Contents of packet for

Nanotechnology and the Public:
Data for Decision Makers

U.S. Congressional Nanotechnology Caucus
Monday, March 9, 2009
Dirksen Senate Office Building, Sd-562
2:00 p.m.-4:00 p.m.

Center for Nanotechnology in Society
Arizona State University
P.O. Box 875603
Tempe, AZ 85287-5603

Phone: 480-727-8190
Fax: 480-727-8791

E-mail: cns@asu.edu
Web: cns.asu.edu

The Center for Nanotechnology in Society
ARIZONA STATE UNIVERSITY

NANOTECHNOLOGY AND THE PUBLIC:
DATA FOR DECISION MAKERS

U.S. CONGRESSIONAL NANOTECHNOLOGY CAUCUS

MONDAY, MARCH 9, 2009
DIRKSEN SENATE OFFICE BUILDING, SD-562
2:00 P.M.-4:00 P.M.

2:00 p.m.-2:05 p.m. *Welcome*

Michael M. Crow (President, Arizona State University)

Moderator

David H. Guston (Arizona State University; CNS-ASU)

2:05 p.m.-2:25 p.m. *Public Understanding of and Attitudes toward Nanotechnology: Overview*

Julia A. Moore (Woodrow Wilson International Center; PEN)
Moore will address the conflicting perceptions of nanotechnology benefits and risks to help the technology avoid the fate of stem cell research, food irradiation, evolution, and genetically-modified food.

Dietram A. Scheufele (University of Wisconsin-Madison; CNS-ASU)
Scheufele will provide an overview of the public opinion dynamics surrounding nanotechnology, including perceptions of nano-related risks among experts and the general public, as well as views on regulatory policy proposals.

2:25 p.m.-2:45 p.m. *Publics and Nano Risk*

Barbara Herr Harthorn (University of California, Santa Barbara; CNS-UCSB)
Harthorn will report findings from deliberation and survey research on factors shaping emergent nanotech risk perception with positive orientation to benefits, but noting implications of on-going low awareness and malleability, application-specific response, and trust.

Dan M. Kahan (Yale University)
Kahan will review key findings in experimental studies that show that individuals react to balanced information about nanotechnology risks in a manner that reflects their cultural predispositions toward environmental risks generally and discuss the need for research aimed at avoiding cultural polarization as the public learns more about nanotechnology.

2:45 p.m.-3:00 p.m. *Public Engagement: National Citizens' Technology Forum*

David H. Guston (Arizona State University; CNS-ASU)
Guston will provide an overview of the National Citizens' Technology Forum on nanotechnology and human enhancement, and describe strong evidence of its high-quality deliberation, including opinion holding, substantive learning, consensus formation, and feelings of efficacy, based on pre- and post-event surveys.

Michael D. Cobb (North Carolina State University; CNS-ASU)
Cobb will report on data from both the National Citizens' Technology Forum and the subsequent national public opinion poll about public values toward nanotechnology and human enhancement. These data suggest, among other findings, that the public remains hopeful about potential therapeutic advances, but that upon deliberation they disfavor many particular potential enhancements.

3:00 p.m.-3:15 p.m. *Public Engagement: Museums' and Science Centers' Forums*

Larry Bell (Museum of Science, Boston; NISE Net)
Bell will present an overview of the NISE Net's activities to engage the public in learning about nanoscale science, engineering, and technology, including its catalog of informal educational materials, capacity-raising activities, and NanoDays.

Christine Reich (Museum of Science, Boston; NISE Net)
Reich will present an overview of the work of the five-museum NISE Net Forum team, which has experimented with programs to involve the public in dialogue about the benefits and risks of nanotechnology. She also will review evaluation findings that indicate how such activities impact the public's views and behaviors

Each panel will include presentation and discussion. The panels will be followed by refreshments and open conversation for 45 minutes with the panelists and other related researchers, including:

Donald Braman, George Washington University School of Law
Joseph Conti, American Bar Foundation
Elizabeth A. Corley, Arizona State University
Jason Delborne, Colorado School of Mines
Mark Philbrick, University of California, Berkeley

Disclaimer: This material is based on work supported by the National Science Foundation, including CCP (SES # 062184 & SES # 0242106), NISE Net (NSF # 0532536), CNS-UCSB (NSF # 0531184), and CNS-ASU (NSF #0531194). Any opinions, findings, and conclusions are those of the authors, and do not necessarily reflect the views of the National Science Foundation.

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About the Speakers:

Larry Bell is senior vice president for strategic initiatives at the Museum of Science in Boston and director of the NSF-funded Nanoscale Informal Science Education Network (NISE Net; NSF #0532536). NISE Net is a network of science museums and researchers working to raise public awareness, understanding, and engagement with nanoscale science, engineering, and technology. E-mail address: lbell@mos.org

Donald Braman is associate professor of law at the George Washington University School of Law. He also is a member of the Cultural Cognition Project (CCP; SES # 062184 & SES # 0242106), an interdisciplinary team of scholars studying risk perception. E-mail address: dbraman@law.gwu.edu

Michael D. Cobb is associate professor of political science at North Carolina State University and a senior investigator with the Center for Nanotechnology in Society at Arizona State University (CNS-ASU; NSF #0531194), where he was a leader on the team that conducted the National Citizens' Technology Forum in March 2008 and the subsequent national survey on nanotechnology and human enhancement. He is studying how public perceptions of emerging nanotechnologies are affected by learning, framing, and deliberation about these new technologies. E-mail address: mdcobbb@social.chass.ncsu.edu

Joseph Conti is a post-doctoral fellow with the American Bar Foundation. In 2008, he received his doctoral degree in sociology from the University of California, Santa Barbara, where he was a graduate fellow in the risk perception and social movements research group at the Center for Nanotechnology in Society at UCSB (CNS-UCSB; NSF # 0531184). E-mail address: jconti@cns.ucsb.edu

Elizabeth A. Corley is associate professor in the School of Public Affairs and a co-principal investigator of the Center for Nanotechnology in Society at Arizona State University (CNS-ASU; NSF # 0531194), where she also is a leader of the public opinion and values research team. E-mail address: elizabeth.corley@asu.edu

Michael M. Crow became the sixteenth president of Arizona State University on July 1, 2002. He is guiding the transformation of ASU into one of the nation's leading public metropolitan research universities, an institution that combines the highest levels of academic excellence, inclusiveness to a broad demographic, and maximum societal impact. Under his direction, the university pursues teaching, research, and creative excellence focused on the major challenges and questions of our time, as well as those central to the building of a sustainable environment and economy for Arizona. He has committed the university to global engagement and to setting a new standard for public service. Prior to joining ASU, Crow was executive vice provost of Columbia University, where he oversaw Columbia's research enterprise and technology transfer operations. A fellow of the National Academy of Public Administration and member of the Council on Foreign Relations, he is the author of books and articles relating to the analysis of research organizations and science and technology policy. E-mail address: michael.crow@asu.edu

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Jason Delborne is assistant professor of liberal arts and international studies at the Colorado School of Mines where he conducts research on highly politicized scientific controversies. In 2008, under the auspices of the Center for Nanotechnology in Society at Arizona State University (CNS-ASU; NSF #0521194), Delborne coordinated the National Citizens' Technology Forum in Madison, Wisconsin – bringing together everyday citizens to discuss the impacts of nanotechnology on technologies of human enhancement. E-mail address: delborne@mines.edu

David H. Guston is professor of political science, co-director of the Consortium for Science, Policy and Outcomes (CSPO), and director of the NSF-funded Center for Nanotechnology in Society at Arizona State University (CNS-ASU; NSF # 0531194). He has served on the Nanotechnology Technical Advisory Group to the U.S. President's Council of Advisors on Science and Technology (PCAST) and co-chaired the 2008 Gordon Research Conference on "Governing Emerging Technologies." E-mail address: david.guston@asu.edu

Barbara Herr Harthorn is professor of feminist studies, anthropology & sociology at the University of California at Santa Barbara, where she also directs the NSF-funded Center for Nanotechnology in Society (CNS-UCSB; NSF # 0531184) and leads its interdisciplinary, international risk perception research team. She also leads a risk perception team in the new NSF/EPA UC Center for Environmental Implications of Nanotechnology (UCLA/UCSB). CNS-UCSB researchers have conducted cross-national deliberation research in the U.S. and UK and experimental survey research on emergent views in the U.S. of nanotechnologies for health and energy. E-mail address: harthorn@cns.ucsb.edu

Dan M. Kahan is the Elizabeth K. Dollard professor of law at Yale Law School and a member of the NSF-funded Cultural Cognition Project (CCP; SES # 062184 & SES # 0242106), an interdisciplinary team of scholars studying risk perception. CCP researchers, in studies supported by the Project on Emerging Nanotechnologies, have conducted a series of experiments examining how ordinary members of the public process information relating to nanotechnology risks and benefits. E-mail address: dan.kahan@yale.edu

Julia A. Moore is deputy director of the Project on Emerging Nanotechnologies – a joint initiative of the Woodrow Wilson International Center for Scholars and The Pew Charitable Trusts. Moore was senior advisor in the Office of International Science & Engineering (2003-2005) and director of legislative & public affairs (1995-2000) at the National Science Foundation. For three years (2000-2003), Moore was a public policy scholar at the Wilson Center working in Washington, D.C. and London on the genetically-modified food controversy. E-mail address: julia.moore@wilsoncenter.org

Mark Philbrick is a PhD candidate in the department of environmental science, policy, and management at the University of California, Berkeley. His research focuses on the governance of the environmental implications and applications of emerging technologies. In particular, his dissertation explores new policies and strategies for facilitating the development and deployment of nanoscale technologies that yield public goods. Additionally, he has over two decades of experience in the high-tech and environmental industries, including ten years as head of a consulting firm. E-mail address: markp@terranetconsulting.com

Christine Reich heads research and evaluation at the Museum of Science and leads both the evaluation team and the diversity, equity, and access team of the Nanoscale Informal Science Education Network (NISE Net; NSF # 0532536). She has guided the evaluation work of NISE Net Forum programs, which engage the public in discussion, dialogue, and deliberation about the societal implications, both benefits and risks, of nanotechnology. E-mail address: creich@mos.org

Dietram A. Scheufele is professor of life sciences communication at the University of Wisconsin. He is a former member of the Nanotechnology Technical Advisory Group to the U.S. President's Council of Advisors on Science and Technology (PCAST) and currently serves on the National Conference of Lawyers and Scientists, a joint committee of the American Association for the Advancement of Science and the American Bar Association. He also is a leader of the public opinion and values research team of the Center for Nanotechnology in Society at Arizona State University (CNS-ASU; NSF # 0531194). E-mail address: scheufele@wisc.edu

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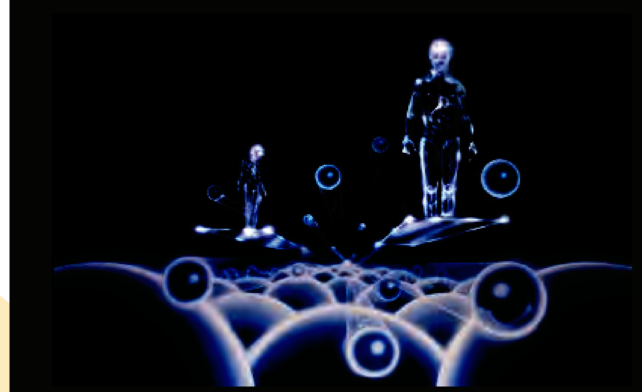

"While technology shapes the future, it is people who shape technology and decide what it can and should be used for." Kofi Annan

What is the Center for Nanotechnology in Society at Arizona State University (CNS-ASU)?

CNS-ASU is a federally-funded academic research, education and outreach center focused on the complex societal relations forming around nano-scale science and engineering (NSE) research. When the President signed the 21st Century Nanotechnology Research and Development Act into law in 2003 (Public Law 108-153), part of the Act mandated "integrating research on societal, ethical, and environmental concerns with nanotechnology research and development" to ensure that NSE advances "bring about improvements in quality of life for all Americans."

CNS-ASU responds to this directive by facilitating the collaboration between NSE scientists and the public in order to build a new capability for understanding and governing the societally transforming power of nanotechnology. Our mission is to:

Research the societal implications of nanotechnologies.

Train a community of scholars with new insight into the societal dimensions of NSE.

Engage the public, policy-makers, business leaders, and NSE researchers in dialogues about the goals and implications of NSE.

Partner with NSE laboratories to introduce greater reflexiveness in the R&D process.

October 2005 began the first year of a five-year grant from the National Science Foundation expected to total $6.2 million over that period. CNS-ASU pursues an ambitious array of interdisciplinary programs with researchers and educators across ASU and six other public research universities: University of Wisconsin-Madison, Georgia Tech, North Carolina State University, Rutgers University, University of Colorado-Boulder, and the University of Georgia.

The Center for Nanotechnology at Arizona State University is affiliated with the Consortium for Science, Policy & Outcomes (CSPO), in the College of Liberal Arts and Sciences. CNS-ASU research, education and outreach activities are supported by the National Science Foundation under cooperative agreement #0531194.

Decades before NSE's most important outcomes begin to unfold, complex social relations are now forming around it. CNS-ASU probes the hypothesis that a greater ability for reflexiveness–that is, social learning that expands the range of available choices–can help guide the directions of knowledge and innovation toward socially desirable outcomes, and away from undesirable ones. Towards this end, we believe:

Public engagement in research and innovation strengthens its societal value.

Science studies scholars have recognized that knowledge and society are "co-produced" through the interaction of scientists and non-scientists in a variety of institutional settings. In the absence of public involvement, science and technology agendas may fail to advance important societal goals.

Societal-level outcomes require collaborative "intellectual fusion."

Research that is able to produce socially desirable outcomes cannot be discipline- focused. Only research that goes beyond traditionally defined boundaries is able to fully comprehend the complexity of the real world. NSE knowledge capacity must be reorganized to include life sciences, physical sciences, social sciences, engineering, and the general public, including participation from under-represented communities. This knowledge capacity must also include a body of "next-generation" scholars.

Greater reflexive capacity increases the opportunity for informed deliberation and conscious choice.

CNS-ASU does not determine which outcomes are desirable or undesirable, nor does it impose agendas on NSE researchers. Rather, we help scientists, technologists, and citizens develop a greater capacity to understand where scientific and social values come from, what they mean, and how they may be related to decisions about NSE. We believe greater reflexiveness will expand the realm and increase the opportunity for informed deliberation and conscious choice, which enhances the quality of NSE outcomes.

CNS-ASU Research

CNS-ASU implements a program of research and engagement called "Real-Time Technology Assessment" (RTTA), which consists of four methods of inquiry:

RTTA1 - Research and Innovation Systems Analysis: Mapping the research dynamics of the NSE enterprise and its anticipated societal outcomes through data-mining and interviews, public value mapping, and workforce assessment. Explores who is doing what kind of NSE research, how we can measure NSE's contribution to broad social goals, and what nano training is needed in regional markets.

RTTA2 - Public Opinion and Values: Monitoring the changing values of the public and of researchers regarding NSE through public opinion surveys, media influence research, and surveys of nanotechnology scientists' opinions. Explores what the public knows and feels about nanotechnology, how the media influences the public perspective, and what NSE researchers know and feel about nanotechnology.

RTTA3 - Deliberation and Participation: Engaging researchers and various publics in deliberative and participatory forums, including the National Citizens' Technology Forum, scenario development, CriticalCorps, and InnovationSpace. Explores plausible nano-enabled futures, how to envision responsible NSE products, the cultural resonances of NSE futures, and how the public can be engaged in NSE decision-making.

RTTA4 - Reflexivity Assessment & Evaluation: Reflexively assessing the impact of the information and experiences generated by our activities on the values held and choices made by NSE researchers, through reflexivity assessment and comparative case studies. Explores how the views of NSE researchers in our network change over time, how CNS-ASU can know that it is being effective, and what CNS-ASU contributes to institutional change.

The above research is is organized around two broad and cross-cutting thematic research clusters (TRCs):

TRC1 - Equity and Responsibility: To explore ways in which NSE research interacts with ideas of social and economic equity and responsible innovation

TRC2 - Human Identity, Enhancement & Biology: To investigate the historical, philosophical, cultural and political dimensions of the interactions between human biology and human values in the context of new nanotechnologies.

CNS-ASU Education

Our education and training programs encourage inter-disciplinary opportunities among NSE students and social science and humanities students. We have introduced curricular innovations at the undergraduate and graduate levels, and we maintain a post-doctoral training program. CNS-ASU partners with other programs, such as the **Hispanic Research Center** to ensure recruitment and retention of students from underrepresented groups. An advanced, multidiscipline **Learning Community** is offered, in which students develop the analytic and conceptual tools for thinking about the interplay among technology, society and policy. Student scientists can get hands-on experience in science policy through a summer workshop in Washington DC, and informal science education is provided through **NISEnet** partnerships.

CNS-ASU Outreach

In addition to the outreach involved in the participatory research programs of RTTA, CNS-ASU collaborates with the Center for Research on Education in Science, Mathematics, Engineering, and Technology **(CRESMET)** to generate NSE-in-society training modules for high school teachers.

CNS-ASU hosts a **Speaker Series** program that is open to the public, featuring high-profile national and international nanotechnology scholars and practitioners. At the end of each academic year, these presentations are collated into a ***Yearbook of Nanotechnology in Society***, published through Springer press.

Once a month, CNS-ASU sponsors a **Science Café** for the general public. These are one-hour, informal discussions that bring together members of the community and university scientists to discuss how science and technology can change the future. In the typical café, a natural scientist and a social scientist speak for 15-20 minutes on a topic, with the rest of the time for the public to ask questions and raise concerns.

Science Cafés are held on the 3rd Friday of the month, from 5:30 to 6:30 p.m. at the Arizona Science Center, 600 E. Washington Street, Phoenix, AZ. Admission is free.

To learn more about CNS-ASU research, education and outreach programs, visit our website:

http://cns.asu.edu

The Center for
Nanotechnology in Society
ARIZONA STATE UNIVERSITY
PO Box 875603
Tempe, AZ 85287-5603
(480) 727-8190
Fax: (480) 727-8791

COMMENTARY

Innovation policy: not just a jumbo shrimp

Policies that predict and direct innovative research might seem to be a practical impossibility, says **David H. Guston**, but social sciences point to a solution.

Innovation policy could be seen as an oxymoron. Like an 'open secret', or 'jumbo shrimp' — which the late comedian George Carlin compared to 'military intelligence' — the words just don't go together. Innovation policy evokes a tension. How does one predict and direct something that is by nature unpredictable and, by necessity, often undirected?

The tension in innovation policy runs deeper than word play, of course. Policies are made too late to change the past that necessitated them and too early to understand the future they are meant to shape. Innovation sparks the difference between that past and future. Policies are incremental, but the goals of innovation often tend toward the revolutionary. An explicit goal of recent initiatives in nanoscience, for example, has been to usher in "the next industrial revolution"[1]. That is about as non-incremental as one could imagine, given that the transformations associated with steam power and information technology affected both industrial organization, and every aspect of social and family life, language and art, politics, warfare and more.

Innovation policy should encourage a dynamic scientific enterprise to contribute to identifiable social outcomes, such as in areas of health, energy and the environment. But research occasionally generates radical changes that are unpredictable and often not associated with those pre-defined social goals. Nations invest in research for social purposes that are often thwarted by the nature of the research process itself. For example, investment in health research may return many high-quality scientific papers, but less in terms of affordable and accessible improvements in health care. Innovation policies for nanotechnology embody these contradictions.

Research initiatives

The US National Nanotechnology Research and Development Act of 2003 authorizes a National Nanotechnology Initiative (NNI) to coordinate about US$1.5 billion in research across some two dozen agencies. Currently in revision before Congress, the act emphasizes commercialization for international competitiveness as a driving rationale on one hand, while requiring research into societal impacts on the other[2]. Interestingly, the societal research promoted by the NNI may provide ways to address the contradictions inherent to innovation policy.

The NNI has funded research to develop 'anticipatory governance'[3], which works by correcting three unspoken and ill-formed premises that underpin these contradictions.

The first of these premises is that policy is supposed to have a clear cause-and-effect relationship in society. But limiting policies to being effective instruments misses the value-laden nature of political deliberation and choice. Policies are, and should rightly be, about articulating public values[4].

Although many pieces of basic legislation contain clear articulations of public values, the NNI act announces none. A close reading of the law's text, however, reveals several guiding public values: nanoscience research should be performed with an interdisciplinary bent. It should be oriented toward improving the economic competitiveness of the United States. It should be subject to suitable administrative oversight. And it should be done in close conjunction with public engagement and societal implications research. But in part because these values must be teased out of the text, they have remained controversial or even unrecognized among the communities that implement the law.

> "We vastly underestimate our ability to productively shape the scientific enterprise."

The second premise is that policy is supposed to be grounded on a clear understanding of the natural world. We must consider both the shortcomings of our understanding of the natural world and the strengths of our understanding the social world. Among the former is that — as Danish physicist Niels Bohr reportedly said — "prediction is very difficult, especially about the future". At any given point in time, science provides both an incomplete and a changing portrayal of the natural world. In matters closely related to policy, such as climate change, it is often not the case that more data helps to make science more complete politically[5]. And even if scientists might have some monopoly over the technical knowledge in their chosen field, they have no similarly exclusive take on the vast bodies of knowledge and practice implicated in turning their discoveries into actual innovations or policy decisions.

Luckily, discarding science-based prediction as an exclusive contributor to legislative action does not disarm policy-makers. Understanding from the social world — concepts such as precaution and anticipation — can help to remove unpredictability as a roadblock. Precaution, as seen in environmental risk management, connotes acting to avoid predicted but uncertain hazards. Anticipation, in contrast, denotes building the capacity to respond to unpredicted and unpredictable risks. Many of us frequent gyms to lift weights. But we do not predict that our lives will depend on our ability to perform a 'lat pull' or a curl, or to bench-press our weight. Instead, we rightly believe that these exercises will build in our bodies a capacity to withstand whatever physical and emotional stresses we might confront. Giving up on prediction does not mean giving up on anticipation. We must exercise the various intellectual and imaginative capacities that will prepare us for the challenges that innovation will surely offer.

The third flawed premise is that ongoing and occasionally revolutionary change is inherent to the scientific enterprise. We vastly underestimate our ability to productively shape the scientific enterprise and effectively steer it. Policy-makers, their scientific advisers and their lab-bench constituents too often cling to Hungarian–British polymath Michael Polanyi's logic that "you can kill or mutilate the advance of science, [but] you cannot shape it"[6]. The scientific enterprise we have — its foci, productivity, contributions, strengths and shortcomings — is at least as attributable to the governing forces of personalities, policies, and institutions as it is to the autonomous play of researchers.

Simple solution

Anticipatory governance addresses these three shortcomings. It prescribes the explicit inclusion of values in deliberations, often through the direct engagement of various groups, including the lay public. Public engagement has been a major theme in nationally sponsored societal research programmes for nanotechnology, including the

B. MELLOR

Nanoscale Informal Science Education (NISE) Network in the United States. Funded by the National Science Foundation, NISE aims to transform the role of science museums from informal educators of the public to conveners of public deliberation. The Center for Nanotechnology in Society (CNS) at Arizona State University in Tempe recently conducted the first-ever National Citizens' Technology Forum held in the United States. Similar public-engagement activities have also been featured in the nanotechnology policies of the European Union, United Kingdom, France and Belgium, among other locales.

Next, anticipatory governance prescribes the creation of what one might call 'anticipatory knowledge', particularly through exercises such as scenario development, to build a broad-based capacity to recognize and understand social change and its relationship to scientific and technical change. Several roadmaps elaborate the technical visions of nanotechnological futures, such as the four stages of nanotechnological development[7]. But more integrated socio-technical scenario projects have flourished, including scenario development by the Project on Emerging Nanotechnology at the Woodrow Wilson International Center for Scholars in Washington DC, the 'open-source' scenario development of the Nano-Futures project by the CNS, and scenarios of converging technologies developed by the University of Oxford's James Martin Institute, UK. Particularly when coupled with engagement activities, the creation of such anticipatory knowledge can help the public voice its concerns about looming socio-technical change.

Anticipatory governance further prescribes the integration of engagement and foresight with scientific and technical work. This informs social scientists' own perspectives with cutting-edge research. It also increases the capacity of natural scientists to understand the societal aspects of their own work, be more reflective about practices and choices within the laboratory and if necessary change their practices to align their research with public visions and values. Such activities have occurred in many small-scale trials. Social scientists and humanists have 'embedded' themselves in research laboratories to become active participants in laboratory activities both to observe researchers and to prompt a more reflexive disposition among them, even modestly reorienting their work in more socially robust directions. The integrative activities at the CNS, for example, are beginning to catalogue concrete, positive consequences within laboratories. Our nanoscientist colleagues report helpful changes and desire more such interactions.

> "Global society needs much of what knowledge-based innovation has to offer."

Beyond nano

The engagement, foresight and integration activities listed here are still too few and too far between. The scale of the research enterprise and the scope of innovation policies dwarfs them. Their few demonstrated successes are not well-disseminated. And they are not linked together in a way that supports anticipatory governance. Yet these early steps offer a prudent approach for innovation policy for nanotechnology and other fields including synthetic biology and neuro-technologies.

Global society needs much of what knowledge-based innovation has to offer. Anticipatory governance is a necessary exercise. It defrays the inherent contradictions of innovation policy, while ensuring that public values and foresight accompany scientific practice, keeping the revolution from turning unproductively against itself and against us. ■

David H. Guston directs the Center for Nanotechnology in Society, co-directs the Consortium for Science, Policy and Outcomes and is Professor of Political Science at Arizona State University, Tempe, 85287, Arizona, USA.
e-mail: david.guston@asu.edu

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LETTERS

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Deliberating the risks of nanotechnologies for energy and health applications in the United States and United Kingdom

Nick Pidgeon[1]*, Barbara Herr Harthorn[2], Karl Bryant[3] and Tee Rogers-Hayden[4]

Emerging nanotechnologies pose a new set of challenges for researchers, governments, industries and citizen organizations that aim to develop effective modes of deliberation and risk communication early in the research and development process. These challenges derive from a number of issues including the wide range of materials and devices covered by the term 'nanotechnology', the many different industrial sectors involved, the fact that many areas of nanotechnology are still at a relatively early stage of development, and uncertainty about the environmental, health and safety impacts of nanomaterials[1]. Public surveys[2–8] have found that people in the United States and Europe currently view the benefits of nanotechnologies as outweighing their risks although, overall, knowledge about nanotechnology remains very low. However, surveys cannot easily uncover the ways that people will interpret and understand the complexities of nanotechnologies (or any other topic about which they know very little) when asked to deliberate about it in more depth, so new approaches to engaging the public are needed. Here, we report the results of the first comparative United States–United Kingdom public engagement experiment. Based upon four concurrent half-day workshops debating energy and health nanotechnologies we find commonalities that were unexpected given the different risk regulatory histories in the two countries. Participants focused on benefits rather than risks and, in general, had a high regard for science and technology. Application context was much more salient than nation as a source of difference, with energy applications viewed in a substantially more positive light than applications in health and human enhancement in both countries. More subtle differences were present in views about the equitable distribution of benefits, corporate and governmental trustworthiness, the risks to realizing benefits, and in consumerist attitudes.

Public participation with nanotechnologies is often described as 'upstream' in nature, reflecting its occurrence before commercialization in real-world applications and before significant social controversy[9,10]. The past five years have seen public engagement efforts of differing forms run in the United Kingdom[3,10–12], the United States[13,14] and continental Europe[15,16]. Most engagement efforts to date have been restricted to a single topic and cultural context, but legitimate questions arise. Will different application domains of nanotechnologies lead to differential public responses in participation events? And will responses also be influenced by geographical or cultural factors? For example, the potential health and environmental risks associated with energy applications of nanotechnologies are likely to be very different from those arising in the medical domain. And beliefs about the latter might in turn be influenced by different cultural values around issues such as the body and health, or experience with different healthcare delivery systems in different countries. Here, we present a generic method for public dialogue about nanotechnologies that can be used to compare responses to different applications (energy and health/human enhancement in the present case), and also in different national contexts. Details about the workshop are given in the Methods section. We discuss the findings under four headings.

Benefit rather than risk continues to frame nanotech risk perception. Risk perception researchers have extensively documented that a technology's acceptability will depend upon people's perceptions of both benefit and risk[17,18], with the balance between the two depending upon the particular technology or the context within which judgements are formed. Nanotechnology survey research in the United States and United Kingdom to date[3,4,7,19,20] shows two clear findings. The first is that most people know little or nothing about nanotechnologies. Second, notwithstanding this, many people nevertheless feel that nanotechnology's future benefits will outweigh its risks.

The discourse of our workshop participants conformed to this general pattern, in spite of the fact that we presented information on and discussed numerous potential downsides during the sessions. An advantage over surveys of the more qualitative exploratory approach adopted here is that it yields additional insights into why benefit frames continue to dominate. In a pattern we would describe as low 'techno-scepticism', participants in both the United Kingdom and United States demonstrated almost complete acceptance of the likelihood of scientific promises being realized at a technical level; while responses ranged from acceptance to wariness to resistance, no one fundamentally questioned the viability of the technology itself. These data are compatible with an interpretation that, under conditions of low knowledge and the absence of any nano-related risk events, attitudes toward technology in general (known to be highly positive in both countries[21,22]) are being reproduced in people's judgements for the case of nanotechnology. This effect is likely involved to some degree, as a confounding variable, in all of the surveys of nanotechnology perceptions conducted to date, making their interpretation as evidence of responses to nanotechnology *per se* particularly problematic.

Past risk perception studies would also predict a likely high level of concern by people about technologies that will actually enter the human body[8,23]. Invisibility and the dependence on other high technology to convey information about embodied risks would also predict higher perceived risk. However, one surprising finding across both nations was the apparent lack of significant expressed

[1]School of Psychology, Cardiff University, Cardiff CF10 3AT, UK, [2]NSF Centre for Nanotechnology in Society, University of California, Santa Barbara, California 93106, USA, [3]Department of Sociology and Women's Studies Program, State University of New York at New Paltz, 600 Hawk Drive, New Paltz, New York 12561, USA, [4]School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK; *e-mail: PidgeonN@cardiff.ac.uk

concern about the medical risks of bodily incorporation of invisible nanomaterials, nanomedical devices and the like. Instead, even in these examples, participants expressed more concern about privacy issues and the control of their personal information rather than concern about unintended technology–body interactions.

Cross-cultural differences: subtle and contextual. Our initial expectation was that distinct differences would emerge on benefits and risks between the United Kingdom and United States, particularly given recent differences in technological risk controversy in the two countries. During the past 15 years Britain had seen the BSE ('mad cow disease') disaster and the dispute over genetically modified organisms (GMO), placing the possible risks of new technologies and failures of government regulation into the media spotlight. As a result, a House of Lords Select Committee argued that Britain has experienced a 'crisis of trust' in science[24]. What we actually observed were more similarities than differences in the data. Using the Eurobarometer survey data Gaskell and colleagues[4] had demonstrated that nano benefit perceptions are higher in the United States than in the United Kingdom and Europe, which they attributed to greater underlying technological optimism in the United States. Our data suggest a more complex pattern. As described above, general technological optimism, expressed as perceptions of the benefits to be gained from new technologies such as nanotech, was uniformly positive in both the UK and US workshops. However, views on some specific and uncertain applications of nanotechnologies did appear to be interpreted by the UK participants against a background of their awareness of recent failures of risk governance in that country (GMO, BSE, foot and mouth disease and so on). Thus, a general high regard for science and technological development can, somewhat counter-intuitively, be accompanied by the amplification of highly specific risk perceptions linked not to the scientific discovery process or even the technology itself, but rather to perceived societal failure[25] or, as Freudenburg puts it, institutional 'recreancy' in the safe management of new technologies[26].

The US case is arguably different from this, with high technological optimism prevailing in both survey data and our own study, alongside a relative absence in our workshops of narratives linking nanotechnologies to past failures to control technology in the United States, which in turn appears to be accompanied by attenuated perceptions of risk, as compared to the UK participants. US participants also showed greater adoption of what might be called a 'consumerist stance', naturalizing the view of new technologies as almost overwhelmingly personally beneficial commodities for which they will compete with others, particularly in the domain of health technologies. In contrast, UK participants showed a greater tendency to discuss the benefits of new technologies at community, national and even at international levels.

On a more nuanced level, however, the framing of risks and benefits between the two countries was found to further differ, in subtle but important respects that interact with the specific application domain under discussion (health/enhancement or energy, respectively). For example, issues of distributional justice or equity took very distinct forms in the two national contexts when discussing the health and enhancement issue, a pattern almost certainly reflecting different cultural assumptions and experiences with health, healthcare institutions and access to care. In all groups, participants judged that, in the very short term, the wealthy would be the most likely to benefit from new health applications in nanotechnologies, with access and choice conditioned by individual economic circumstance. However, the US participants voiced faith that an eventual 'trickle down' of benefits from developments in nanotechnologies would occur over the longer term, although not necessarily in an equitable fashion by race and class. Participants in the United Kingdom voiced more scepticism, tending to focus on how the wealthy would always accrue greater benefits, particularly in the health and enhancement context. By contrast, in the discussions of the energy applications of nanotechnology both sets of participants believed that there would be eventual communal and societal benefit from developments in this area.

Application matters. Reflecting the findings of the original Royal Society/Royal Academy of Engineering[3] workshops held in the United Kingdom in 2003, participants in all of our groups thought that the impacts of nanotechnologies would ultimately depend upon the ways in which they are used. Nanotechnologies, of course, span a very wide range of applications, and our two cases (health/enhancement and energy) were selected precisely to reflect some of this diversity. It is no surprise, then, to find that the type of nanotechnology application matters a great deal to the form dialogue takes, to projected resistances, and to outcomes. As discussed above, although talk of benefits predominated over risks in all groups, participants in both countries were far more easily engaged in positive discussion of energy than of health and enhancement applications.

In both countries new technology development to resolve energy issues was seen as an unchallenged good, with discussion of the potential for energy applications more consistent and more urgent, and responsibility for control being thought to lie primarily in a traditional combination of expert regulation, markets and the individual choices of consumers. With health and enhancement the discussion was, for both US and UK participants, more nuanced, more layered and more multivalent. As one might expect, and in complete contrast to the energy sessions, applications for health and enhancement were thought to raise particular 'moral' and ethical questions, while in both countries participants, unprompted, raised the possibility that responsibility for control should involve a dialogue, or some form of multi-party body, where everybody (citizens, government, business and scientists) could debate their implications. These clear cross-application differences to some extent dwarfed the more subtle cross-national differences present in our study. When discussing societal and ethical implications, nanotechnology is often compared, perhaps unfairly, with biotechnology[4,27]. In demonstrating that people are highly sensitive to the characteristics of different nanotechnology application domains, it seems far more likely that the public will draw upon a range of analogies (some positive, some less so) to help them interpret the nature and implications of specific current and future nanotechnology developments.

One methodological lesson learned, common to both the health and energy deliberations, was that our participants displayed little distinction between present, near-term or long-term application, or between these and the fantastical. This suggests that considerable care has to be exercised in the design of both general (what is nanotechnology) and more domain-specific (health, energy and so on) engagement materials for deliberating such upstream issues.

The social trumps the technological in the discussion of 'risk'. Studies of the conditions under which people's perceptions of risk escalate or amplify have focused on the specific perceived characteristics of the technological risk object[17,18] or the social-dynamics of the events, including media and other portrayals, surrounding a technology's use or misuse[25]. These past studies have all been conducted retrospectively, after technologies have become well known, and, in some cases, highly stigmatized. In contrast, nanotechnologies so far do not appear to elicit beliefs about physical risk as such; rather, they stimulate discussion of social conditions. It is notable that this pattern was consistent across both nations in spite of numerous obvious political, cultural and social differences between the participants. Indeed, in spite of many expectations about public interest in and concern about the science and technology of nanomaterials and nano-enabled products, and the provision of scientific expertise and informational materials about a diverse range of applications, participants in all of the workshops displayed a marked tendency to veer towards discussion of the social or societal implications of technologies rather than the technologies *per se*. For example, a US participant argued, regarding new nanotech medical diagnostics, that 'ethics in medicine for instance has had thousands of years to develop and be tested and so forth, but I'm not sure we have the luxury of time, nanotechnology is changing so fast, the capabilities are increasing so rapidly, that maybe our ethical foundation isn't sufficiently developed to observe, analyze and make recommendations on what's happening'.

Allied to this, discussion of potential risks often focused on societal factors that could limit realization of benefit, as when a US participant argued, regarding nanotech energy benefits, 'I don't think that adding a new technological silver bullet is going to make people any more likely to make changes in terms of conservation and efficiency [of energy] just because it has some new buzz word attached to it', a theme paralleled in the UK group during a lengthy discussion about how use of nanotechnologies for energy efficiency might simply result in greater consumption.

Consistent with academic analysis of public discourses about new technology[28,29], and other qualitative studies of nanotechnologies in both countries[3,30], the issue of trust, and the potential activities of institutions such as government, regulatory agencies and corporations were discussed as a source of risk. UK participants in particular displayed a far more detailed sense of potentials for misuse, and hence were more pessimistic about the eventual realization of potential benefits of health and energy nanotechnologies, for themselves, for the United Kingdom and for global society. They also appear to have a far more explicit understanding of how politics affect investment in technology R&D and innovation and how that in turn affects likely realized social benefit. Regarding specific institutions, the US participants show far more ardent anticorporate sentiments, citing corporate greed, environmental exploitation and complete lack of control as important factors for nanotechnology regulation. The UK participants show more antigovernment and antiscientist feelings (again in line with the recent history of regulatory failures in the United Kingdom), while acknowledging self interest and profit motives of corporations as a problem. At the same time, as a theme of technological saturation and ambivalence, both US and UK participants sought to impugn everyday people's laziness and unwillingness to take advantage of available knowledge and educational opportunities, and saw technological development as colluding with this less desirable side of human nature.

Discussion. The study sought to develop and evaluate a novel form of deliberative workshop using a generic structure capable of being used for comparing complex public discourses about different nanotechnology applications, and in different national contexts. In this task we believe we have broadly succeeded. In more substantive terms, one inference to draw from all of the workshops is that benefit framing currently dominates understandings of the future of nanotechnologies in both the United States and United Kingdom, and persists even when participants are provided with the opportunity for balanced engagement with a range of information and perspectives regarding potential risks. Where downsides are discussed they are, in large part, restricted to more generic concerns about the trustworthiness of the institutions charged with managing and regulating nanotechnologies. It is impossible to say currently whether this pattern of perceptions is likely to be an enduring one, or might prove fragile were any significant health, environmental or safety issue with a nanotechnology material or product to occur in the near future in either of these two countries. Any such event, if significantly amplified through media coverage, would likely provide the (currently missing) 'mental model' or narrative allowing people to connect nanotechnology risks in more concrete terms to their everyday lives.

At a much finer grained level of analysis, our experiment suggests that discursive complexities are significant for the ways that ordinary people approach this topic; qualitative differences in perceptions were found between the two technological domains studied, alongside more subtle shades of cross-national difference too. This implies that, as nanotechnology risk perceptions emerge, context matters. In particular, much will depend upon whether early risks are adequately managed to avoid major incidents, and whether appropriate systems of risk governance can be evolved in parallel. This also suggests that a 'one cap fits all approach' (across applications and/or nations) for the social oversight and regulation of nanotechnology risks is unlikely to prove entirely satisfactory.

The present research is only the starting point in the critical task of understanding how nanotechnology risk perceptions are emerging, and how they will further evolve over the coming decades. This task will require a range of methods that are both interdisciplinary in scope and genuinely sensitive to contextual and cultural nuances arising in the future interpretation and framing of nanotechnology, its risks and benefits.

Methods

The research team developed an effective deliberative workshop format that allowed people from different age, class, educational, occupational, ethnicity and gender positions to participate. Essential components of each workshop include: (1) a quasi-representative group of the public; (2) a focus on specific nanotech application domains (energy, human health and enhancement). Following extensive piloting, a total of four parallel deliberative workshops were conducted in February 2007, two in the United States (Santa Barbara) and two in the United Kingdom (Cardiff). In each country one of the workshops focused upon energy applications of nanotechnologies and the second on human health and enhancement. The generic structure of a workshop, which lasted for about 4.5 hours, included several stages, beginning with initial open-ended discussions of understandings of energy and health, respectively, before the term 'nanotechnology' was ever introduced. This was followed by systematic introduction to the idea of nanotechnologies in general and energy or health applications in specific. A series of 'World Café' table groups then followed to prompt, very successfully, open-ended exploration and discussion amongst subsets of 4–5 participants organized around increasingly complex technologies and applications. The culmination was a guided dialogue with the whole group, once again about issues of benefit and risk, trust and responsibility, societal issues and individual preferences. Sessions were audio- and video-recorded, and full verbatim transcriptions made of all conversations. Systematic qualitative data analysis of the transcripts was conducted using NVivo software and independent cross-cultural assessment to validate identification of themes and interpretations.

Recruitment of participants took place through a neutral third party and involved advertisement, screening and construction of a sample for each group that matched local area demographics as closely as possible. Because initial identification necessarily took place through an open invitation, widely advertised to the public, rather than a randomized procedure, the resultant samples are best described as 'quasi-representative'. Screening eliminated those employed in the health or energy industries, limited student participants to ensure a diverse sample, and determined race, class, gender, education and other characteristics for sample construction. Workshops were held in public spaces within the communities, rather than on university campuses, and participants were compensated \$100 in the United States and £80 in the United Kingdom for giving up most of a weekend day and obtaining transportation to the site, and were provided a meal and coffee/tea breaks. The costs of the workshops in both countries were funded by the United States National Science Foundation.

In developing the procedure considerable effort was expended to ensure the materials on nanotechnologies in general, and on energy and health applications in particular, were as accurate as possible in scientific terms. Powerpoint presentations were prepared by an interdisciplinary team at the Center for Nanotechnology in Society at University of California at Santa Barbara that included nanoscale science and engineering (NSE) experts, and these were then vetted by other NSE experts for accuracy during the pilot process. NSE experts also assisted in the selection of the publications and informational materials offered at the World Café.

Other distinctive elements of these workshops included small group size suitable for focused discussion-based interaction ($n = 12$–15), a cross-culturally comparable, well piloted, detailed protocol that enabled uniform facilitation across sites, and self-directed learning and interaction opportunities in the sub-groups supported by an extensive array of informational materials. Informational materials used included short journal, newspaper and web-based articles that provided information and analysis of nanotechnologies in general, and energy and health applications in particular. Materials included extensive information on the benefits and risks of the technologies, and participants made their own selections among these articles, which they discussed in small ($n = 4$–5) table groups in the World Café stage. In addition, we made every attempt to frame the discussion in a balanced way that presented valid information and current arguments about nanotechnologies, including a carefully calibrated range of potential benefits and possible risks.

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Author contributions

All authors contributed to the design and piloting of the workshop procedure. N.P. and T.R.H. collected the UK data, and B.H.H. and K.B. collected the US data. All authors contributed to data analysis. Manuscript preparation was primarily the work of N.P., B.H.H. and K.B.

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LETTERS

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Cultural cognition of the risks and benefits of nanotechnology

Dan M. Kahan[1]*, Donald Braman[2], Paul Slovic[3], John Gastil[4] and Geoffrey Cohen[5]

How is public opinion towards nanotechnology likely to evolve? The 'familiarity hypothesis' holds that support for nanotechnology will likely grow as awareness of it expands. The basis of this conjecture is opinion polling, which finds that few members of the public claim to know much about nanotechnology, but that those who say they do are substantially more likely to believe its benefits outweigh its risks[1-4]. Some researchers, however, have avoided endorsing the familiarity hypothesis, stressing that cognitive heuristics and biases could create anxiety as the public learns more about this novel science[5,6]. We conducted an experimental study aimed at determining how members of the public would react to balanced information about nanotechnology risks and benefits. Finding no support for the familiarity hypothesis, the study instead yielded strong evidence that public attitudes are likely to be shaped by psychological dynamics associated with cultural cognition.

Cultural cognition refers to the tendency of people to base their factual beliefs about the risks and benefits of a putatively dangerous activity on their cultural appraisals of these activities[7,8]. From a psychological point of view it is easier to believe that behaviour one finds noble is socially beneficial, and that behaviour one finds debased is dangerous, than vice versa[9,10]. Those who are 'individualistic' and 'hierarchical' in their cultural worldviews tend to dismiss claims of environmental risk, for example, because acknowledging such hazards would threaten the autonomy of markets and the authority of social elites. Persons who hold 'egalitarian' and 'communitarian' worldviews, on the other hand, take environmental risks seriously because they believe unregulated markets are a source of inequality and, therefore, harmful to society[11,12]. Consistent with this dynamic, researchers have found evidence that people of opposing cultural outlooks polarize on various environmental and technological risks—from nuclear power[13] and global warming[14] to genetically modified foods and 'mad cow' disease[15].

The 'cultural cognition' hypothesis holds that these same patterns are likely to emerge as members of the public come to learn more about nanotechnology. That is, rather than adopt uniformly positive attitudes, as the familiarity hypothesis suggests, members of the public who hold relatively egalitarian and communitarian worldviews will perceive its risks to be greater and its benefits smaller than will those who hold relatively hierarchical and individualistic worldviews.

We designed a public opinion study to test the familiarity and cultural cognition hypotheses. The study reflected an experimental design aimed at detecting causal links, if any, between information exposure and attitude formation. We divided a diverse, national online sample of 1,862 Americans into two groups. Those in the 'no-information condition' were told nothing about nanotechnology other than it is a scientific process for producing and manipulating very small particles. Those in the 'information-exposed condition,' in contrast, were furnished with two paragraphs of equal length and comparable information content, one identifying possible benefits of nanotechnology, the other possible risks. We then compared the two groups' perceptions of nanotechnology risks and benefits to see what effect information exposure had.

Like most members of the American public[1,2], our study subjects reported being relatively unfamiliar with nanotechnology. The vast majority—over 80%—reported having heard either 'just a little' (28%) or 'nothing at all' (54%) about it. Only 4% reported having heard 'a lot' about nanotechnology before the study, and 14% reported having heard 'some,' an amount in between 'just a little' and 'a lot.' Among subjects in the no-information condition, familiarity with nanotechnology was positively correlated with the perception that nanotechnology's benefits outweigh its risks ($r_s = 0.38$, $P < 0.001$), a finding also consistent with previous public opinion studies[1-4].

Information exposure had no discernable main effect on subjects' perceptions of nanotechnology risks and benefits. The mean assessment on a four-point risk–benefit measure (NANORISK) for subjects in the information-exposed condition ($M = 2.37$, s.d. $= 1.03$) was virtually identical to the mean assessment for subjects in the no-information condition ($M = 2.34$, s.d. $= 0.99$).

To assess whether the impact of information exposure varied based on either familiarity with nanotechnology or cultural worldviews, we performed a multivariate regression analysis. The dependent variable for the analysis was whether subjects perceived the benefits of nanotechnology to be greater than its risks or vice versa. Independent variables included cultural worldview measures, the interaction of those worldviews, the degree of self-reported knowledge, and appropriate interactions of these variables with the experimental condition to which subjects were assigned. This analysis (see Supplementary Information, Fig. S1) can be used to determine how information exposure influences individuals either conditional on their cultural worldviews holding their level of familiarity constant, or conditional on their level of familiarity holding their cultural worldviews constant.

The results are illustrated in Fig. 1. Holding cultural worldviews constant (at the sample mean), information exposure does not have a significant effect on the likelihood that either a subject who is relatively unfamiliar with nanotechnology or one who is relatively familiar with it will perceive the benefits of nanotechnology to be greater than its risks (Fig. 1a).

In contrast, information exposure has a relatively large and statistically significant impact on subjects defined with reference to their cultural worldviews (Fig. 1b). In the no-information condition,

[1]Yale Law School, PO Box 208215, 127 Wall Street, New Haven, Connecticut 06520, USA, [2]The George Washington University Law School, 2000 H Street, NW, Washington, Dictrict of Columbia 20052, USA, [3]Decision Research 1201 Oak Street, Suite 200 Eugene, Oregon 97401, USA, [4]Department of Communication, University of Washington, Box 353740 Seattle, Washington 98195, USA, [5]Department of Psychology, University of Colorado, Boulder, Muenzinger Psychology Building, Boulder, Colorado 80309, USA; *e-mail: dan.kahan@yale.edu

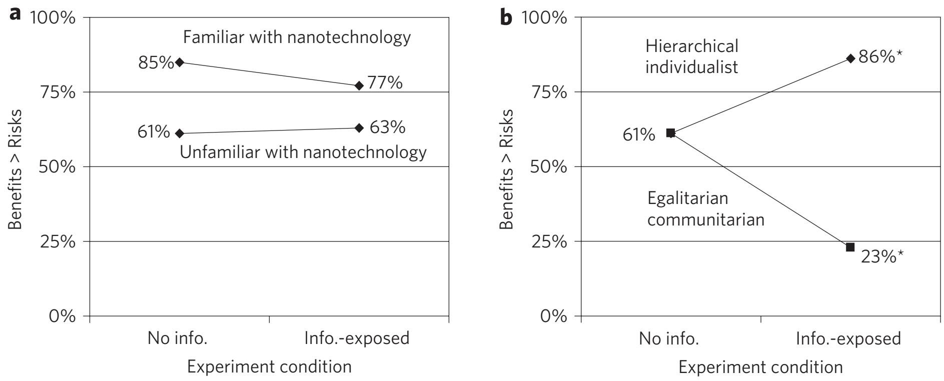

Figure 1 | Effect of information on risk–benefit perceptions of subjects defined by self-reported familiarity with nanotechnology and cultural worldviews. Likelihoods of response are derived by statistical simulation[29] from the logistic regression analysis (see Supplementary Information, Table S1). **a**, Likelihoods of response for the benefits of nanotechnology exceeding the risks in the no-information and information-exposed conditions when cultural worldviews are controlled (set to their means) for respondents who are unfamiliar (bottom line) and familiar (top line) with nanotechnology. **b**, Likelihoods of response across conditions when familiarity is controlled for (set to its mean) and the culture variables are set at values that reflect the worldviews of modestly hierarchical and individualistic subjects (top line), and modestly egalitarian and communitarian ones (bottom line). $N = 1,672$. *Change in likelihood across conditions significant at $P \leq 0.05$.

subjects whose cultural worldviews are moderately hierarchical and individualistic, on the one hand, and subjects whose worldviews are moderately egalitarian and communitarian, on the other, are equally likely (61%) to see the benefits of nanotechnology as outweighing its risks if we hold their level of self-reported knowledge constant (at the sample mean). In the information-exposed condition, however, the likelihood that hierarchical individualists will perceive benefits as greater than risks grows by 25%, while the likelihood that egalitarian communitarians will do so shrinks by 38%—opening up a 63% gap (86% to 23%) between them.

These results support the cultural cognition hypothesis but not the familiarity hypothesis. Our subjects did not react uniformly, much less in a uniformly positive manner, when exposed to information. Instead, they reacted divergently, in a manner consistent with their opposing cultural predispositions toward technological risk generally. This finding displays the signature of 'biased assimilation and polarization'—the tendency of persons to conform information to their predispositions and thus to become more, not less, divided when exposed to balanced information[16].

This result also raises the question why those who report greater familiarity with nanotechnology—in the no-information condition of our study and in previous opinion surveys—tend to see the benefits of nanotechnology as great and the risks as small. One possibility is selection bias. The relatively small portion of the population who say they have heard either a modest amount or a great deal about nanotechnology are obviously different from the vast majority who have heard little or nothing. The same set of forces that creates their unique motivation to learn about nanotechnology might also be uniquely disposing these persons to form positive views about it.

The study also yielded two other findings that reinforce this conclusion. First, we found that the subjects (in both conditions) who reported being relatively familiar with nanotechnology—the 18% who claimed to have heard either 'a lot' or 'some' about it—were not only less likely to perceive the risks of nanotechnology as greater than its benefits. They were also less likely than nanotechnology-unfamiliar subjects to be concerned with all manner of risk—whether from genetically modified foods, mad cow disease, nuclear power generation or the internet (Fig. 2). Obviously, it is not plausible to think that their familiarity with nanotechnology is the reason these persons are relatively unworried about these other risks. Instead, it is more sensible to think that

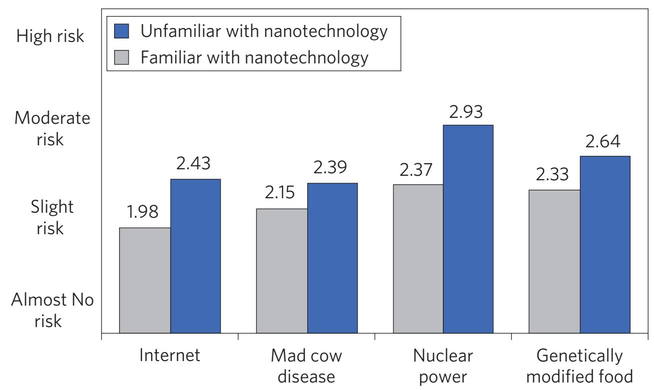

Figure 2 | How people familiar and unfamiliar with nanotechnology view the risks and benefits of other technologies. Risk variables are four-point measures of 'risk to people in American Society' posed by the internet, mad cow disease, nuclear power and genetically modified food. Canonical correlation between familiarity and the risk measures significant at $P \leq 0.01$. Differences between group means all significant at $P \leq 0.01$.

there is something else that is causing people who are generally sceptical of environmental and technological risks to learn more about (or at least claim they have learned more about) nanotechnology.

The second finding sheds some light on what that influence—or set of influences—might be. Regressing self-reported familiarity with nanotechnology on various individual characteristics revealed that being simultaneously hierarchical and individualistic predicted greater familiarity with nanotechnology (see Supplementary Information, Table S2 and Fig. S1). Because these worldviews generally dispose individuals to be sceptical about technological risks[13–15,17], it is no surprise that experimental subjects of this sort reacted positively when exposed to balanced information on nanotechnology. By the same token, it is no surprise that egalitarians and communitarians, who are less likely in the normal course to learn about nanotechnology, react less favourably when such information is brought to their attention.

In total, the study findings suggest a particular model of how cultural predispositions and exposure to information about nanotechnology work (Fig. 3). In the model, such predispositions both affect

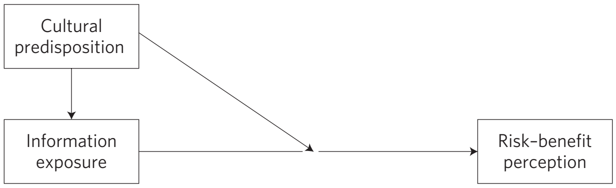

Figure 3 | Relationships between cultural worldviews, information exposure and risk–benefit perceptions. The study results suggest that cultural worldviews influence perceptions of the risks and benefits of nanotechnology both by influencing how likely subjects were to be exposed to information (or report being exposed to information) about nanotechnology, and by determining what effect—positive or negative—they gave to that information.

the likelihood of information exposure and moderate how information affects risk–benefit perceptions. People who have a pro-technology cultural orientation are thus more likely to become exposed to information about nanotechnology and to draw positive inferences from what they discover. Individuals who lack that predisposition, in contrast, are less likely to become exposed to information, and when they do become exposed to it they are significantly more likely to react negatively.

Our study reinforces the conclusions of other researchers who have cautioned against assuming that enlightened public opinion will spontaneously emerge from accumulating scientific information on the risks and benefits of nanotechnology[5,18]. Indeed, because individuals in the real world are likely to select information in a biased fashion that matches their cultural and political dispositions[19], one might anticipate even more extreme polarization outside the psychology laboratory than we observed in it when we exposed our subjects to a small bit of balanced information.

At the same time, nothing in our study suggests that cultural polarization over nanotechnology is inevitable. Social psychology is making important advances in identifying techniques for framing information on controversial policy issues in a manner that makes it possible for people of diverse values to derive the same factual information from it[20]. With further study, it is likely that these techniques can be used to guide risk communication and thus enhance democratic deliberations on risk-regulation policy—on nanotechnology[6] and other issues[21].

The practical lesson of our study, then, is that those who favour informed public deliberations on nanotechnology should be neither sanguine nor bleak. Instead they should be psychologically realistic. If they are, they will see the urgent need for additional efforts to develop risk communication strategies that make it possible for culturally diverse citizens to converge on policies that promote their common interests.

Methods

The sample consisted of 1,862 adults recruited by Knowledge Networks to be members of a probability-based online panel representative of the United States population. There has been considerable study of how probability-based online sampling, which is becoming increasingly common in scholarly public opinion research, performs relative to random-digit-dial telephone and other survey methods[22–24]. More information on the sampling methods of Knowledge Networks can be found at http://www.knowledgenetworks.com/ganp/index.html. Subjects participated in the study using Knowledge Networks' online facilities in December 2006.

In addition to standard demographic data, the study collected data on subjects' cultural values. Measures, adapted from previous studies of cultural cognition and the cultural theory of risk[13,17,25], assessed subjects' values with two scales, 'Individualism–Communitarianism' ($\alpha = 0.83$) and 'Hierarchy–Egalitarianism' ($\alpha = 0.81$). Each scale was designed to measure a separate dimension of the 'group-grid' worldview typology proposed by Mary Douglas[26]. In the regression-based simulation (Fig. 1), the culture variables for 'hierarchical, individualists' were set at values one standard deviation from the mean towards the hierarchy and individualist ends of the those scales; the culture variables for 'egalitarian communitarian' subjects were set at values one standard deviation from the mean towards the egalitarian and communitarian ends of those scales.

Subjects' perceptions of nanotechnology were also solicited. All subjects responded to a self-reported knowledge item (NANOKNOW) used in previous studies[1–4] that stated, 'How much have you heard about nanotechnology before today?' and permitted the responses, 'nothing at all', 'just a little', 'some' or 'a lot'. For certain analysis (see Supplementary Information, Table S2 and Figs 1, 2), subjects who answered 'some' or 'a lot' were deemed 'familiar' with nanotechnology, and those who answered 'nothing at all' or 'just a little' were deemed 'unfamiliar'. All subjects also responded to a four-point item (NANOBENEFIT), which required them to indicate whether they believed (1) 'the risks of nanotechnology will greatly outweigh its benefits', (2) 'the risks of nanotechnology will slightly outweigh its benefits', (3) 'the benefits of nanotechnology will slightly outweigh its risks', or (4) 'the benefits of nanotechnology will greatly outweigh its risks'. A reverse-coded item (NANORISK) was used to compute the mean scores for subjects in both conditions. In the multivariate logistic regression analysis (see Supplementary Information, Table S1), responses to this item were collapsed into a dichotomous 'Benefit > Risk' (0) and 'Risk > Benefit' (1) measure.

Before responding to NANOBENEFIT, all subjects read this introductory statement:

Now we would like to know what you think about nanotechnology. Nanotechnology is the ability to measure, see, predict and make things on the extremely small scale of atoms and molecules. Materials created with nanotechnology can often be made to exhibit very different physical, chemical and biological properties than their normal size counterparts.

Subjects assigned to the information-exposed condition were also asked to read the following two paragraphs (the order of which was rotated) before responding to NANOBENEFIT:

The potential benefits of nanotechnology include the use of nanomaterials in products to make them stronger, lighter and more effective. Some examples are food containers that kill bacteria, stain-resistant clothing, high performance sporting goods, faster, smaller computers, and more effective skincare products and sunscreens. Nanotechnology also has the potential to provide new and better ways to treat disease, clean up the environment, enhance national security and provide cheaper energy.

While there has not been conclusive research on the potential risks of nanotechnology, there are concerns that some of the same properties that make nanomaterials useful might make them harmful. It is thought that some nanomaterials may be harmful to humans if they are breathed in and might cause harm to the environment. There are also concerns that invisible, nanotechnology-based monitoring devices could pose a threat to national security and personal privacy.

All subjects, before responding to the items relating to nanotechnology, also indicated their perceptions of a variety of other risks on a four-point scale that permitted them to characterize a set of activities or states of affairs as presenting 'almost no risk', 'slight risk', 'moderate risk' or 'high risk'. This item, too, was patterned after one used in previous risk-perception studies[27,28]. Because few subjects ever report seeing 'no risk', 'almost no risk' has been shown more accurately to separate out the subjects who are the most risk-sceptical from those who are the next most risk-sceptical.

The complete study instrument is available on request from D.M.K.

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Author contributions

All authors participated in the design of the study, in analysis of the results, and in drafting and revision of the paper.

Additional information

Supplementary Information accompanies this paper at www.nature.com/naturenanotechnology. Reprints and permission information is available online at http://npg.nature.com/reprintsandpermissions/. Correspondence and requests for materials should be addressed to D.M.K.

The Cultural Cognition of the Risks and Benefits of Nanotechnology: Supplementary Information

Predictor	*Effect*
Information	6.95 (4.00)
Self-reported Familiarity (NANOKNOW)	-0.85* (0.08)
Individualism (v. Communitarianism)	1.79* (0.81)
Hierarchy (v. Egalitarianism)	2.14* (0.86)
Hierarchy x Individualism	-0.77* (0.31)
Information x Self-reported Familiarity (NANOKNOW)	0.33* (0.16)
Information x Hierarchy	-3.18* (1.57)
Information x Individualism	-2.63 (1.45)
Information x Hierarchy x Individualism	1.11* (0.55)
Log Likelihood	-1,045.09
Prob > Chi^2	0.00
Pseudo R^2 (McKelvey -Zavoina)	0.14

Table S1. Logistic Regression Analysis: Risk-Benefit Perceptions Across Experimental Conditions. *N* = 1,672. The dependent variable is a dichotomous measure: Nanotechnology Benefit > Risk (0) vs. Nanotechnology Risk > Benefit (1). Independent variable effects are expressed in log-odds (logit) coefficients. * denotes significant at $p \leq .05$. Standard errors are in parentheses. "Information" is a dummy variable for the experimental condition: "0" for "no information" and "1" for "information exposed." The coefficient for any individual predictor indicates its impact on the likelihood that risks will be perceived to be greater than benefits in the "no information" condition; the coefficient for the product of Information and that predictor indicates its impact on risk-benefit perceptions in the "information exposed" condition relative to the "no information" condition. Thus the sign for Self-reported Familiarity is *negative*, indicating that in the "no information" condition, familiarity predicts a *decrease* in the likelihood that risks will be seen as greater than benefits. In contrast, the sign for Information x Self-reported Familiarity is *positive*, indicating that familiarity does not decrease the likelihood that risks will be perceived as greater than benefits as much in the information-exposed condition as it does in the no-information condition. Because the signs of both Hierarchy and Individualism are significant and *positive*, and the signs for Information x Hierarchy and Information x Individualism are both *negative*, information exposure predicts a decrease in the likelihood that risks will be perceived to be greater than benefits as worldviews become either more hierarchical or more individualistic. The significant coefficients for Hierarchy x Individualism and Information x Hierarchy x Individualism, however, mean that in both conditions the impact of each worldview predictor varies as the other increases. The most straightforward way to determine the effect of any combination of variables when set at values of interest is by a statistical simulation based on the regression model[1,2].

Predictor	*Effect*
Male	0.94* (0.14)
White (vs. Black)	0.48 (0.27)
Other Minority (vs. Black)	0.60* (0.30)
Education	0.29* (0.04)
Age	-0.01* (0.00)
Household Income	-0.02 (0.02)
Republican (vs. Democrat)	0.07 (0.17)
Independent (vs. Democrat)	-0.21 (0.32)
Conservative (vs. Liberal)	0.02 (0.06)
Hierarchy (vs. Egalitarianism)	-3.10* (0.71)
Individualism (vs. Communitarianism)	-2.01* (0.66)
Hierarchy x Individualism	0.99* (0.25)
Log Likelihood	-768.40
Prob > Chi^2	0.00
Pseudo R^2 (McKelvey –Zavoina)	0.16

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Table S2. Logistic Regression Analysis: Self-Reported Familiarity with Nanotechnology. *N* = 1,785. The dependent variable is a dichotomous measure of self-reported knowledge of nanotechnology based on NANOKNOW (“Nothing at all” and “a little” = 0; “Some” and “A lot” = 1). Independent variable effects are expressed in ordered log odds (logit) coefficients. * denotes significant at $p \leq .05$. A positive coefficient (e.g., for “Male” or for “Education”) indicates that the specified predictor increases, a negative coefficient (e.g., for Age) that it decreases, the likelihood of self-reported familiarity. The significance of the interaction term, Hierarchy x Individualism, indicates that a disposition toward hierarchy increases the likelihood of self-reported familiarity by a larger amount as the disposition toward individualism increases, and likewise that a disposition toward individualism increases the likelihood of self-reported familiarity by a larger amount as the disposition toward hierarchy increases. (The coefficients for Hierarchy and Individualism do not admit of meaningful interpretation in the model[3]).

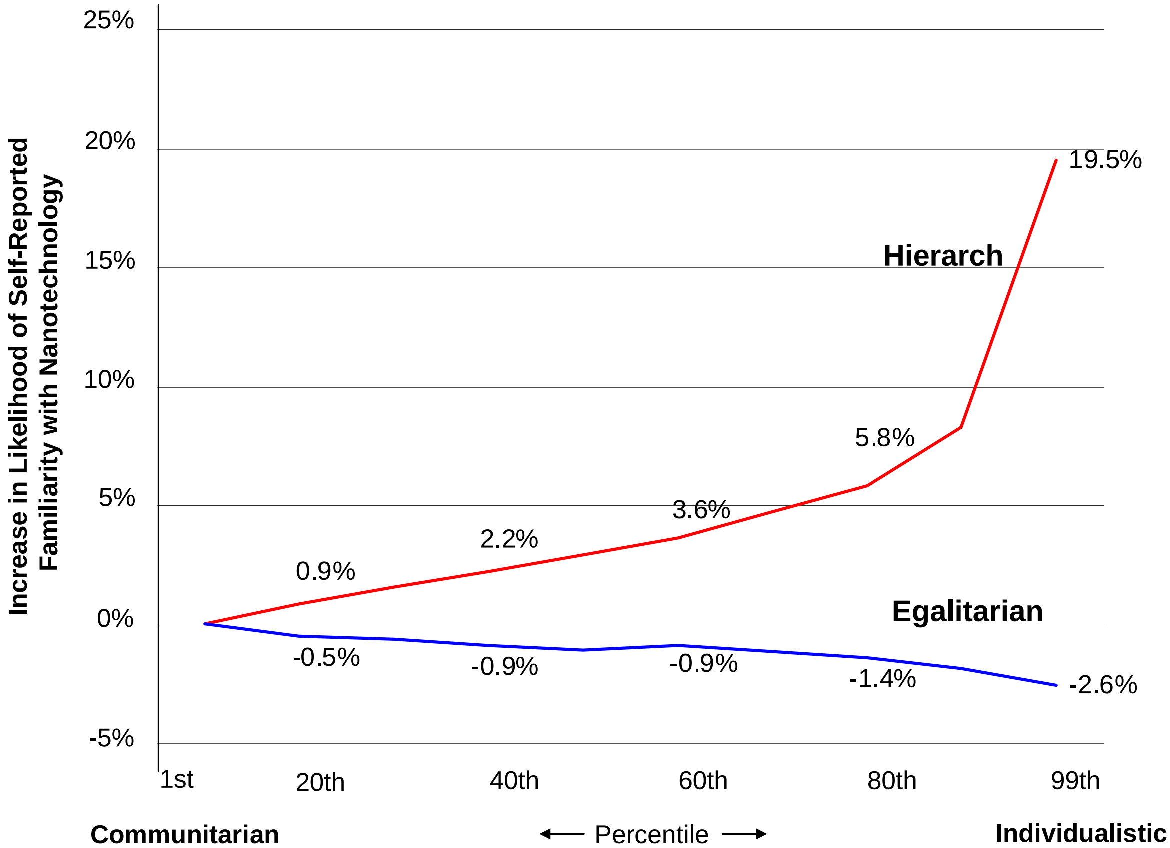

Figure S1. Predicted Increase in Likelihood Of Self-Reported Familiarity With Nanotechnology As Individualism Increases. *N* = 1,785. Likelihoods are derived by statistical simulation[1] from the logistic regression analysis reported in Table S2. The curves for "Hierarch" and "Egalitarian" show the impact of increasing degrees of individualism when the value for Hierarchy in the regression model is set one standard deviation from the mean toward the hierarchy and egalitarianism ends of the Hierarchy-Egalitarianism scale, respectively. Values for all other predictors are controlled for (by being set to their sample means).

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Scientists worry about some risks more than the public

DIETRAM A. SCHEUFELE[1]*, ELIZABETH A. CORLEY[2], SHARON DUNWOODY[3], TSUNG-JEN SHIH[3], ELLIOTT HILLBACK[3] AND DAVID H. GUSTON[4]

are in [1]the Department of Life Sciences Communication, University of Wisconsin–Madison, 440 Henry Mall, Madison, Wisconsin 53706, USA; [2]the School of Public Affairs, Arizona State University, 411 North Central Avenue, Phoenix, Arizona 85004, USA; [3]the School of Journalism & Mass Communication, University of Wisconsin–Madison, 821 University Avenue, Madison, Wisconsin 53706, USA; [4]the Department of Political Science, Arizona State University, PO Box 874401, Tempe, Arizona 85287, USA.
*e-mail: scheufele@wisc.edu

A comparison between two recent national surveys among nanoscientists and the general public in the US shows that, in general, nanoscientists are more optimistic than the public about the potential benefits of nanotechnology. However, for some issues related to the environmental and long-term health impacts of nanotechnology, nanoscientists were significantly more concerned than the public.

In previous controversies surrounding emerging technologies, such as nuclear energy and food biotechnology, scientists, in most cases, perceived lower risks associated with these new technologies than the general public or the journalists covering these stories. These findings seem to hold in both the US and Europe[1,2,3], and most recently, an exploratory comparison of a quota sample of 375 lay people and a convenience sample of 46 experts in Switzerland suggested that the same pattern is beginning to emerge for nanotechnology as well[4].

However, two large-scale systematic data collections in the US now show that the dynamics surrounding risk perceptions of nanotechnology among members of the general public and nanoscientists shape up to be much more complex than for previous issues. In particular, historical patterns of the difference between the perceptions of scientists and the general public of risks may be reversed for nanotechnology.

We collected survey data from both lay individuals and nanotechnology scientists. Both surveys used questions with identical wording, providing a unique opportunity for systematic comparisons across two large-scale, national data sets. The first data source was a general population telephone survey of 1,015 US adults; the second data source was a mail survey of 363 nanotechnology scientists and engineers. The fieldwork was conducted from May to July 2007 for the public opinion survey, and from May to June 2007 for the scientist survey (see Methods).

Not surprisingly, scientists were generally more optimistic about the benefits and less concerned about the risks of nanotechnology than the general public. For example, scientists were more optimistic about the potential for nanotechnology to lead to breakthroughs in medicine, environmental cleanup or national defence (Fig. 1a). Members of the general public, in contrast, were more concerned about potential drawbacks of nanotechnology than scientists, including the potential loss of privacy or adverse economic impacts (Fig. 1b).

However, scientists expressed more concerns than the general public about two areas of potential risks: more pollution and new health problems as a result of nanotechnology. This makes nanotechnology unusual among emerging technologies in that scientists working directly with the technology express stronger concerns about specific potential risk areas than the general public does.

These differences in risk perceptions between scientists and the general public for nanotechnology can be explained to some degree by how the issue has evolved, both in scientific circles and in the public debate. In particular, the fact that scientists are more concerned about new health problems and potential pollution than the general public should not be too surprising for at least two reasons.

First, there has been an ongoing debate in science and policy circles about a lack of systematic nano-related risk research in both academia and business[5]. Although many of these discussions were initially driven by specific toxicological concerns, similar concerns are now being voiced more broadly. In 2006, for instance, the Royal Society and the Royal Academy of Engineering in the UK recommended an expansion and standardization of research on the environmental, health and safety (EHS) impacts of nanomaterials[6]. Similarly, concerns about these have been the subject of public hearings in the US, organized by the Food and Drug Administration and, most recently, the Environmental Protection Agency.

Second, and somewhat related, interest groups in the US have pushed for specific regulations and safety procedures for new nano-enabled products. For example, in a letter dated November 22 2006, the National Resource Defense Council lobbied the Environmental Protection Agency to regulate products containing silver nanoparticles under the Federal Insecticide, Fungicide, and Rodenticide Act. As a result, Amazon.com and Sharper Image removed from their websites all references to nanotechnology in descriptions of products that contained silver nanoparticles (such as Fresher Longer food containers). These changes went largely unnoticed by the general public[7].

The reasoning behind the strategies by some of these interest groups, of course, is to set the agenda among policy makers and other scientific elites, and ultimately to shape policy. Ironically, all these efforts take place without much media attention and without large-scale involvement of the public[8]. As our data show, one result is that health and environmental concerns are not at the forefront of most people's thinking. This is not to say that scientists are necessarily right and the public wrong in their assessments, and neither is it to say that other concerns that scientists and the public share, such as privacy, should be neglected. But it does suggest that, similar to findings from earlier research[9,10], public attitudes toward nanotechnology continue to be shaped by predominantly positive media frames[11] and what Gaskell *et al.* have called a culture of technological optimism in the US[12].

We do not mean to suggest, either, that the public should be more alarmed about environmental or health-related risks associated with nanotechnology than they currently are, or that concerns among scientists are simply an outcome of agenda-building efforts by interest groups or policy makers. Rather, our findings show a gap in risk perceptions among scientists and the general public that — regardless of its origin — is indicative of serious communication deficits.

The relatively low levels of attention that health and environmental risks of nanotechnology have received in mass media[11], therefore, provide industry and university scientists working in this area with a unique opportunity to take a leadership role in engaging the public in a meaningful dialogue about nanotechnology. And we strongly echo the argument of Currall *et al.*[13] that "now is the time to educate the public aggressively with facts about the risks and benefits of nanotechnology".

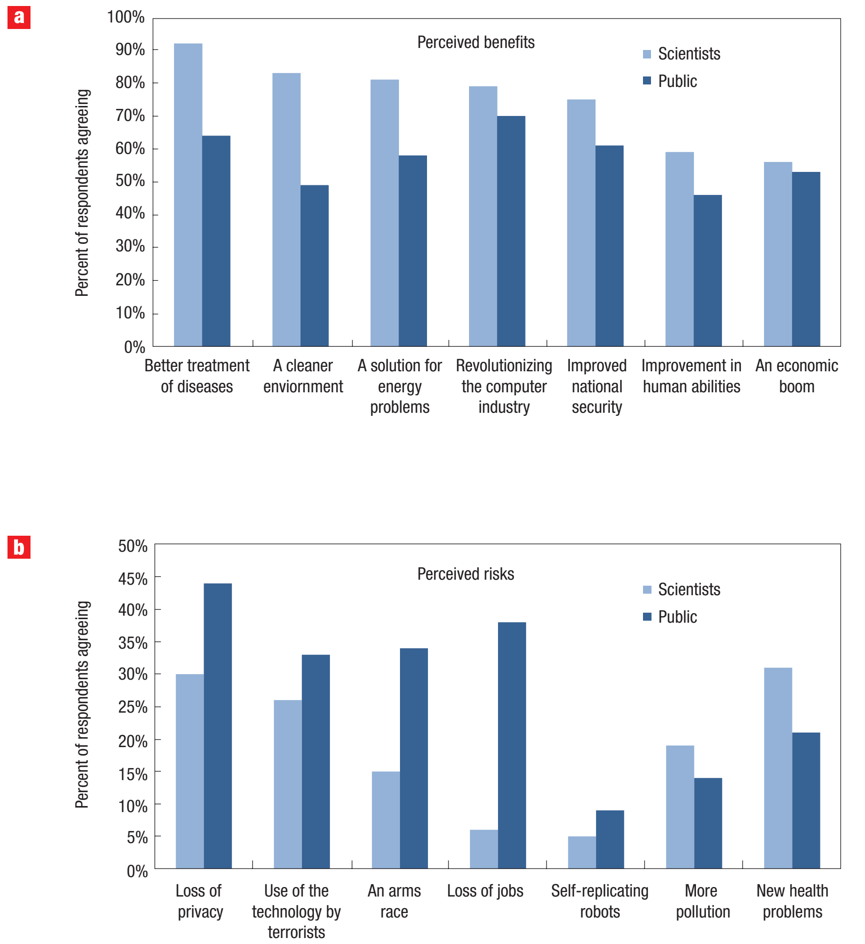

Figure 1 Perceived risks and benefits of nanotechnology. Scientists are more optimistic than the public about the potential benefits. They are also more concerned about environmental and health risks, but not other risks. **a**, Scientists (pale blue columns) were significantly more likely than the general public (dark blue) to agree that nanotechnology may lead to "new and better ways to treat and detect human diseases" or to "new and better ways to clean up the environment". **b**, Members of the general public, in contrast, were more concerned about five of the seven potential drawbacks of nanotechnology explored in the survey, such as the "loss of personal privacy because of tiny new surveillance devices" or the loss of "more US jobs". However, scientists were more concerned than the public about the potential of nanotechnology to lead to "more pollution and environmental contamination" and "new human health problems".

In fact our research shows that industry and university scientists are among the handful of groups the public trusts the most for information about nanotechnology — much more than governmental bodies, regulatory agencies and news media. Nanotechnology may, therefore, be one of the first emerging technologies where academia and business have the ability to reach out directly to a public who trusts the information they provide. Ironically, nanotechnology may also be the first emerging technology for which scientists may have to explain to that public why they should be more rather than less concerned about some potential risks.

METHODS

The first data source was a general population telephone survey of 1,015 US adults (AAPOR RR-3: 30.6%)[14]. The fieldwork was conducted from May to July 2007, and the approximate margin of error was ±3%. In order to minimize systematic non-response, we invested significant time and effort in call backs and refusal conversions.

The second data source was a mail survey of 363 nanotechnology scientists and engineers that was administered in three waves, following Dillman's Total Design Method[15] (AAPOR RR-3: 39.5%). The survey was based on a rigorous sampling design that identified first authors and contact authors of more than 90,000 nanotechnology publications indexed in the ISI Web of Knowledge database between January 2005 and July 2006. (See ref. 16 for background on this method).

In order to construct our target sample, we compiled names and detailed contact information for a complete list of the roughly 1,000 US scientists (first or contact authors) whose nano-related work was cited five times or more in the publication database. By focusing on the most highly cited and most active scientists within the nanotechnology field, we were able to capture opinions from scientists with an established track record in the field of nanotechnology, rather than from scientists in unrelated disciplines who happened to publish on a nanotechnology-related topic during the timeframe outlined in our sampling frame. Given that many of the graduate students who were listed as authors on papers in our sample had moved to other labs or institutions by the time the survey went in the field, it was difficult to reliably identify contact information for many of them. The small number of students who were listed as lead or contact authors were therefore excluded from the sample. The fieldwork was conducted from May to June 2007. The approximate margin of error was ±5%.

Both surveys were conducted by the University of Wisconsin Survey Center. Additional methodological details for both studies are available from the corresponding author.

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The Center for Nanotechnology in Society
ARIZONA STATE UNIVERSITY

National Citizens' Technology Forum Report

National Citizens' Technology Forum: Nanotechnologies and Human Enhancement

Patrick Hamlett
North Carolina State University

Michael D. Cobb
North Carolina State University

and

David H. Guston
Arizona State University

Center for Nanotechnology in Society
Arizona State University

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EXECUTIVE SUMMARY

Many observers believe that the "converging technologies" of nanotechnology, biotechnology, information technologies, and cognitive science (NBIC) could lead to radical and pervasive enhancements of human abilities. Both supporters and critics of NBIC technologies acknowledge that their continued development and deployment portend dramatic social and cultural challenges. Stakeholders see a need for *informed citizen input* early in the process of developing such technologies. Indeed, the legislation that authorizes the US National Nanotechnology Initiative (P.L. 108-93) speaks to the importance of public input in decision making about such research and development.

This report discusses the results of one major effort at public input. In March 2008, the Center for Nanotechnology in Society at Arizona State University (CNS-ASU) and its collaborators at North Carolina State University held the nation's first "National Citizens' Technology Forum" (NCTF), on the topic of nanotechnology and human enhancement. Organizers selected from a broad pool of applicants a diverse and roughly representative group of seventy-four citizens to participate at six geographically distinct sites across the country. Participants received a sixty-one page background document – vetted by experts – to read prior to deliberating. They also completed a pre-test questionnaire to record their initial attitudes and understandings of the topic. They deliberated face-to-face in their respective geographic groups for one weekend at the beginning of the month, and they deliberated electronically across their geographic groups in nine, two-hour sessions during the rest of the month. Electronic deliberations included question-and-answer sessions with a diverse group of topical experts. The NCTF concluded with a second face-to-face deliberation at each site. Participants drafted reports that represented the consensus of their local groups, and they completed a post-test questionnaire to record their perspectives on the NCTF and any changes in their attitudes and understandings.

Findings from the reports include:

- Unanimous support (six of six sites) among sites regarding
    - concern over the effectiveness of regulations for NBIC technologies, and
    - the need to provide public information, including more public deliberative activities and K-12 education, about NBIC technologies;
- Near-unanimous support (five of six sites) among sites regarding
    - concern about the equitable distribution of new enhancement technologies,
    - the greater importance of therapeutic over enhancement research and the important role that stakeholders might play in setting that research agenda,
    - the need for careful monitoring of such technologies and the development of international safety standards for them, and
    - the development of such technologies to maximize their benefits with both public and private investment;
- majority support (four of six sites) among the sites regarding
    - formal inclusion of ethicists and ethical considerations into decision-making for NBIC technologies;

  - the careful protection of individual privacy in the development and deployment of these technologies; and
  - the potentially problematic role of health insurance in limiting access to new enhancement technologies; and
- split support (three of six sites) among the sites regarding
  - concerns that NBIC technologies might fall into the hands of terrorists or have other unanticipated military applications,
  - concerns about potential environmental consequences, and
  - ensuring the protection of civil liberties and free choice – particularly the choice to refuse enhancements.

Findings about the participants' views on human enhancement technologies from the pre- and post-test questionnaires include:

- reduced certainty about the benefits of human enhancement technologies;
- increased worry about the affordability of NBIC enhancements and overwhelming support for the government to guarantee access to them if they prove too expensive for the average American;
- reduced, but still strong, support for publicly funded research for developing human enhancement technologies;
- conflicting emotions – continued, extensive hope and increased worry – about NBIC developments;
- opposition to many particular kinds of hypothetic human enhancements as described in the background literature.

Findings about the participants' experience on the NCTF process from the pre- and post-test questionnaires include:

- significant increases in the percentage of participants who hold opinions about NBIC technologies;
- significant substantive learning by participants about the details of nanotechnology and human enhancement technologies;
- very high levels of individual support for the conclusions of the respective geographic groups;
- increased feelings of efficacy and trust as a result of participants' role in the NCTF; and
- changes in preferences from on-line mediated deliberations to face-to-face deliberations.

We conclude that average citizens want to be involved in the technological decisions that might end up shaping their lives. Citizens remain strongly supportive of research that might lead even to transformational technologies, provided that reliable information about and attentive and trustworthy oversight of their development exists. Such information and oversight should not be restricted to environmental health and safety but should include social risks such as equity, access, and civil rights. With the appropriate information and access to experts, citizens are capable of generating thoughtful, informed, and deliberative analyses that deserve the attention of decision makers.

INTRODUCTION

A new area of technological change has been emerging onto the agendas of decision makers around the globe: the "converging technologies" of nanotechnology, biotechnology, information technologies, and cognitive science (NBIC). Many observers believe that these new technologies could lead to radical and pervasive enhancements of human abilities. Some visionaries expect NBIC technologies to dramatically enhance strength and endurance, alleviate or eliminate pain, improve or restore sight and hearing, enhance memory, speed information processing, spark artistic expression, and extend life.

Some anticipate, however, significant social change as these technologies move into widespread use, and many are concerned about public reactions them: What would relationships between "enhanced" and "un-enhanced" people in society be like? What does fairness mean when previously immutable aspects of a person's abilities are alterable? What would significantly increased life expectancy do to families, to work, to cultural continuity and innovation, and to society more generally?

These concerns have led to a flurry of interest among scholars, policymakers, and interest groups both in the United States and Europe. A number of committees, conferences, and scholars have generated in-depth reports about human enhancement technologies in general and NBIC implications in particular (see p. 12 for Selected Further Readings). Despite their disagreements on the prospective value of these new technologies, both supporters and critics of NBIC acknowledge that their continued development and deployment portend dramatic and powerful social and cultural challenges.

Such promises and challenges raise the stakes for the development and introduction of NBIC technologies, and many people across government, business, academe, and public interest and advocacy groups see a great need for *informed citizen input* early in the process of developing such potentially revolutionary technologies. With numerous examples of major technologies having become entangled in divisive political conflict and legal action—e.g., nuclear energy and genetically modified foods—decision makers are often eager to find ways to elicit the values and concerns of ordinary people and incorporate them into the process of developing these technologies. Indeed, the federal legislation that authorizes much of the US National Nanotechnology Initiative (Public Law 108-93) speaks to importance of public input in decision making about nanotechnology research and development.

CONSENSUS CONFERENCES AND CITIZENS' TECHNOLOGY FORUMS

In recent decades, new techniques for eliciting informed, deliberative public opinion have been developed and used in several countries. These techniques are often more helpful than traditional public opinion polls when the topics of concern are those, like emerging technologies, about which the public has initially very modest levels of information.

One of these practices, developed in Denmark and known as a "Consensus Conference," involves recruiting ordinary, non-expert citizens, providing them with background information and access to experts on the particular topic, and assisting them as they deliberate toward a set of agreed-to recommendations. The Danish Parliament's Board of Technology, which organizes the consensus conferences, helps communicate the recommendations to the parliament, the press, and the public.

Over the past ten years, a technique based on the Danish consensus conferences – called the "Citizens' Technology Forum" (CTF) – has been developed by scholars at North Carolina State University for use in the American context. To the original Danish model, the CTF adds the Internet as a mode of interaction, in addition to face-to-face interactions, among the citizen participants. On-line communication allows deliberations involving multiple groups of citizens in multiple geographic locations – a crucial innovation if such a process is to take root across a country that spans a continent and has multiple population centers, compared to one roughly twice the size of Massachusetts with one central city.

The CTFs conducted in the US, which have examined topics including genetically modified foods, climate change, and nanotechnology, have usually been run in university contexts as research and demonstration projects and have not been part of official policy making bodies. As part of this research orientation, many CTFs have included questionnaires administered to the participants before and after their participation, allowing researchers to collect significant amounts of data about processes of learning, attitude changes, and personal interactions in which citizens engage.

THE NATIONAL CITIZENS' TECHNOLOGY FORUM

In March 2008, the first National Citizens' Technology Forum (NCTF) took place. It employed the basic CTF process, but this time involved six locations across the country, and the participation of seventy-four individuals.

The NCTF was organized under the auspices of the Center for Nanotechnology in Society at Arizona State University (CNS-ASU), which is funded by the National Science Foundation to perform research, training and outreach on the societal aspects of nanotechnology. The six sites participating in the NCTF, representing six distinct regions of the country, were:

- the University of New Hampshire (Durham), in the North East;
- Georgia Institute of Technology (Atlanta), in the South;
- the University of Wisconsin (Madison), in the Upper Midwest;
- the Colorado School of Mines (Golden), in the Mountain region;
- Arizona State University (Tempe), in the South West; and
- the University of California (Berkeley), on the West Coast.

The results of the study, therefore, are not limited to one section of the country, but reflect a truly national, informed, deliberative public assessment of NBIC potentials.

Each campus formed a facilitation team including a faculty leader and other assisting faculty and students. A complete list of facilitation team members can be found in

Appendix A. Dr. Patrick Hamlett (North Carolina State University, NCSU), coordinated the overall project, including the on-line components, and Dr. Michael Cobb (NCSU) oversaw the data gathering and analysis elements. Drs. Hamlett and Cobb both have experience in running the earlier CTFs and, under subcontract from CNS-ASU, coordinated many of the operational aspects of the NCTF as well.

Panelists. Each geographic site recruited its own panelists using newspaper and Internet advertising. While some sites attracted large numbers of volunteers and other sites attracted fewer – possibly due to the exotic and unfamiliar nature of the technologies in question – each site endeavored to create panels that were broadly representative of the communities from which they were drawn. Prospective panelists also answered a questionnaire to elicit demographic information and discover any possible conflicts of interest. Efforts at matching local and, in aggregate, national demographics were largely successful (see **Appendix B**), although both applicants and participants were somewhat more liberal and educated than the population as a whole. A small number of potential panelists were excluded for reasons of conflict.

Panelists were required to have Internet access in order to participate, although sites also arranged for the use of local libraries or other accessible venues if that became a hardship for participants. Because of the intensive nature of the NCTF and the considerable time commitment involved– two full weekends of face-to-face (F2F) meetings and 18 hours of Internet, or keyboard-to-keyboard (K2K) communication – organizers paid the participants $500 upon completion of their duties.

Background Materials. The organizers prepared a sixty-one page background document and delivered it to each panelist prior to the first F2F meeting. The document, describing the emergence of NBIC technologies and the debates about their anticipated social impacts, was drafted and edited by many researchers across CNS-ASU.

Following the Danish pattern, an Oversight Committee reviewed drafts of the document to help ensure that the materials were accurate, balanced, and accessible. The Oversight Committee consisted of Ida-Elisabeth Andersen, a project manager for the Danish Board of Technology in Copenhagen, and David Rejeski, the director of the Project on Emerging Nanotechnologies of the Woodrow Wilson International Center for Scholars in Washington, DC. The background document is available at http://www4.ncsu.edu/~pwhmds/.

Pre-and Post-tests. A pre- and post-test questionnaire was developed and administered to all panelists. The questionnaires assess several possible impacts of participation by the citizens, including factual learning and shifts in attitudes about NBIC technologies, as well as qualities of the deliberative process itself, including the presence and strength of cognitive and affective pathologies of deliberation and the level of consensus among the participants.

First F2F Weekend. During the first weekend of the NCTF, citizens gathered for face-to-face discussions that were led by facilitators from each of the campuses. The panelists discussed the background materials, the structure and goals of the project, and began to raise whatever concerns or issues they found significant. While the background document provided substantial information and framed the inquiry, the panelists had significant control over what specific issues or concerns should be addressed.

Internet Elements. The panelists from all six sites joined together for nine, two-hour synchronous online discussion sessions. During these Internet sessions, panelists from all the sites were exposed to the concerns, interests, values, and perspectives of panelists at all the other sites. During some of these sessions, content experts joined the discussions to respond to follow-on questions developed by the panelists and to fill in any gaps in the background materials. The content experts included technical specialists, a philosopher, and a specialist in regulatory processes. The content experts who participated were:

- Dr. Roberta M. Berry, the Georgia Institute of Technology (a specialist on the legal, ethical, and policy implications of life sciences research and biotechnologies);
- Dr. Steven Helms Tillery, Arizona State University (a specialist on cortical neuroprosthetics);
- Dr. Maxwell J. Mehlman, Case Western Reserve University (a specialist in the federal regulation of medical technology);
- Dr. Kristin Kulinowski, Rice University (Executive Director of the Center for Biological and Environmental Nanotechnology); and
- Dr. Jason Scott Robert, Arizona State University (a philosopher of science and the bioethicist).

Final F2F Weekend. The panelists gathered for a second and final F2F weekend during which they reconsidered the issues, problems, and concerns they had expressed during the first weekend in light of the additional information and discussions provided by the Internet sessions. Working with a facilitator, they then deliberated toward a set of policy recommendations that all panelists could endorse. The panelists themselves then compiled these recommendations into each site's Final Report.

Final Reports. After each panel reached a consensus among its members about what recommendations to advance, the panelists at each site wrote a Final Report representing that consensus. Each site's Final Report (available at http://www4.ncsu.edu/~pwhmds/final_reports.html) contains the specific recommendations that each panel endorsed, along with a discussion of issues, concerns, and values the panelists believe should be important in the management of NBIC technologies.

While the panelists at each site had been exposed to the concerns and issues panelists at the other sites thought were important, there was no effort to reach a single consensus involving all six sites; thus, each Final Report represents concerns and issues specific to that site. Nevertheless, when we compare the Final Reports, we find significant overlap among all six sites.

Findings from the Reports. An examination of the recommendations contained in the Final Reports illustrates the areas of concern expressed by panelists from all areas of the country about NBIC technologies of human enhancement.

- **Regulatory adequacy.** All sites (6 of 6) expressed significant concern about effective regulation of new NBIC technologies. Some sites recommended creating a new regulatory agency specifically charged with managing these technologies, while others recommended strengthening the Food and Drug Administration (FDA).
- **Public information.** All sites (six of six) strongly endorsed programs intended to keep the public informed about developments in human enhancement technologies, including conducting more deliberative panels and including discussions in high school and K-12 education.
- **Access & equity**. Nearly all the sites (5 of 6) included recommendations that emerging enhancement technologies be made available on an equitable basis to those who need them most.
- **Funding accountability**. Nearly all the sites (5 of 6) recommended that funding be prioritized for the treatment of disease before enhancements and that stakeholders should have a say in research decisions.
- **Safety**. Nearly all the sites (5 of 6) included recommendations for the careful monitoring of enhancement technologies, including the development of international safety standards for them.
- **Entrepreneurship & development**. Nearly all the sites (5 of 6) included recommendations that the development of these technologies should maximize their benefit, and that both public and private investment in these technologies is critical.
- **Ethical consideration.** A majority of the sites (4 of 6) recommended that ethicists and ethical considerations should be a formal part of decision-making about these technologies.
- **Privacy**. A majority of the sites (4 of 6) recommended that individual privacy be carefully protected in the development and deployment of enhancement technologies.
- **Health insurance**. A majority of the sites (4 of 6) were concerned about whether health insurance providers should be required to cover the costs of enhancements, and how health providers can provide adequate information about enhancements and other alternatives in health care.
- **Military uses**. Half of the sites (3 of 6) worried that NBIC enhancements might fall into the hands of terrorists or have other unanticipated military applications.
- **Environmental impacts**. Half of the sites (3 of 6) expressed concerns about possible environmental degradation from the use of NBIC technologies, especially in areas of waste management and toxicity.

- **Rights**. Half of the sites (3 of 6) wanted to ensure that individuals retain the right to refuse enhancements and that civil liberties and free choice be protected if and when these NBIC technologies are deployed.

<u>Findings from the Pre- and Post-tests</u>. Examination of responses to the pre- and post-tests provides statistically reliable data about the panelists' attitudes toward NBIC and human enhancement technologies. The data also provide insights into the quality of the deliberation in the NCTF.

- Deliberation resulted in reduced certainty among the participants about the benefits of enhancing human capabilities. Pre-deliberation, 82% were at least somewhat certain the benefits would exceed the risks; post-deliberation the percentage of these respondents dropped to 66%. Conversely, deliberation slightly strengthened participants' perception that most scientists were confident the benefits would exceed the risks (92% pre-deliberation and 96% post-deliberation).

- Despite concerns about risks, participants overwhelmingly favored government's guaranteeing access to human enhancements if they proved to be too costly for the average American. Prior to deliberation, 57% held that government should provide such guarantees; after deliberation, 63% said it should. On the other hand, deliberation resulted in a significant increase in the belief that individuals should have to pay out of pocket for most kinds of enhancement. Before deliberation, 74% thought insures should pay for most kinds of enhancements; after deliberation that percentage had shrunk to 55%.

- Deliberations increased general concern on the part of participants about NBIC developments but not at the expense of optimism. The percentage of those who expressed worries about NBIC technologies increased from 65% pre-deliberation to 80% post-deliberation, while the percentage of those who were not worried at all decreased from 35% pre-deliberation to 21% post-deliberation. Despite the shifts, the percentage of those who describe themselves as "hopeful" about NBIC technologies was 98% pre-deliberation and 98% post-deliberation.

- Deliberation increased specific worry about affording enhancements. Before deliberation, 63% were at least somewhat worried that the average family would not be able to afford enhancements; after deliberation, that percentage increased to 76%. Similarly, before deliberating, 48% of participants were at least somewhat worried that their own family would not be able to afford enhancements; after deliberating, that percentage increased to 60%.

- Despite increased concerns about costs, the panelists increased their support for individual responsibility for meeting the costs of enhancements. Those who believe that individuals, not insurance companies, should pay for enhancements shifted from 14% pre-deliberation to 32% post-deliberation.

Those who thought that we should avoid technologies that interfere with natural human development increased from 39% (29% strongly) pre-deliberation to 53% (41% strongly) post-deliberation.

- Deliberation reduced support for government spending for research on human enhancements. Before deliberating, participants' average score was 7.3 on an 11-point scale, where "11" meant they favored dramatically increased government spending and "1" meant dramatically decreased government spending. After deliberating, the average score fell to 6.3, which was the sharpest decline among five stimuli (health services, new energy sources, space exploration and weapons for defense). This finding is supported by another question that forced participants to decide between spending on enhancements versus space exploration; preference for spending on enhancements over space remained high, but it declined from 90% to 81%.

- Deliberation resulted in opposition to most kinds of hypothetical human enhancements that they were described in the Background Materials. Participants were asked to express their support or opposition to five kinds of enhancements on a five-point scale. After deliberating, participants opposed all enhancements except for "implants to catch diseases before they became dangerous". Before deliberating, participants also supported "bionic eyes" and were neutral about using nano-wires and implants to communicate with other people or computers. Respondents remained opposed to "administering drugs to prisoners to prevent escapes."

Some scholars who study small group deliberations – like those that go on in the NCTF – worry that such groups too easily fall prey to dynamics that can distort their results. Among these pathologies are what are known as "reputational cascades" and "social effects" which, they fear, induce members of deliberating groups to endorse statements of the group that, in fact, they reject personally. Thus, in order not to stand out from an apparent majority position, isolated individuals may agree to provisions that they actually object to. The pre- and post-test questionnaires attempted to assess the presence of such processes within the NCTF. The results strongly suggest that such pathologies were not present in these deliberations, and that panelists, in fact, deliberated.

- Given the highly speculative nature of the NBIC technologies, and the general lack of public knowledge about their development and implications, the panelists showed significant firming of opinions about them. Comparing pre-deliberation and post-deliberation results, the percentages who believed that the risks of NBIC technologies exceed the benefits increased from 6% to 28%, the percentage who believed that the risks equaled the benefits increased from 16% to 23%, and the percentage who thought that the benefits would exceed the risks also increased from 23% to 46%. Overall, the percentage pre-deliberation who had no opinion about the relative risks and benefits decreased from 55% to just 3% post-deliberation.

- The panelists showed significant increases in their substantive knowledge of nanotechnology and human enhancements. The pre- and post-tests assessed substantive learning by asking a set of factual questions and companion questions about the level of certainty of the panelists' answers to those factual questions. Deliberation increased panelists' knowledge on the factual question from an average of 4 correct responses of 6 to an average of 5.3 correct responses. When the panelists' level of certainty was included in the analysis – by having panelists say whether they were certain or were guessing and, e.g., rewarding correct and certain answers more highly than correct guesses – panelists' knowledge improved from 3.7 to 9.0 (on a scale from -6 to +12).

- The panelists demonstrated high levels of support for the specific provisions of each group's final report and high levels of congruence between their individual preferences and the contents of those reports. Overall, 89.9% of participants agreed or strongly agreed that their group's consensus report accurately reflected their individual preferences. Similarly, 81.2% said that they personally endorse almost every major point in their group's Final Report, while an additional 15.9% said that they personally objected to a few of the major points, and only 2.9% personally objected to many of the major points in the Final Report.

- The panelists' sense of internal efficacy – that is, their feeling of being competent to discuss issues like those raised in the deliberations as measured across several questions in the pre- and post-test – increased significantly. Similarly, their sense of trust – that is, their notion that other people will not attempt to take advantage of them – increased. However, their feelings of external efficacy – that is, their belief that their opinions or actions can actually affect political outcomes – decreased after the deliberations.

- The panelists found face-to-face deliberations to be significantly preferable to on-line only or to mixed formats. Those who preferred online communication shifted from 18% pre-deliberation to 3% post-deliberation. Those who favored face-to-face communication shifted from 33% pre-deliberation to 70% post-deliberation. And those who favored online and face-to-face communications equally shifted from 49% pre-deliberation to 27% post-deliberation.

CONCLUSIONS

We offer five conclusions from this national scale study.

First, average citizens very much want to be involved in the decisions that shape technologies that, in turn, shape their lives. Given good information, access to experts, and the time to discuss their concerns with other citizens, average people are able to learn the important details of even very complex issues, and to generate *thoughtful, informed, deliberative* recommendations. They also fully expect governmental and private sector decision-makers to listen to their ideas.

Second, although average people sometimes express reservations and concerns about new technologies, they remain strongly supportive of scientific and technical creativity and innovation. What they desire, however, is effective, trustworthy, and attentive monitoring of those new technologies. They believe that there have been too many episodes of highly touted new technologies that generated unexpected dangers for them to passively accept whatever technologies the market may generate.

Third, average citizens insist that they have continuous access to reliable, nonpartisan information about new technologies, and that they have frequent and repeated opportunities to express their concerns about how new technologies are managed.

Fourth, in addition to concerns about individual and environmental health and safety, average citizens express concern for a wider array of social risks that they think are important in the development of new technologies. For instance, issues of economics, equal access and equity are important, as are technological impact on personal freedom, civil rights, and political rights. Ordinary people have a fairly nuanced and sophisticated view of the role of new technologies in their everyday lives and in society at large.

Fifth, decision-makers in the government and in the private sector should pay careful attention to the concerns and issues expressed in this study. These panelists spent several weeks studying the issues involved in NBIC technologies, proposed trenchant questions to content experts, and engaged each other -- both in their local panels and with the panelists from across the country -- in clarifying, exploring, impressing political, cultural, moral, and economic values that they think will be affected by these technologies. These were thoughtful, committed, and well-informed panelists, not misinformed, hysterical, individuals being manipulated by outside groups.

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APPENDIX A: LIST OF FACILITATION TEAMS AT PARTICIPATING UNIVERSITIES

Arizona State University
David Guston, Professor of Political Science and Director, CNS-ASU
Cynthia Selin, Assistant Research Professor, CNS-ASU
Roxanne Wheelock, Graduate Assistant, CNS-ASU

Colorado School of Mines
Carl Mitcham, Professor, Director, Hennebach Program in the Humanities
Jennifer Schneider, Assistant Professor of Liberal Arts & International Studies

Georgia Institute of Technology
Susan Cozzens, Associate Dean of Research, Ivan Allen College
Ravtosh Bal, Graduate Assistant, School of Public Policy/Georgia State University

University of California, Berkeley
David Winickoff, Assistant Professor of Bioethics and Society
Mark Philbrick, Graduate Assistant, Department of Environment and Management
Javiera Barandiaran, Graduate Assistant, Goldman School of Public Policy

University of New Hampshire
Tom Kelly, Professor, Director, University Office of Sustainability
Elisabeth Farrell, Program Coordinator, Culture & Sustainability, Food, & Society Initiatives

University of Wisconsin, Madison
Daniel Kleinman, Professor of Rural Sociology
Jason Delborne, Post-doctoral Research Associate, Holz Center for Science and Technology Studies

APPENDIX B: SUMMARY DEMOGRAPHIC STATISTICS

	Applicant	Panelists	National
Sex	42% Male	50% Male	49% Male
	58% Female	50% Female	51% Female
Education	25% some college	29% some college	50% some college
	33% college degree	31% college degree	or degree
	33% grad school	31% grad school	9% grad school
Party ID	48% Democrat	44% Democrat	36% Democrat
	11% Republican	9% Republican	27% Republican
	30% Independent	36% Independent	37% Independent
Political Ideology	48% Liberal	41% Liberal	25% Liberal
	14% Conservative	14% Conservative	36% Conservative
	28% Moderate	27% Moderate	35% Moderate
Race	71% White	65% White	66% White
	16% Black	15% Black	12% Black
	5% Asian	6% Asian	4% Asian
	5% Hispanic	7% Hispanic	15% Hispanic
	<1% Native Amer	2% Native Amer	
Household Income	9% <$15K	9% <$15K	
	16% >$15K <$35K	21% >$15K <$$35K	
	21% >$35K <$50K	16% >$35K <$50K	Median household
	23% .$50K <$75K	20% >$50K ,$75K	income = $46K
	15% >$75K <$100K	16% >$75K <$100K	
	16% >$199K	17% >$100K	
Median Age	37 yrs old	39 yrs old	37 yrs old

APPENDIX C: FUTURE SCENES OF NANOTECHNOLOGY AND HUMAN ENHANCEMENT INCLUDED IN BACKGROUND MATERIALS

Included in the background material: "The following fictional scenes are extrapolations from current nanoscale research; they have been vetted for their technical plausibility by scientists currently working in nanoscale research. We hope these scenes will stimulate you to reflect upon the meanings, potentials and problems surrounding nanotechnology. The goal is to cultivate our collective ability to govern the implications of our technological ingenuity."[1]

Engineered Tissues

What are your thoughts on synthetically grown tissues and organs?
Using tissue printing technology, this system is able to build tissues with a vascular structure enabling the building of new organs.

Newly developed artificial tissues have been approved for use in wound healing as well as for skin grafts. These artificial tissues are made by "seeding" cells into a bioengineered scaffold where upon they reorganize it into a material suitable for use as an artificial tissue. In the process of tissue engineering the cell makes use of the scaffold components as nutrients. The starting scaffold is usually three dimensional Jello like material called a collagen gel. Made up mostly of water, sugars, and carbohydrates the gel also contains fibrous proteins like collagen, fibrin, and fibronectin which allow the cells to interact with the scaffold. The fibrous proteins are large and tend to form bundles of fibers, or fibrils. After some time the cells use up the scaffold materials reorganizing some of them into an artificial tissue that can then be used for surgical procedures.

Because the tissue is grown from the patients own cells there is almost never any rejection of the transplant. In some cases such as cancerous tissues this is not possible. However, using compatible cells from an appropriate donor gives a high success rate with no risk to the cell donor. Further developments of tissue engineers have made it possible to replace not only tissues, but also organs. One such technology is tissue printing which would allow one to produce whole organs from gel scaffolding and cells in an ingenious way.

This advanced technique allows for cells to be arranged within the scaffold in order to shape the tissue into larger structures. Cells are arranged by inserting them into a device analogous to an inkjet printer where cells are ink. The cells are then printed in a two dimensional pattern such as a circle. After a circle of cells is laid down on top of a sheet of scaffold, another layer of scaffold is placed on top, followed by yet another circle of cells and another sheet of scaffold. Several circles placed in this way will reorganize the scaffold to form a tubular tissue, thus creating a tissue with a vascular system. This is one of the biggest breakthroughs in tissue engineering, because it allows blood and nutrients to flow through the artificial tissue. Tissue printing thus allows us to develop microstructures. These developments have lead to externally grown tissues which can replace vital organs, as well as more general tissues like skin, bone, muscles, and arteries. The lack of transplant materials is no longer a problem.

[1] Technical background on the generation of the scenes may be found in C. Selin (forthcoming). "Negotiating Plausibility: Intervening in the Future of Nanotechnology." *Science and Engineering Ethics*.

Living with a Brain Chip

What are your thoughts on using cranial chips to enhance cognition?
This cranial chip features a data feed that puts information into the brain while the user is resting.

The next generation of cranial chip implants enables data transmission directly to the brain during rest without interfering with sleep. This data feed feature dramatically decreases the amount of time needed to assimilate new data each day, in fact the chipped person will just wake up knowing what was streamed into their head the previous night. The presence of the chip interferes with REM sleep, but the new data feed does not actually disrupt or alter in any way the sleep of the person with the implant.

The new disruptor cage is constructed out of more advanced materials that are lighter and more comfortable for the wearer. No longer is it necessary to lock head, neck and torso in to a rigid structure, the new generation of disruptor cages need only to lock to the head and upper vertebrae of the neck. This new format still provides the same protection against magnetic damage to the brain, advances in real time processing now allow for emergency shut off if the magnetic pulses are not directed exactly at the chip. The use of rare earth magnets in a wider net around the cranium makes for a more thorough disruption of the chip (even while undergoing data feed). This improves sleep by removing annoying dream sequences, restlessness, or need for sedatives previously common in past cranial chip implants.

These advances in cranial chip disruptors will work with all cranial chips. However, those with the newer (Gen. 3.4 or higher) cranial chips will see the most improvements and those who receive the soon to be released Gen. 4.0 will be able to take advantage of many new options. The 4.0 chips, like those before it, are a sandwich of carbon nanotubes, and gate molecules that are covered in neural growth promoters. The 4.0 chip features advances in neuron-to-chip interface, allowing for more neurons to contact the chip in more functional ways. This in turn increases the rate of information in and out of the chip, further increasing cognitive ability.

With this increase in connectivity of brain to chip and chip to brain comes increased assimilation and learning time. After implantation (still an outpatient procedure) it will take 30 to 90 days of neuron growth around the chip for it and the brain to become fully integrated. Upon chip integration, the newly chipped person will need to attend nine months of intensive classroom based courses, where they are taught new ways to think, process thoughts, and to categorize memories and data.

It is during this time, as the chip becomes enabled, that they will begin to feel the effects of the continuously running chip. As the brain becomes dependant on the chip the implantee will find it difficult to sleep. The first effects will be tossing and turning at night, followed by repetitive dreams, and finally inability to sleep. It is at this point that the cranial chip disruptor is needed and technicians will work with the chip implanted person (and spouse if necessary) insuring proper technique in fitting the disruptor, allowing the user to have the best nights sleep ever.

Automated Sewer Surveillance:

What are your thoughts on tracking individuals using their genetic material?
Ultra fast sequencing technology is used to analyze the DNA in harvested waste water, thus screening large populations.

Capitalizing on recent advances in very fast genome sequencing technologies, Sentinel Genetics is pleased to offer its new real-time in-stream wastewater sequencing system. Genetic material is randomly harvested from the waste-stream, usually at the sewage treatment facility. The automated system then prepares the DNA for sequencing and individual samples can be sequenced to the extent necessary to compare it to the National Registry in less than one second. A small bank of sequencers can process tens of thousands of samples each hour.

Sentinel Genetics developed the single strand sequencing technology, which works by quickly pulling strands of DNA through tiny nanoscale pores. Breakthroughs in micro and nanoscale mechanical devices that are small enough to automate preparations with the very small DNA strands have allowed for sequencing prices as low as pennies per thousands. Due to the large amount of non-human DNA that is in a wastewater stream, it was only through this high speed processing of samples at low price that large scale screening of municipal populations could become cost beneficial.

The database of America's genetic information has been available to law enforcement agencies since the inception of the United States Genomic Registry, but only in the last several years has it been complete enough to look for individuals. The Sentinel Genetics Sequencer data processing system is fully compatible with the Registry and provides advanced algorithms for comparing genomic and partial genomic material against the data in the Registry. By combining the massive throughput of the treatment-facility-based sequencer bank with portable units for signal triangulation through upstream testing, it is possible to track the location of individuals in metropolitan areas.

Disease Detector:

What are your thoughts on diagnosing disease before you are ill?
Doc in the Box is a device that tracks an individuals protein levels to monitor changes that imply early stage illness or disease before symptoms emerge.

BioMarker Detector created Doc in a Box with the ability to track a person's health status on a day-to-day basis from the comfort of their home. Doc in a Box is able to detect and record the health level of an individual by examining multiple proteins that are present in their blood, which are collected through a nearly-invisible needle causing no detectable pain. The proteins present in the blood will fluctuate, either up or down, as the body changes. These changes can be due to many different naturally occurring events such as puberty, pregnancy, or menopause, along with more unfortunate changes such as getting cancer, flu, or Alzheimer's disease. Doc in a Box is able to measure the amounts of specific proteins, or biomarkers, which are correlated to particular diseases, infections, or changes in the human body. These biomarkers are measured and recorded over time as health markers and tracked to develop a particular pattern specific for each individual called a biosignature. When there is a change in the body, there is an immediate change in the biomarkers outside the range of the biosigniture and detected by Doc in a Box.

Since the Doc in a Box is detecting markers on the molecular level, users will be informed of a cold or flu before a sore throat or cough ever occur. With the ability of Doc in the Box to detect diseases pre-symptomatically, people will be able to get treatment before they feel the illness and far before it is too late to treat the disease. For cancer patients, there will be biological implications of cancer before a tumor develops and before the cancer has time to spread. For Alzheimer's patients, early detection of biomarker changes will enable more effective treatment options, possibly before any memory loss.

Barless Prison:

What are your thoughts on a barless prison?
NanoCage has developed a caged drug that is injected into prisoners that becomes activated by radio control if prisons cross designated boundaries.

Ever since the first true nanomedicine product came on the market, a caged cancer drug that releases once bound to the cancer cell, researchers have been working towards utilizing these technologies for control purposes. This week it was announced that NanoCage, in collaboration with United Penitentiary Systems, have developed the first barless prison. Upon entry, inmates are injected with a cocktail of caged drugs that have a variety of effects when released via radio control. The base technology utilizes focused radio waves to target deep tissue tumors in places such as the abdominal cavity.

The basis for security is a net of radio transmitters that surrounds the facility. As a prisoner crosses the perimeter threshold, the radio signals will cause the release of one type of caged drug. For instance, if the prisoner crosses an inner 'warning' perimeter, a drug will be released that causes extreme vertigo and mild nausea. If the prisoner continues, the next perimeter will signal the release of incapacitating sedatives, and if the next signal is reached it will trigger a fatal dose of narcotics. These perimeters are spaced far apart enough to prevent unintentional crossing of more than the first.

The caged drug is connected to an antenna that upon receipt of a specific radio signal causes the physical break down of the carbon-nanotube-based cage. The package including the antenna is roughly half the size of a red blood cell. A coating of biocompatible molecules minimizes the physiological side effects from the caged drugs. There is, on very rare occasions, mild inflammatory responses that can be treated with over the counter anti-inflammatory drugs. Because some degradation of the caged drugs occurs naturally in the body, supplemental injections are advised every six weeks and always after drugs have been released.

Guards in barless facilities will be equipped with radio transmitters that can be aimed at individual inmates or larger areas to quell local unrest. The transmitters used by the guards will be unable to access the frequencies that trigger the fatal dosages.

NanoCage and United Penitentiary Systems claim this is the new model for working prisons, where inmate labor is unencumbered by restraints or monitoring devices and physical investment costs are not much more than traditional factories. The perimeter of these facilities need only be physically secured to keep people from trespassing on the grounds.

Bionic Eyes:

What are your thoughts on visual enhancement?
Opti-scan is an optical implant that looks and functions like a normal eye, yet has new enhancements enabling magnification, visualizing infra-red, and night vision.

Penetrode Inc. presents the Opti-scan visual enhancement system, the latest in ocular prosthetics. Opti-scan is capable not only of restoring sight to the blind but also of providing them with additional capabilities beyond those of the normally sighted. The housing of the implant is designed to mimic the external appearance of the eye and comes with an iris capable of changing colors to suit the daily tastes of our customers. A series of small motors implanted within the eye socket will provide human like eye movements while allowing for much greater tracking speeds than is possible with normal muscle.

The heart of the technology is thin film photosensitive ceramic panels that are located in the back of the eye. These panels take light signals and transduce them into electrical signals that stimulate the ganglial cells. The stimulated ganglial cells allow for the signal to be processed along the optical nerve to the visual cortex. If there is extensive damage to the ganglial cells or the optical nerve then the signal can be routed directly to the lateral genicuate nucleus, which is where the optic nerve connects to the visual cortex.

A massive zoom/magnification function will allow for telescopic sight similar to that of a high grade set of binoculars and the ability to greatly magnify nearby objects achieving magnification power similar to that of many laboratory microscopes. Opti-scan uses digital magnification features similar to those found in most digital cameras to achieve this additional functionality. Opti-scan is also available with night vision, thermal imaging, and high definition video and still photo capture. Images captured through the Opti-scan can be downloaded via Bluetooth and WiFi to any personal computing device. Depending upon the condition of your optic nerve, Opti-scan can be implanted through outpatient surgery and after a brief, two week course of training and therapy you and your new eyes will be fully functional.

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