

What drives public acceptance of nanotechnology?

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How do the risks and benefits of nanotechnology, as viewed by the public, compare with those associated with other technologies such as genetically modified organisms, stem cells, biotechnology and nuclear power? And when deciding to use a specific nanotechnology product, will consumers consider the risks, the benefits, or both? We report the first large-scale empirical analyses of these questions.

Recent reports indicate that over 300 nanotechnology-based products have entered the marketplace¹, and that these products were worth over \$32 billion in 2005². As the public comes into more regular contact with applications of nanotechnology, will its appetite for the benefits of nanotechnology lead to increased support for research? Or will a fixation about the risks of nanotechnology — which could be real or imagined, health- or environment-related — slow progress in the field?

Much of the current debate about the future of nanotechnology correctly focuses on the types and magnitude of risks. In July, Andrew Maynard of the Project on Emerging Nanotechnologies, an initiative launched by the Woodrow Wilson International Center for Scholars and The Pew Charitable Trusts in 2005, published the most comprehensive research strategy yet for applying physical sciences and engineering to understand the environmental, health and safety implications of nanotechnologies³. Maynard argued in favour of, for example, national governments taking greater responsibility for interagency coordination, and more aggressive funding for the study of

short-, intermediate- and long-term risk priorities. And last month Maynard and others⁴ proposed a list of five grand challenges — such as the development of instruments to assess exposure to engineered nanomaterials in air and water — for “developing safe nanotechnologies through sound science”.

As scientists and engineers work to establish the objective facts about the risks and benefits of nanotechnology, we believe it is also vital that social scientists contribute rigorous research on how the public perceives risks and benefits. Indeed, one government legislator recently stated⁵, “If I had to pick the No. 1 challenge facing nanotechnology firms, it’s environmental, health, and safety regulation and the question of public perceptions.”

Understanding public sentiment towards nanotechnology is pivotal because, historically, public perceptions and attitudes have shaped the direction and pace of scientific activity in a number of fields. This has been and continues to be the case with nuclear power, genetically modified organisms (GMO), embryonic stem-cell research and biotechnology. In the case of GMO, negative public sentiment has had an adverse effect on governmental funding of research, especially in Europe⁶.

Research on nanotechnology must involve innovative interdisciplinary collaboration among researchers in the physical sciences, engineering and social sciences. Indeed, one of us (NL) recently called for a new research paradigm to inform policy making about emerging technologies such as nanotechnology: “[W]e have come to recognise how such things as human dynamics and institutional behaviour can either enhance or impede the benefits to society of our research achievements. All of this can occur only by engaging the nation’s top social scientists, including policy experts, to work in collaboration with scientists and engineers from many fields and diverse institutions on multidisciplinary research efforts that address large but well-defined national and global problems.”⁷

WHAT THE PUBLIC THINKS

Although previous social science research has studied public perceptions of research developments in nanotechnology^{8,9}, we have conducted the first large-scale empirical effort to (1) compare nanotechnology with other technologies, and (2) analyse risks and benefits of specific nanotechnology

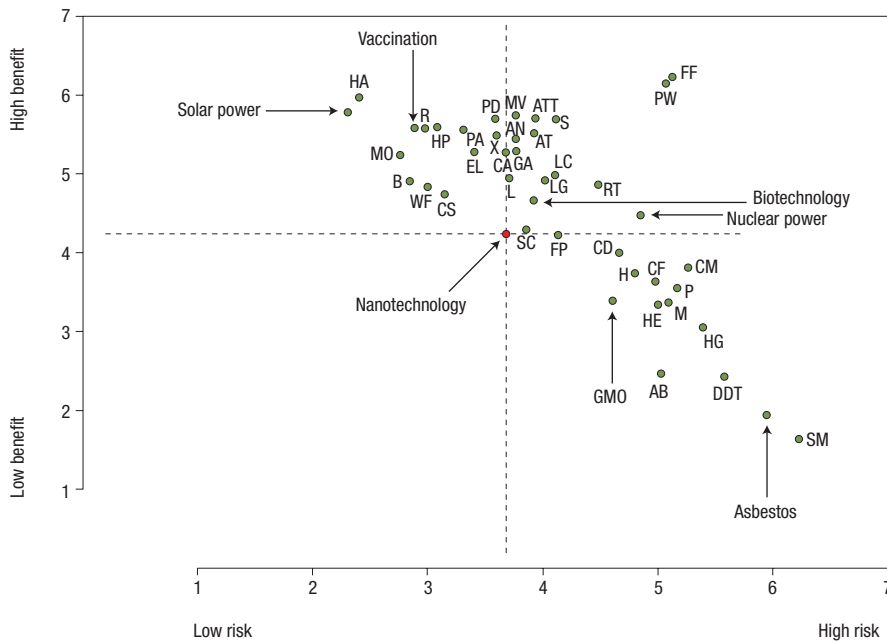


Figure 1 Perceived risks and benefits of nanotechnology and 43 other technologies, based on 503 responses to a national telephone survey. In the survey, 1 corresponds to very low risk or benefit and 7 corresponds to very high risk or benefit. Results showed that, at present, nanotechnology is viewed as medium risk and moderate benefit. The acronyms are: alcoholic beverages (AB), anaesthetics (AN), air travel (AT), automobile travel (ATT), bicycles (B), commercial aviation (CA), chemical disinfectants (CD), chemical fertilizers (CF), chemical manufacturing plants (CM), computer display screens (CS), dichloro-diphenyl-trichloroethane (DDT), electric power (EL), fire fighting (FF), food preservatives (FP), general aviation (GA), herbicides (H), home appliances (HA), human genetic engineering (HE), handguns (HG), hydroelectric power (HP), lasers (L), large construction (LC), liquid natural gas (LG), motorcycles (M), microwave ovens (MO), motor vehicles (MV), pesticides (P), prescription antibiotics (PA), police work (PW), railroad (R), radiation therapy (RT), surgery (S), stem-cell research (SC), smoking (SM), water fluoridation (WF), X-rays (X). Figure 1 presents results from our surveys, previously unpublished literature.

applications. Specifically, we present a method for comparing the risks and benefits of nanotechnology relative to those of other technologies. This method can track shifts in public opinion as the results of new research into the risks and benefits of nanotechnology are published. Additionally, we call into question an assumption that the public thinks about nanotechnology applications only in terms of possible risks. Although not unconcerned about risks, people engage in a complex calculus whereby the risk of nanotechnology is but one consideration.

How does nanotechnology compare with other technologies? A recent report suggested that when assessing the risks and benefits of nanotechnology, people may “draw upon analogies to past technologies, many of which may be misleading, such as asbestos, dioxin, Agent Orange, or nuclear power”⁸. We used a national random-digit telephone-dialling survey to conduct interviews with 503 individuals in the United States

to study whether nanotechnology was seen as more or less risky/beneficial than 43 other technologies. The list of technologies was based on previous research on perceptions of new technologies¹⁰, which we supplemented with several emerging technologies (for example, GMO and stem-cell research).

Individuals were asked the following question: “In general, how risky/beneficial do you consider each of the following items to be for the United States society as a whole?” Our results showed that nanotechnology was seen as relatively neutral; it was perceived as less risky and more beneficial than a number of other technologies such as GMO, pesticides, chemical disinfectants and human genetic engineering (Fig. 1). On the other hand, it was seen as more risky and less beneficial than solar power, vaccinations, hydroelectric power and computer display screens.

It is likely that, over time, public sentiment towards nanotechnology

will shift towards either the upper left quadrant of Fig. 1 (that is, high benefit and low risk) or the lower right-hand quadrant (that is, low benefit and high risk). But will the fate of nanotechnology be determined by rumour and supposition, as some believe has been the case for GMO? Or will public opinion be based on objective science and engineering findings? Based on our results showing that society is relatively neutral about nanotechnology, now is the time to educate the public aggressively with facts about the risks and benefits of nanotechnology. Education can prevent opinions from becoming polarized on the basis of misinformation. Our research methodology provides a ‘scorecard’ that can track how public attitudes to nanotechnology change over time (for example, annually) in light of media coverage of new research into the risks and benefits of nanotechnology.

As an example of interdisciplinary collaboration, we formed a partnership with scientists and engineers at the Center for Biological and Environmental Nanotechnology (CBEN) at Rice University in Houston, Texas, to create four hypothetical nanotechnology applications with which consumers could plausibly come into contact: a medical product (a drug), a skin lotion, automobile tyres and refrigerator gas coolant. We then used a nationwide web survey in the United States to collect data from 4,542 likely consumers. The survey first presented respondents with the following generic definition of nanotechnology, which was developed with our science and engineering colleagues: “Nanotechnology involves human-designed materials or machines at extremely small sizes (atomic or molecular level) that have unique chemical, physical, electrical, or other properties”. This definition was followed by descriptions where we manipulated the level (high or low) of the health or environmental risks and benefits of the four nanotechnology applications. Respondents were then asked how likely they would be to use such applications on a scale that ran from 1 (extremely unlikely to use) to 7 (extremely likely). To validate the web study, we also conducted telephone interviews with a national random sample of 501 adults (see Methods).

Our results showed that for both the web and telephone samples, respondents did not consider the risks or benefits of nanotechnology independently. Rather, in a pattern that held true for both health- and environment-related

applications, the effect of benefits on the use of nanotechnology applications was more pronounced when risks were lower than when risks were high (see Fig. 2). Thus, our findings showed that public perceptions of nanotechnology are not as simple as previously assumed — risks and benefits are both enmeshed in a complex decision-making calculus. For instance, when the benefits are low, consumers are more concerned about risks than when benefits are high. Although the difference between the responses for high benefit/low risk and low benefit/high risk may seem modest, it is substantial for a survey of this nature. Similarly, the fact that the most positive response (that for high benefit/low risk) is still slightly below the mid-point of the 1–7 scale is not surprising because many respondents had not been exposed to nanotechnology products before the survey.

WHAT NEXT?

With respect to the future, government funding should be provided for interdisciplinary research centres that promote collaborative research among physical scientists, engineers and social scientists. Additionally, social scientists should be encouraged, through research grant opportunities, to develop metrics and track the public's understanding of the risks and benefits of nanotechnology. For example, we have presented a research methodology that can be used as a scorecard for gauging how the public compares nanotechnology with other technologies.

Given the separation that typically exists between publicly-funded research and the regulatory functions of government, special interagency coordination must bridge this gap. However, we do not favour placing coordination responsibility entirely within a single regulatory agency in a given country. A number of authors have made similar recommendations concerning nanotechnology, but often with an emphasis on risk. We argue for a more balanced approach, where potential benefits and risks are addressed together. Only in that way will the public have an informed outlook on this important emerging technology.

Academic bodies, such as the Royal Society and Royal Academy of Engineering in the United Kingdom and the National Academies in the United States, should be asked to summarize and update the current state

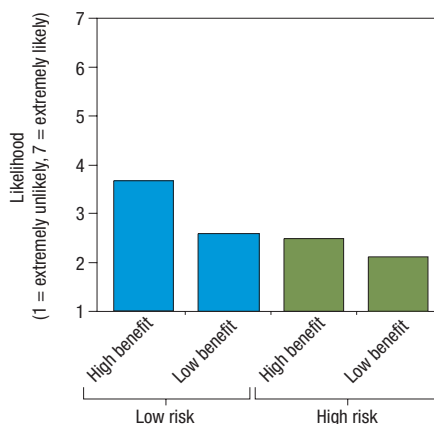


Figure 2 Likelihood of people using a nanotechnology product for four combinations of risk and benefit, based on the combined averages from 4,542 responses to a national web survey and 501 responses to a national telephone survey. The inclusion of an 'interaction variable' (risk \times benefit) revealed that respondents did not consider risk and benefit independently. The statistical test for the influence of the interaction variable is distributed as an F distribution with degrees of freedom of 1 and $n - k - 1$, where n is the number of observations in the empirical sample (that is, the number of survey respondents) and k is the number of predictor variables in the ordinary least-squares regression model. For the web sample we found $F[1, 4,531] = 11,301.4, P < 0.001$, where P is the probability that the interaction effect was found by chance. For the telephone sample we found $F[1, 490] = 34.52, P < 0.001$, which again means that the probability that the interaction was due to chance was less than 1 in 1,000.

of knowledge about risks and benefits of nanotechnology. Based on these findings, interagency 'societal impact' subgroups can be formed to coordinate education and public outreach efforts by creating a clearing house in each country that synthesizes information about the health and environmental impacts of nanotechnology, including performance indicators and the latest scientific findings on risks and benefits.

In this regard, it is vital that bench researchers who are conducting toxicological analyses of nanotechnology, and others who are studying its potential benefits, redouble their efforts to be thorough, transparent and timely in disseminating their results. This information will minimize the likelihood

that the public develops polarized perceptions of nanotechnology based on rumour and supposition and hence avoid potential overreactions such as those that occurred with GMO.

METHODS

Methodological details of our studies are available from the corresponding author. Zogby International administered all our surveys. Our web survey was conducted in June 2004. To avoid attracting only respondents who were knowledgeable about, or sympathetic towards, nanotechnology, the word "nanotechnology" was not included in the request for participation; respondents were invited to participate in a "survey about commercial products using new technologies." The format of the "extremely unlikely" to "extremely likely" response scale is a 'behavioural estimation' format, which measures the immediate determinant of actual behaviour¹¹. To control for individual differences across respondents in the subjective value they placed on risks and benefits we used analysis of variance with individual respondent as a 'blocking variable'. This procedure statistically controlled for individual differences among respondents. Our national telephone survey examining nanotechnology applications, and the other national telephone survey examining how nanotechnology compared with 43 other technologies, were both conducted in August 2005. The authors are currently conducting detailed analyses based on this research, which will appear in future publications.

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