

## Perception and Acceptance of Risk from Nanotechnologies (Lessons from the Risk Assessment Battlefield)

Paul Slovic

Safer Nano 2007 Conference

March 11, 2007

### Toxic Potential of Materials at the Nanolevel

Andre Nel et. al. Science, 2006

There is almost unanimous opinion among proponents and skeptics alike that the full potential of nanotechnology requires attention to safety issues.

Already there are outcries from environmental activists calling for a worldwide moratorium on NM research and marketing until protocols are in place to ensure worker safety.

### Some Questions:

1. Do lay people's and experts' risk assessments related to nanotechnology differ across applications?
2. Which applications will the public accept? Which applications will not be acceptable to the public?

### Overview

- I. Introduction
- II. The Complexity of Risk
  - Conflict
  - Problems
- III. Studies of Perceived Risk
  - Experts' and laypersons' perceptions
  - Perceptions have impacts: e.g., stigma
  - Intuitive toxicology
- IV. Trust

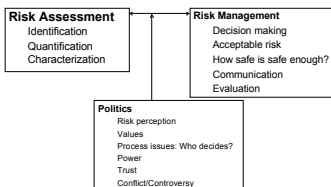
### Overview, continued

- V. Risk as Feelings
  - The Structure of Feeling
  - The Importance of Affect
- VI. The Affect Heuristic
- VII. Implications
  - The importance of perceived benefits
- VIII. A recent survey of nanotechnology risk perceptions
- IX. -importance of worldviews, values, and affect
  - implications for risk communications and democratic deliberations

### Some Lessons from the Risk Battlefield

1. Don't count on risk assessment to ensure the viability of nanotechnology.

### Risk Analysis



Perception is reality  
Complexity of risk

### What Is Risk?

- Risk does not exist "out there," independent of our minds and cultures, waiting to be measured.
- Human beings have invented the concept **risk** to help them understand and cope with dangers and uncertainties of life.
- There is no such thing as "real risk" or "objective risk." The nuclear engineer's probabilistic risk estimate for a nuclear accident or the toxicologist's quantitative estimate of a carcinogenic risk are both based on theoretical models, whose structure is subjective and assumption-laden, and whose inputs are dependent on judgment.

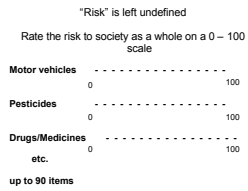
### Some Lessons from the Risk Battlefield

- Public risk perceptions are driven by values that are often not considered in technical risk analyses.

### The Multidimensional Nature of Risk

- The public has a broad conception of risk, qualitative and complex, that incorporates considerations such as uncertainty, dread, catastrophic potential, controllability, equity, risk to future generations, and so forth, into the risk equation.

### Studies of Perceived Risk



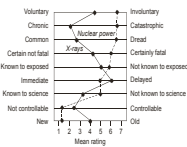
### Experts vs. Laypersons Perceptions of Risk

Rank Order		
1977 Laypersons		Experts
1	Nuclear power	20
2	Motor vehicles	1
3	Handguns	4
4	Smoking	2
↓		↓
17	Electric power (non-nuclear)	9
↓		↓
22	X-rays	7
↓		↓
30	Vaccinations	25

### Risk is Multidimensional

#### Qualitative Risk Concerns

- Voluntary – Involuntary
- Chronic – Catastrophic
- Common – Dread
- Certainly not fatal – Certainly fatal
- Known to exposed – Not known to exposed
- Immediate – Delayed
- Known to science – Not known to science
- Not Controllable – Controllable
- New – Old
- Equitable – Not equitable



### General (Negative) Attributes of Hazards that Influence Risk Perception and Acceptance

- Involuntary exposure to a risk
  - Lack of personal control over outcomes
  - Uncertainty about probabilities or consequences of exposure
  - Lack of personal experience with the risk (fear of unknown)
  - Difficulty in imagining risk exposure
  - Effects of exposure delayed in time
  - Genetic effects of exposure (threatens future generations)
  - Infrequent but catastrophic accidents
  - Benefits not highly visible
  - Benefits go to others (inequity)
  - Accidents caused by human failure rather than natural causes
- Source: Adapted from Olway & von Winterfeldt

### Some lessons from the risk battlefield

#### 3. Perceptions Have Impacts!

e.g., Stigma





Table 1  
Ingredients for a Product Crisis

1. **The Risk Is Uncontrollable**
  - a. science poorly understands problem
  - b. widespread involuntary exposure
  - c. contamination not observable to consumers
  - d. effects are latent
  - e. officials in charge are distrusted
2. **The Risk Is Dread**
  - a. consequences fatal and horrific
  - b. contamination is
    - i. long lasting — no end to it
    - ii. consequences latent (time bomb)
  - c. risk is increasing and unbounded
3. **The Risk Is Abnormal**
  - a. not inherent in the product
  - b. victims are otherwise healthy
4. **There Are Available Substitutes**

Another Example

Nuclear Stigma



What comes to mind when you hear the words  
'underground nuclear waste storage facility'?

Category	Frequency	Images included in category
1. Dangerous	179	dangerous, danger, hazardous, toxic, unsafe, harmful, disaster
2. Death/disease	107	death, sickness, dying, destruction, lethal, cancer, deformities
3. Negative	99	negative, wrong, bad, unpleasant, terrible, gross, undesirable, awful, dislike, ugly, horrible
4. Pollution	97	pollution, contamination, leakage, spills, Love Canal
5. War	62	war, bombs, nuclear war, holocaust
6. Radiation	59	radiation, nuclear, radioactive, glowing
7. Scary	55	scary, frightening, concern, worried, fear, horror
8. Somewhere else	49	wouldn't want to live near one, not where I live, far away as possible
9. Unnecessary	44	unnecessary, bad idea, waste of land
10. Problems	39	problems, trouble
11. Desert	37	desert, barren, desolate
12. Non-Nevada locations	35	Utah, Arizona, Denver
13. Storage location	32	caverns, underground salt mine
14. Government/industry	23	government, politics, big business

Source: Slovic et al Survey of 400 residents of Phoenix, Arizona (1989).

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Perceptions of risk associated with nuclear waste are even more negative than perceptions of nuclear power. When asked to state whatever images or associations came to mind when they heard the words 'underground nuclear waste storage facility', a representative sample of Phoenix, Arizona, residents could hardly think of anything that was not frightening or problematic (see table). The disposal of nuclear wastes is a technology that experts believe can be managed safely and effectively. The discrepancy between this view and the images shown in the table is indeed startling.

(Slovic, 1996)

Implications of ☹️ and Stigma

- Prevention is important — not just mitigation — even at great cost
  - e.g., tamper-resistant packaging
  - airport security
  - remote siting of hazardous facilities
  - dedicated trains for hazardous material

A contamination model of perceived risk and stigma

The work of Kai Erikson

Erickson describes the exceptionally dread quality of technological accidents that expose people to radiation and chemicals in ways that

'contaminate rather than merely damage; . . . pollute, befoul, and taint rather than just create wreckage; . . . penetrate human tissue indirectly rather than wound the surface by assaults of a more straightforward kind' (p. 120).

Unlike natural disasters, these radiation and chemical accidents are unbounded. Unlike conventional disaster plots, they have no end.

'Invisible contaminants remain a part of the surroundings — absorbed into the grain of the landscape, the tissues of the body, and worst of all, into the genetic material of the survivors. An 'all clear' is never sounded. The book of accounts is never closed' (p. 121).

Erickson's 'contamination model' may explain the reaction of the public to exposures to carcinogens.

- Numerous studies have found that a high percentage (60-75%) of people believe that if a person is exposed to a chemical that can cause cancer, that person will probably get cancer some day.

- A similarly high percentage believe that 'exposure to radiation will probably lead to cancer some day.'

- The belief that any exposure to a carcinogen is likely to lead to cancer tends to coincide with the belief that it can never be too expensive to reduce such risks.

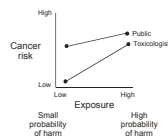
## Intuitive Toxicology

(Kraus, Malmfors, & Slovic)

### Intuitive Toxicology — Main Result

Many people lack dose-response sensitivity for exposure to chemicals that can produce effects that are dreaded, such as cancer (high affect).

If large exposures are bad, small exposures are also bad.



### Some Lessons from the Risk Battlefield

4. The science of toxicology has increased public concerns and aversion to chemicals.

Toxicologists have not done a good job of informing and educating the public about risks from chemicals.

### Intuitive Toxicology Subtopics

- conceptions of toxicity, including the toxicity of natural vs. synthetic substances,
- effects of chemical concentrations on perceptions of risk,
- the value of animal studies for predicting toxicity in humans,
- interpretation of evidence regarding cause-effect relationships between exposure to chemicals and human health,
- confidence in the ability of scientific methods to discover and quantify the toxic effects of chemicals
- interpretations of scientific expressions commonly used in reporting chemical risks,
- attitudes toward chemical use & regulation.

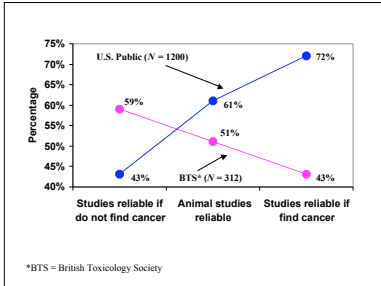
### HEALTH RISK PERCEPTION SURVEY

Instructions:  
We are interested in your opinions about health risks associated with chemicals and other hazards. When we speak in a general way about chemicals we mean all chemical elements and compounds, including pesticides, food additives, industrial chemicals, household cleaning agents, prescription and non-prescription drugs, etc.  
Please read each statement or question carefully and then indicate your response on the scale, or in the space provided.  
If you wish to comment on any questions or qualify your answers, please feel free to use the space in the margins.  
Your cooperation is greatly appreciated.  
Please return your questionnaire to:

Studies with U.S. SOT	N = 180	1988
Canada SOT	N = 150	1993
European SOT	N = 125	1993
British Toxicological Society	N = 312	1994
U.S. Public		1988
		1997
Canadian Public		1993

Q32: The way that an animal reacts to a chemical is a reliable predictor of how a human would react to it.

Q34: If a scientific study produces evidence that a chemical causes cancer in animals, then we can be reasonably sure that the chemical will cause cancer in humans.



### Q32 and Q34 Findings

1. Low percent of agreement that animal studies predict human effects.
2. Toxicologists: Even less confidence when animal studies indicate cancer.
3. Public: More confidence if animal studies indicate cancer.
4. Disagreements among toxicologists are systematic – linked to gender, affiliation, etc.
5. Women toxicologists respond like general public.
6. What are the implications of these findings?

### Some Lessons from the Risk Battlefield

5. Trust is critical and fragile.



### Importance of Trust

“Acceptance of any risk is more dependent on public confidence in risk management than on quantitative estimates of risk”

C. Starr

### TRUST is the Key to Communication Problems

- If you have trust the path is smooth
- If you do not have trust, no form of phrasing or presentation is likely to be successful

### Trust Is Fragile

“If you *once* forfeit the confidence of your fellow citizens, you can *never* regain their respect and esteem”

A. Lincoln

### Trust: The Asymmetry Principle

- It is far easier to destroy trust than to create it!
- Negative (trust-destroying) events outweigh positive events
- Negative events more sharply defined (accidents, lies)
- Positive events often fuzzy or indistinct  
e.g., how many positive events are represented by the safe operation of a nuclear power plant for one day?
- Sources of bad news are more credible than sources of good news
- Risk is easier to demonstrate than absence of risk

### Trust-Increasing Events

- There have been no reported safety problems at the plant during the past year
- There is careful selection and training of employees at the plant
- Plant managers live nearby the plant
- The county medical examiner reports that the health of people living near the plant is *better* than the average for the region

- ### Trust-Decreasing Events
- A potential safety problem was found to have been covered up by plant officials
  - Plant safety inspections are delayed in order to meet the electricity production quota for the month
  - A nuclear power plant in another state has a serious accident
  - The county medical examiner reports that the health of people living near the plant is worse than the average for the region

Name \_\_\_\_\_ Sec. M. F. Date \_\_\_\_\_

Trust

Imagine that there is a large nuclear power plant in your community. The following page lists some different kinds of events or incidents involving the operation of that plant that you might think of as either decreasing your trust in management or increasing it. In addition, for each event, indicate your **level of the management of that plant should be increased or decreased** (think back to the event. After doing this, indicate enough your trust would be affected by the event.

The response scale looks like this:

4. Government inspection was conducted regularly at the plant.

• The above would  INCREASE  DECREASE my trust

• 1 2 3 4 5 6 7

1=Very much decrease    2=Somewhat decrease    3=Not important    4=Not important    5=Not important    6=Not important    7=Very much increase

For each event, check either the "INCREASE" or "DECREASE" box, then circle a number from 1 to 7, indicating how much the event would tend to increase or decrease your trust of you. (For the management of this nuclear power plant, check 4.)

There are no right or wrong answers. We are only interested in your considered opinion about the impact of these events on your trust.

Please think carefully about how great an impact each of these factual events would have on your trust in the management of this nuclear power plant. Then list something in having a high impact makes you feel before that each an event would increase or decrease your trust in a significant event.

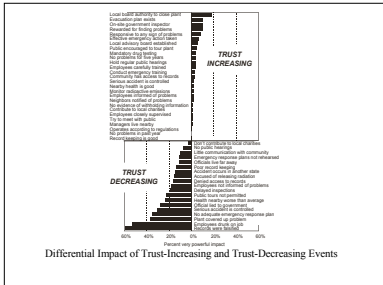
Please rate each event separately — no though it's the only event you had heard about recently regarding the nuclear power plant.

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	Impact	
	Very small	Very powerful
The county medical examiner reports that the health of people living near the plant is worse than the average for the region	3.0	8.0 26.0 24.0
The county medical examiner reports that the health of people living near the plant is better than the average for the region	21.5	14.0 16.1 2.2

	Impact	
	Very small	Very powerful
An advisory board of local citizens and environmentalists is established to monitor the plant and is given legal authority to shut the plant down if they believe it to be unsafe	6.1	8.1 20.2 18.2

- ### The "System" Destroys Trust
- Psychological Tendencies (Asymmetry Principle) amplified by
    - Powerful news media emphasizing bad (trust-destroying) news
    - Rise of special interest groups
    - Adversarial risk-management system
      - litigation
      - expert vs. expert
    - Proliferation of risk-assessment studies
      - many studies
      - science limited
      - studies increase perceived risk

Some Lessons from the Risk Battlefield

6. Acceptable decision processes are as important as acceptable risk assessments

- ### Where Next?
- | Restrict public input   | Expand public input   |
|---|---|
| <ul style="list-style-type: none"> <li>Florida law</li> <li>Congress vs. Nevada</li> <li>Stephen Breyer's view</li> </ul> | <ul style="list-style-type: none"> <li>make risk assessment sensitive to public views</li> <li>Improve mechanisms for public participation</li> <li>Power sharing</li> <li>Negotiation</li> <li>Process is the key — Not more quantitative risk assessment</li> </ul> |

- The limitations of risk science, the importance and difficulty of maintaining trust, and the subjective and contextual nature of the risk game point to the need for a new approach — one that focuses upon introducing more public participation into both risk assessment and risk decision making in order to make the decision process more democratic, improve the relevance and quality of technical analysis, and increase the legitimacy and public acceptance of the resulting decisions.



Some Lessons from the Risk Battlefield

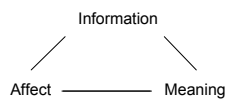
7. Relying on "feelings" to navigate risk situations is natural, rational, and sometimes problematic.

## Part 2

### Risk As Analysis and Risk As Feelings

### What is Affect?

- A valenced feeling (e.g., goodness or badness) associated with a stimulus
- A faint whisper of emotion



- Affect conveys meaning upon information
- Without affect, information lacks meaning and will not be used in judgment and decision making
- Affect is a key ingredient of rational behavior
- Affect sometimes leads to poor decision making

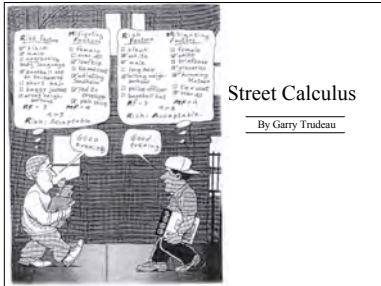
There is no dearth of evidence in everyday life that people apprehend reality in two fundamentally different ways, one variously labeled intuitive, automatic, natural, non-verbal, narrative, and experiential, and the other analytical, deliberative, verbal, and rational.

Seymour Epstein; 1994, p. 710

### Two Modes of Thinking: Comparison of the Experiential and Analytic Systems

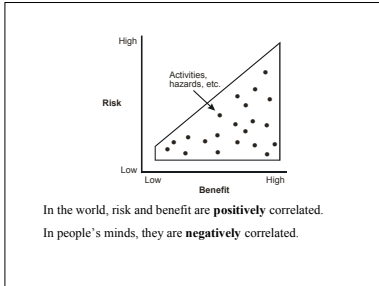
Experiential System	Analytic System
<ul style="list-style-type: none"> <li>• Holistic</li> <li>• Affective: pleasure-pain oriented</li> <li>• Associationistic connections</li> <li>• Behavior mediated by "vibes" from past experience</li> <li>• Encodes reality in concrete images, metaphors and narratives</li> <li>• More rapid processing: oriented towards immediate action</li> <li>• Self-evidently valid: "experiencing is believing"</li> </ul>	<ul style="list-style-type: none"> <li>• Logical: reason oriented (what is sensible)</li> <li>• Logical connections</li> <li>• Behavior mediated by conscious appraisal of events</li> <li>• Encodes reality in abstract symbols, words and numbers</li> <li>• Slower processing: oriented towards delayed action</li> <li>• Requires justification via logic and evidence</li> </ul>

Note: Adapted from Epstein, 1994

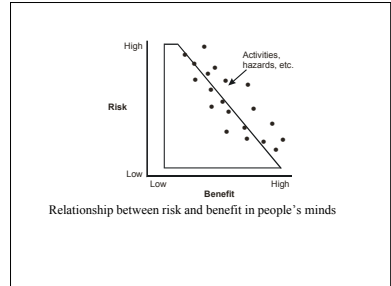


**Street Calculus**

By Gary Trudeau



In the world, risk and benefit are **positively** correlated.  
In people's minds, they are **negatively** correlated.



Relationship between risk and benefit in people's minds

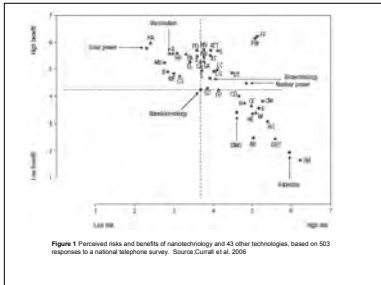


Figure 1. Perceived risk and benefits of nanotechnology and 43 other technologies, based on 503 responses to a national telephone survey. Source: Curral et al., 2008

The strength of the inverse (negative) relationship between risk and benefit judgments for a particular hazard (e.g. nuclear power) depends on the degree to which that hazardous activity is judged to be: good or bad.

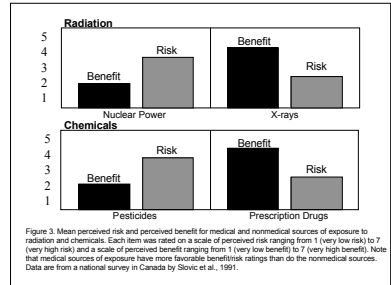
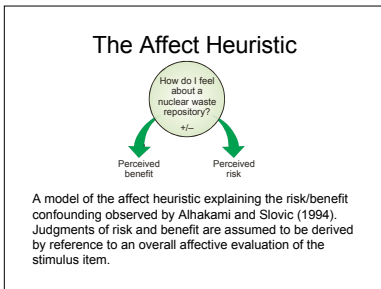


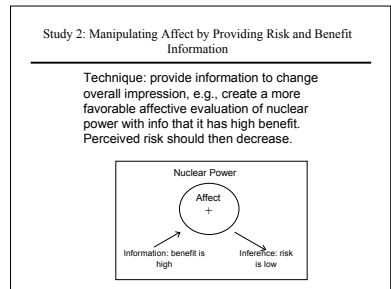
Figure 3. Mean perceived risk and perceived benefit for medical and nonmedical sources of exposure to radiation and chemicals. Each item was rated on a scale of perceived risk ranging from 1 (very low risk) to 7 (very high risk) and a scale of perceived benefit ranging from 1 (very low benefit) to 7 (very high benefit). Note that medical sources of exposure have more favorable benefit/risk ratings than do the nonmedical sources. Data are from a national survey in Canada by Slovic et al., 1991.

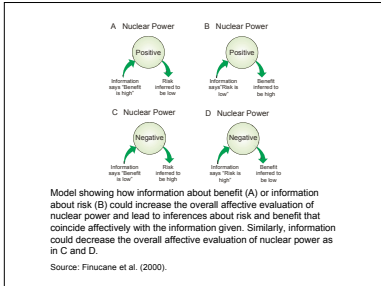


**Study 1: Risk and Benefit Judgments under Time Pressure**

- ◆ Time pressure reduces opportunity for analytic deliberation, and increases reliance on affect
- ◆ Prediction: Under time pressure people are more likely to use the affect heuristic to make judgments.

Result: Time pressure increases the inverse relationship between risk and benefit.





An important implication of the affect heuristic.

Risk and benefit co-mingle in the mind as feelings. Strong positive benefits will dampen perceived risks.

Acceptance of a particular nanotechnology will depend critically on perceived benefits, much like acceptance of chemical, nuclear, and bio technologies.

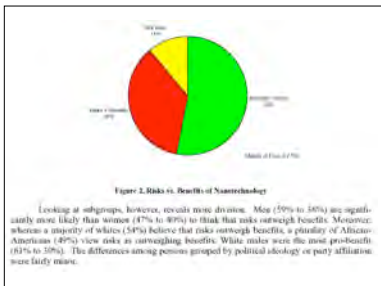
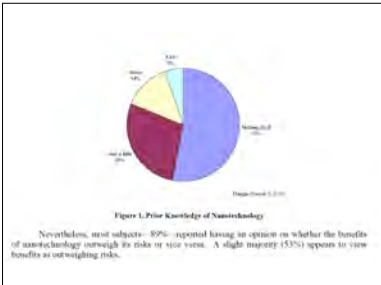
Part 3

Results from a very recent national survey on Nanotechnology



**Study Design**

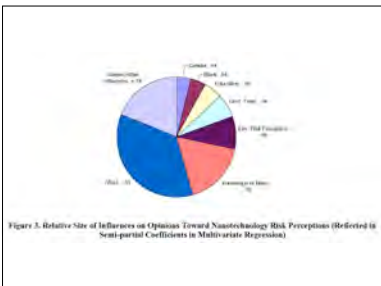
The sample consisted of approximately 1,850 Americans recruited by Knowledge Networks, a leading on-line survey firm, for participation in scholarly public opinion analysis. The sample was demographically diverse (51% female, 49% male; 72% white, 10% African American) and weighted to assure national representativeness. The subjects completed an on-line survey experiment that collected information on relevant individual characteristics and attitudes toward nanotechnology risks. To enable an experimental test of the effect of information exposure, a 350-subject subsample was furnished with more detailed information about the risks and benefits of nanotechnology before their views were elicited. Survey responses were collected between December 14, 2006, and December 28, 2006.



**Affect Item**

How would you say nanotechnology makes you feel?

Very bad  
bad  
Neither good nor bad  
good  
Very good



### The Impact of Information: Cultural/Ideological Polarization

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.

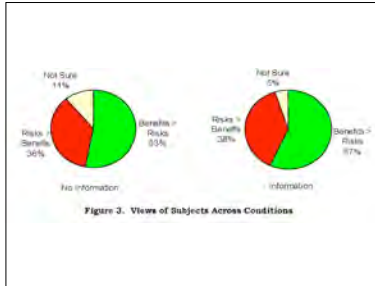


Figure 3. Views of Subjects Across Conditions

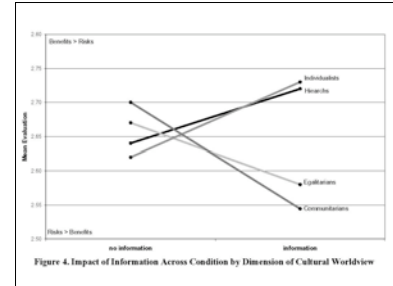


Figure 4. Impact of Information Across Condition by Dimension of Cultural Worldview

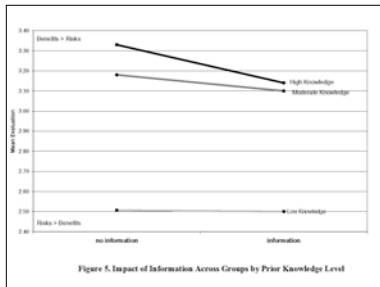


Figure 5. Impact of Information Across Groups by Prior Knowledge Level

#### Findings:

1. Peoples' attitudes toward nanotechnology derive from their affective or emotional responses to it. Those who know little or nothing about the concept of "nanotechnology" experience a quick, visceral reaction to it that strongly influences their judgment about the relative size of nanotechnology's potential risks and benefits. That visceral reaction is strongly influenced by their perceptions of more familiar environmental risks, such as those associated with global warming and nuclear power.

#### Findings:

2. As people learn more about nanotechnology, their reactions depend heavily on their values. When exposed to balanced and accurate information, people who hold largely individualistic and hierarchical cultural outlooks tend to see nanotechnology as more beneficial. People who hold largely communitarian and egalitarian outlooks, in contrast, tend to see nanotechnology as more risky when exposed to that same information. These patterns of opinion, too, are consistent with ones that characterize conflict over more familiar environmental issues. The same polarization occurs between people who, in political terms, describe themselves as conservatives and those who describe themselves as liberals.

3. It does not appear that learning more about nanotechnology tends in general to make people more favorably disposed to it. There is at present a positive relationship between how much people know about nanotechnology and the belief that its benefits outweigh its risks. But when people who know little or nothing are supplied with more information, they do not become uniformly more favorable: some form a positive impression, some a more negative one, depending (again) on their values. This finding suggests that the relationship now observed between knowledge about nanotechnology and a favorable view toward it is based on the causal influence of the latter on the former. That is, people who are already predisposed to like nanotechnology (most likely because of the values or emotions) have been more inclined so far to learn about it than have those who are predisposed to dislike it.

#### Recommendation:

The results of this study point up the need for additional research on techniques for effectively communicating information about nanotechnology. Because people with different values are predisposed to draw different factual conclusions from the same information, it cannot be assumed that simply supplying accurate information will allow members of the public to reach a consensus on nanotechnology risks, much less a consensus that promotes their common welfare. Those interested in promoting informed public responses toward nanotechnology must therefore attend not only to the content of information but also to the framing of it. To enable informed public deliberation, it is essential to develop strategies for communicating scientifically sound information that make it possible for people of diverse values to draw the same factual conclusions from it.

It would be a mistake, this study suggests, to assume that nothing more need be done than to supply people with scientifically sound information. People adopt an initial stance toward nanotechnology that tends to reflect their general emotional orientation toward environmental hazards; that stance then takes an even more partisan shape as they conform information about nanotechnology to their cultural and political values. If this process is permitted to unfold unchecked, it spells a future for nanotechnology marked by the sort of conflict and division that historically attended nuclear power and today characterizes the global warming debate. Whatever one anticipates science will reveal about the relative risks and benefits of nanotechnology, no one who favors constructive, democratic deliberation, much less the adoption of sensible risk regulations, should be heartened by this prospect.

At the same time, there is nothing in this study to suggest that such a future is inevitable. It seems unlikely that the tendency of people to filter information through emotion and values can be neutralized. But the tendency of these information-processing mechanisms to divide people certainly can be. Social psychology is making important advances in techniques for framing information on controversial issues of policy in a manner that makes it possible for people of diverse values to derive the same factual information from it (Cohen et al., 2000; Cohen et al., in press). With further study, it is likely that these techniques can be used to guide risk communication and thus enhance democratic deliberations about risk-regulation policy—on nanotechnology and on other issues (Kahan et al., 2006).

The practical lesson of this study, then, is that those who favor informed public deliberation over nanotechnology should be neither sanguine nor bleak. Instead, they should be psychologically realistic. And 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.

### Conclusion

The scientific study of risk perception and risk communication is essential to the effective management of Nanotechnologies.