pollution). The authors report these non-significant observations only for the sake of completeness since they provide the only evidence of risk amplification even if remotely suggested by our small-sample study.

Comparison with national data

Our data show little evidence of opinion change or polarization over time. Despite the limitations of a very small sample size and the use of a non-random, non-representative sample, this basic finding of stability is lent credence by national polls that have also failed to find strong evidence of change or polarization. A major U.S. national poll by Hart Research Associates conducted annually from 2006 to 2009 in cooperation with the Woodrow Wilson International Center's Project on Emerging Nanotechnologies showed very little change in awareness over time, with (for example) 30% having heard "a lot" or "some" about nanotechnology in 2006 and 31% having heard "a lot" or "some" in 2009 (Hart Research Associates 2009).[3]

Unfortunately this most recent poll in the Hart series did not explore nanotechnology public opinion in depth. However, their earlier 2008 poll had shown that 48% of U.S. adults had had no opinion when initially asked about the trade-offs between nanotechnology's risks and benefits, 25% believed benefits and risks would be about equal, 20% that the benefits would outweigh the risks, and just 6% that the risks would outweigh the benefits (Hart Research Associates 2008). Providing the respondents with information about nanotechnology apparently allowed people to make up their minds, causing the "no opinion" proportion to decline to 9% and the proportion thinking risks and benefits were about equal to rise to 38%. Those with more self-reported pre-survey familiarity were reported to be more optimistic. However, adding information during the survey caused the "more risks" group to rise from 6 to 23%. The "more benefits" group also went up (albeit less steeply, to 30%), and the "about equal" group rose as well to remain largest.[4]

Our panel respondents did not report getting much additional information from the media or elsewhere during the course of our study. Nevertheless, their participation in the study would likely have created some level of sensitization to whatever information they did receive, and they were exposed to some information in the course of the baseline interviews.

[3] That report notes, by comparison, that awareness of synthetic biology increased from 9 to 22% between 2008 and 2009, also based on responses of "a lot" or "some"; however, the series likely does not go back far enough to capture the initial awareness curve for nanotechnology since it begins at 30%, so the trajectories reported are not necessarily comparable.

[4] Another way of looking at these data would be to consider that the more *initially* familiar respondents were the most optimistic, whereas—in contrast—adding information during the survey caused a sharper increase in those seeing more risk than in those seeing more benefit. A straightforward possible explanation is simply that those with the most familiarity going in were the most pro-technology more generally, perhaps due to personal interest in technology or to their occupations, etc., rather than their having been exposed to more information per se. Extra information seemingly had the opposite effect on others.

Furthermore, of our initial cohort, 64.5% had claimed some initial level of familiarity with the term "nanotechnology" (compared to 56% in a 2007 Hart survey reviewed in Hart Research Associates 2009), confirming a small, but potentially important bias toward familiarity in comparison to the national data. This reservation aside, our results seem consistent with national poll results: Most people are relatively unconcerned about nanotechnology's risks, and this does not seem to be changing very rapidly.

Managing attenuated risk

Our research reported here was explicitly exploratory and guided by a general interest in the question of how opinions were formed over time, with a design based on intensive study of a purposive sample of a small number of individuals. While the authors originally anticipated that nanotechnology might become more controversial to our panelists as more risk information was reported, this did not occur, at least at an observable level, after the initial year of the study.

Our study took place under conditions of relatively low media attention to conflicts or specific risks associated with the subject matter and little evidence of public opinion polarization. The authors collected some data about media consumption but were unable to relate it to opinion formation, except for the finding already reported elsewhere that heavier media consumers were more cognizant of risks in the initial year of the study and that modest increases in risk perception occurred by T2 for both light and heavy media consumers—increases that the authors cannot claim were sustained.

While the initial goals for this study might have been easier to meet had more substantial controversy erupted over nanotechnology, the evidence obtained points clearly to the conclusion that both ordinary citizens and community leaders, at least if they are given the opportunity to think through and articulate their views on technology, can form stable opinions, opinions that are believed to be meaningful reflections of their thoughtful assessments of both risks and benefits. The respondents of this study did not provide radically different assessments at different points in the study and, based on the exit interviews, did not self-report much in the way of opinion change when given an open-ended opportunity to comment.

While this may be seen as good news for the promoters of nanotechnology, as well as for the promoters of deliberative democracy, there is still a cloud on the horizon. On the basis of our results, the authors would certainly not claim, as have been done by some reports, that opinion on nanotechnology is fickle or spurious—that public perceptions of nanotechnology are necessarily subject to shift like the wind at any moment and in unpredictable directions. The authors certainly do not believe that ordinary citizens, whether leaders or followers, are incapable of forming reasoned opinions in this or other complex areas, at least if given the opportunity to think through their opinions by articulating them to an interviewer. The difficulty lies elsewhere.

Given the rocky road of public opinion traveled by nuclear power, genetically modified foods, and stem cell research, regulators and developers concerned with nanotechnology might be tempted to breathe a sigh of relief. These historically *amplified* risks have become almost notorious for the tenacity with which people have held to their opposing points of view. Nanotechnology is different, however, and may best be thought of as involving *attenuated* risks. Many citizens seem willing to withhold, giving nanotechnology the benefit of the doubt, even as evidence of potential environmental and health consequences for some forms of nanotechnology accumulates. Managing attenuated risks in an environment of uncertainty may be more difficult, in some ways, than managing risks where public pressure has created an incentive to devote resources to strengthening regulatory oversight; in the absence of explicit political and public pressure, regulators may feel they have no authority—and certainly no mandate—to implement change. Certainly the business risks of operating in a largely unregulated arena are readily apparent. Future research on risk management for nanotechnology should consider these dynamics.

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