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Religiosity as a perceptual filter: examining processes of opinion formation about nanotechnology

Dominique Brossard, Dietram A. Scheufele, Eunkyung Kim and Bruce V. Lewenstein

Using national survey data, we examine how people use science media, factual knowledge related to nanotechnology, and predispositions such as strength of religious beliefs, to form attitudes about nanotechnology. We show that strength of religious beliefs is negatively related to support for funding of the technology. Our findings also confirm that science media use plays an important role in shaping positive attitudes toward the technology. Overall public support for funding nanotechnology is not directly related to levels of knowledge among the electorate, but on risk and benefits perceptions and the use of media frames. However, knowledge about the technology does tend to be interpreted through the lens of religious beliefs and therefore indirectly affect levels of support.

1. Introduction

Nanotechnology is one of the fastest-growing areas of research in the United States, with federal and private funding being funneled to universities for both basic and applied research. In his State of the Union speech on 31 January 2006, President Bush proposed to double funding for emerging areas of research, including nanotechnology, over the course of the next 10 years. And consumers are already seeing almost 500 commercial applications on the market. The American public, at least for now, seems to focus mostly on these novel applications and their potential benefits and is not particularly interested in or concerned about the potential risks of the new technology (Scheufele and Lewenstein, 2005).

This phenomenon can at least in part be explained by the fact that most applications of nanotechnology so far have been in areas that are relatively uncontroversial, such as clothing or cosmetics. However, new sub-areas, such as nanobiotechnology or agrifood applications of nanotechnology will have an increasingly important impact on people's lives, and the question that needs to be asked is if these "nano-bio" applications will trigger public concerns that are similar to those that we saw for agricultural biotechnology, when they reach the marketplace.

Previous research on public perceptions of new technologies has largely focused on the potential incompatibilities between "knowledge deficit" models, on the one hand, and more emotional or predispositional variables on the other hand (Besley and Shanahan, 2005; Brossard and Nisbet, 2007; Gaskell et al., 2005; Scheufele and Lewenstein, 2005). Knowledge and understanding are, at best, very weak predictors of public support (see Brossard and Nisbet, 2007, for a discussion). Independently of its primary focus, however, most research in this area so far has paid little attention to the idea that *the context* in which

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people perceive a new technology and in which they interpret related knowledge facts is an important factor determining how individuals process information related to possible risks.

Specifically, we argue in this paper that people use perceptual filters as interpretative frameworks to help them make sense of complex knowledge when reaching judgments about a controversial technology. More particularly and as we will discuss, we expect religiosity to be one of these perceptual filters in the case of nanotechnology. In order to complement recent research examining the formation of public attitudes toward nanotechnology (Gaskell et al., 2005), we also examine the potential role of mass media in attitude formation. Finally, we consider how public understanding of nanotechnology and perceptions of its related risks and benefits might impact attitudes, and place this discussion within the current broad debate around the ambiguous nature of "scientific literacy" in modern societies. Our examination of support for nanotechnology will focus more specifically on attitudes toward federal funding of nanotechnology since the issue of public support for expanded research and funding is increasingly important in order to sustain federal funding initiatives and maintain general support for science and technology in the political arena.

2. Religiosity and nanotechnology

With science and religion providing a different understanding of the nature of the world, the interplay between religious beliefs and technological innovations has always been complex. Recent research has shown that religious beliefs can play an important role in shaping public attitudes toward science and technology (Gaskell et al., 2005; Nisbet, 2005). Given the normative inconsistencies between science and technology and religious belief systems (Miller et al., 1997), this finding is not very surprising. For instance, some people may feel that science interferes with nature or is equivalent with playing God (Sjöberg and Winroth, 1986; Sjöberg, 2004) and is therefore incompatible with strong religious beliefs. Gaskell et al. (2000) found that moral issues and concerns about "unnatural" technologies were important in explaining negative attitudes toward genetically modified (GM) organisms. These technologies were seen as disturbing nature and natural processes, and perceived as risky and immoral. Respondents who held strong religious beliefs were more likely to show strong opposition to GM related scientific research that involved human beings.

The potential conflict between religiosity and science has also been discussed for nanotechnology. According to the official definition of nanotechnology as provided by the US Food and Drug Administration (FDA), "nanotechnology" is based on Nano-Bio-Info-Cogno (NBIC) technologies that emphasize the unity of nature at the nanoscale, as well as intelligible processes of evolution that have constructed life and intelligence, from the nanoscale, without divine intervention (Bainbridge, 2003; Sententia, 2004). This all-encompassing approach to nanotechnology, of course, may threaten many people's religious beliefs and make them more likely to oppose further research in that area (Bainbridge, 2003).

While not necessarily rejecting technology per se, religious individuals might also be more cautious about its potential ethical implications and consequences for the human species. A writer in *Christianity Today*, a religious magazine, argues: "Christians must not become techno-dystopians, suspicious of all new technologies. While converging technology is not our salvation, neither is it intrinsically evil. Technology has enhanced our ability to show compassion and to spread the gospel" (Hook, 2004: 40). But some religious leaders have also expressed very concrete concerns over nanotechnology. For example, the head of the Church of Scotland's "Society, Religion and Technology Project" warns that use of nanotechnology might help create "a superhuman soldier" or "enhanced humans" (Johnston, 2006: 13).

It is therefore reasonable to assume that nanotechnology will be perceived by some religious respondents as potentially "going too far" and as being in conflict with their strong moral and religious beliefs. We therefore expect individuals' strength of religious beliefs to be a powerful predispositional factor explaining opposition to nanotechnology. On the basis of this reasoning, we put forth the following hypothesis:

Hypothesis 1: Strength of religious beliefs will be negatively related to support for nanotechnology.

3. The role of mass media in shaping attitudes toward nanotechnology

Science media coverage (in terms of content and valence) has also been shown to play an important role in changing attitudes toward specific technologies and science in general (Nisbet et al., 2002). In fact, some researchers have argued that the nature of media coverage of these technologies serves as a simple decision rule for audiences when forming attitudes (Scheufele and Lewenstein, 2005).

While the amount of media coverage devoted to nanotechnology is still minimal, its tone has been overwhelmingly positive, with print stories focusing on the progress and potential economic benefits that the technology could bring (Gorss and Lewenstein, 2005). Even when the stories were focused on potential risks of nanotechnology, these risks did not overshadow the positive aspects of nanotechnology in most of the articles (Friedman and Egolf, 2005). Not surprisingly, this dominance of positive coverage of nanotechnology has also helped promote positive attitudes among audiences (Lee et al., 2005). Science media use therefore is critical in explaining attitudes toward nanotechnology, and we put forth the following hypothesis:

Hypothesis 2: Science media use is positively related to support for nanotechnology.

4. Knowledge and perceptions of risks: information processing and nanotechnology

As we discussed earlier, religiosity and science media use are likely to be important predictors of support for nano funding. But where does people's understanding of nanotechnology or nano literacy fit in? We expect that levels of understanding of nanotechnology and perceptions of its potential risks and benefits might come into play differently. More importantly, we also expect that strength of religious beliefs might temper or attenuate some of these effects (Scheufele, 2006a).

The role of "knowledge" or "public understanding of science" in explaining public attitudes toward science has generated debate and disagreement among scholars (see Brossard and Nisbet, 2007, for a discussion). At one end of the spectrum are the scholars who argue that scientific knowledge is socially constructed, a matter of frame of reference and hard to quantify (Johnson, 1993). Attempts to link knowledge and attitudes, in their view, are therefore useless. At the other end of the spectrum, technocratic approaches to science believe in a purely "cognitive deficit" model and argue that the lack of knowledge and understanding among the general public also explains its lack of support (Bodmer, 1985). Recent research suggests that the answer lies somewhere in the middle (Brossard and Shanahan, 2003). Although also claiming that knowledge and understanding are hard to measure, these authors believe that a basic understanding of scientific facts is necessary to a modern enlightened citizenry.

However, recent research suggests that other factors might be more important than knowledge and understanding when it comes to explaining public attitudes toward technological innovations (Sturgis and Allum, 2004). Among those factors are emotional reactions to science and technology (e.g., fears, skepticism about benefits from science and technology, perceptions of risks and so on) that might have direct effect on public attitudes toward controversial technologies such as nanotechnology (e.g., Lee et al., 2005). In addition, levels of trust in scientists, regulatory authorities and industry could outweigh the role attributed to scientific knowledge (Brossard and Shanahan, 2003; Priest, 2001a, 2001b; Wynne, 2001). In fact, people who lack scientific knowledge might use social trust as a standing decision rule in order to reduce the complexity of decision-making processes related to science (Siegrist, 2000).

Results regarding the relationship between scientific knowledge and attitudes toward science are therefore mixed. In some instances, higher levels of scientific literacy have been linked to more positive views of science (Besley and Shanahan, 2005; Miller and Kimmel, 2001; Miller et al., 1997; Priest, 2001b). Others have argued that the relationship between factual technical knowledge and the perceived risk related to a technology is tentative at best (Johnson, 1993), has a limited impact in promoting positive views of a technology (Brossard and Nisbet, 2007), and plays no significant role in predicting support for nanotechnology (Scheufele and Lewenstein, 2005).

Moreover, research suggests that the relationship between scientific knowledge and public attitudes toward science could be more complex than previously assumed and that other factors might mediate the knowledge–attitude link. For instance, Jallinoja and Aro (2000) found that there was indeed an association between knowledge about genes and attitudes toward genetic testing; however, more scientific knowledge did not simply lead to unambiguous approval of genetic tests. Instead, several factors, such as an increase in people's ability to seek and understand information about genetics, mediated the association between knowledge and acceptance of genetic testing.

In this study, we are interested in exploring the relationship between basic understanding of nanotechnology and support for this technology. In line with previous research findings related to general public support for new technologies (such as agricultural biotechnology or stem cell research), we do not expect a significant direct effect of levels of scientific knowledge on support for nanotechnology. This null effect, of course, cannot be formally hypothesized.

As we have discussed earlier, however, science literacy may interact with personal predispositions to influence support for nanotechnology. In particular, highly religious individuals might be opposed to nanotechnology on the basis of moral considerations. These individuals are likely to use these moral considerations as perceptual lenses (Scheufele, 2006b) in order to make sense of what they know about science in general and nanotechnology in particular. However, given the limited number of studies on the combined effects of scientific knowledge and religiosity on nanotechnology, we do not formally hypothesize these effects but simply put forth the following research question.

Research Question 1: Does the link between scientific knowledge and support for nanotech funding vary for respondents with different levels of religiosity?

Perceptions of risks, perceptions of benefits and support for nanotechnology

Scientific knowledge, of course, is not the only type of information that might influence support for funding for research related to nanotechnology. Citizens may also rely on quick calculations of potential consequences (i.e., the weighing of risks vs. benefits) to reach a judgment about funding and other social implications of new technologies (Slovic, 1992).

Laypersons' perceptions of the risks and benefits related to a technology can be significantly different from scientific quantification of the same concepts. Lay individuals are more likely to perceive hazards or issues as risky if they are not under their control (Starr, 1969), seem "dreadful" and "novel" (Fischhoff et al., 1978), and "tamper with nature" (Sjöberg, 2002). Others have argued that risk perceptions vary depending on individuals' personal values, level of education, personal experiences, level of community involvement, and stake in outcomes (Covello and Sandman, 2001; Dunwoody and Neuwirth, 1991; Slovic, 1999). In any case, the more individuals perceive a hazard or a technology as risky, the less likely they are to accept it.

Perceived risks/benefits have been associated with levels of acceptance of a technology in numerous research settings (Frewer et al., 1998; Siegrist et al., 2000; Siegrist, 2000; Sjöberg, 2002, 2004). In the specific context of gene technology, Siegrist (2000) found that acceptance of gene technology was directly negatively related to the perceived risks and was positively related to the perceived benefits associated with the technology. In fact, some have argued that perceiving high risks in a new technology was the fundamental reason for its rejection (Sjöberg, 2004).

This link can be in part explained by the use of risks as "heuristics," i.e., shortcuts that individuals use to reach quick judgments. Citizens tend to use only information that is most easily available to them when forming judgments about an issue (Popkin, 1994), particularly for issues that are not directly relevant to their lives (Petty et al., 1981). In this case, frames provided by the media in terms of potential risks and benefits of a technology are likely to constitute powerful heuristics (Scheufele and Lewenstein, 2005). In an experimental setting, Cobb (2005) confirmed that media frames about specific risks and benefits of nanotechnology indeed affected public attitudes. He found that exposure to risk frames lowered respondents' trust in industry leaders and generated negative feelings about nanotechnology. Taking into account the current nature of the coverage, we can expect the media to foster the feeling that nanotechnology will have overwhelmingly positive effects for society and that the related risks are minimal. These perceptions, in turn, will most likely promote support for the technology.

We therefore posit that perceptions of risks and benefits related to nanotechnology are likely to influence support for the technology, and put forth the following hypotheses:

Hypothesis 3a: A higher level of *perceived risks* is negatively related to support for nanotechnology.

Hypothesis 3b: A higher level of *perceived benefits* is positively related to support for nanotechnology.

We have pointed out earlier that religious beliefs can serve as an important filter when individuals consider the information available to them to form judgments about the technology. In the case of nanotechnology, we expect that religious individuals will assess the *benefits* of the technology (which, as we have discussed, are currently featured very prominently in news media) differently than those who are not religious, and consequently form different judgments. In other words, we expect religiosity to moderate the effect of perceived benefits on support of the use of the technology. However, the dearth of empirical findings on the interplay between religiosity and the perceived benefits of supporting the use of nanotechnology has led us to propose Research Question 2:

Research Question 2: Does the link between perceiving benefits for nanotechnology and supporting nanotechnology vary across different levels of religiosity?

5. Methods

Our analyses are based on a representative national telephone survey with a sample size of $N = 706$, conducted in the fall of 2004. The cooperation rate (based on standard definitions developed by the American Association for Public Opinion Research) was 43 percent. The sample was based on a carefully constructed probability sample that minimized sampling and non-response biases. In order to minimize systematic non-response, we invested above-average resources in careful monitoring of interviews and multiple callbacks for non-contacts and initial refusals.

Dependent variable

As outlined earlier, our study focused on support for nanotechnology funding, given the relevance of public support in this area for policymaking and long-term federal support for this new technology. *Support for funding of nanotechnology* ($M = 5.36$, $SD = 2.81$) was measured with a 10-point scale item (1 = not at all; 10 = very much) asking respondents their level of agreement with the following statement: "overall I support federal funding of nanotechnology."

Independent variables

Socio-demographic variables included standard measures of age ($M = 50.02$, $SD = 17.72$), gender (58.8 percent females), and education (median: some college education).

Religiosity ($M = 6.39$, $SD = 3.44$) was measured by asking respondents on a 10-point scale how much guidance religion played in their everyday lives (1 = no guidance, 10 = a great deal of guidance).

Science media use measures. "Newspaper science news use" was constructed as a summative index of six 10-point scales asking 1) how much attention respondents paid to the following stories: a) science and technology, b) specific scientific developments such as nanotechnology, c) investment and market potential; and 2) how often they read stories in the following areas: a) science and technology, b) new areas of research, and c) investment and market potential ($M = 24.34$, $SD = 16.95$, Cronbach's alpha = .95). "Television science news use" was a summative index of four 10-point scales asking 1) how much attention they paid to the following television programs: a) science and technology and b) specific science developments; and 2) how often they watched the following type of programs: a) science and technology and b) specific science developments ($M = 12.57$, $SD = 7.94$, Cronbach's alpha = .97).

Factual knowledge about nanotechnology was an additive index of six true–false items asking respondents whether 1) nanotechnology involved materials that were visible to the naked eye, 2) US corporations were using nanotechnology to make products sold today, 3) experts considered nanotechnology to be the next industrial revolution of the US economy, 4) a nanometer was a billionth of a meter, 5) nanotechnology allowed scientists to arrange molecules in ways that do not occur in nature, and 6) a nanometer was about the same size as an atom. The additive index of all six questions ranged from 0 to 6 had a mean of $M = 3.90$ ($SD = 1.55$, KR-20 = .56).

Perceptions of risk was operationalized as an additive index of four 10-point scales (1 = not at all, 10 = very much), tapping respondents' level of agreement with the following statements: 1) because of nanotechnology, we may lose more US jobs; 2) nanotechnology may lead to the loss of personal privacy because of tiny new surveillance devices; 3) nanotechnology may lead to an arms race between the US and other countries; and 4) nanotechnology may lead to the uncontrollable spread of very tiny self-replicating robots (M = 18.89, SD = 8.58, Cronbach's alpha = .71).

Perceptions of benefits was an additive index of four 10-point scales (1 = not at all, 10 = very much), asking respondents' level of agreement with the following statements: 1) nanotechnology may lead to new and better ways to treat and detect human diseases, 2) nanotechnology may help us develop increased national security and defense capabilities, 3) nanotechnology may lead to new and better ways to clean up the environment, and 4) nanotechnology may give scientists the ability to improve human physical and mental abilities (M = 26.27, SD = 8.89, Cronbach's alpha = .81).

6. Results

We used hierarchical ordinary least squares (OLS) regression models to test separately models predicting each of the two following dependent variables: 1) support for the use of nanotechnology and 2) support for federal funding of nanotechnology. OLS regression tests the relationships between potential explanatory variables (or independent variables) and a dependent variable (in this case, levels of support) by fitting a linear equation to observed data. In hierarchical regression modeling, the independent variables are entered in blocks according to their assumed causal order in order to examine their relative explanatory power. In our analysis, the blocks were as follows:

1) Demographics (age, gender, education)
2) Strength of religious beliefs (which we called religiosity)
3) Science media use (newspaper use, television use)
4) Nanotechnology related factual knowledge
5) Risks/benefits (perceived risks, perceived benefits).

We also calculated interactions in order to assess the degree to which religiosity tempered both the potential effects of factual nano knowledge and the perceived benefits related to nanotechnology on our dependent variable. As outlined earlier, statistical interactions represent the notion that the relationship between two variables (e.g., the link between factual knowledge and support for nanotechnology) differs across different social groups (e.g., respondents with higher or lower levels of religiosity).

Each of the interaction terms was constructed by multiplying the standardized values of the main effect variables. This was done to prevent possible multicollinearity problems between the interaction term and its components (Cohen and Cohen, 1983). In our analyses, we therefore included two multiplicative terms in the final blocks for each of the regressions predicting our two dependent variables: 1) the interaction between religiosity and scientific knowledge, and 2) the interaction between religiosity and perceptions of benefits.

Overall, respondents tended to support federal funding for nanotechnology (Figure 1).

As shown in Table 1, the regression model predicting support for funding of nanotechnology performed equally well, accounting for a total of 29.8 percent of the variance in the dependent variable. Socio-demographics accounted for 6.7 percent of the variance in support for funding of nanotechnology; science media use accounted for an additional 11.9 percent. Religiosity, nanotechnology related knowledge and perceptions of risks and benefits accounted for an additional 0.9 percent, 1.1 percent and 9 percent of the variance in support for nano funding, respectively.

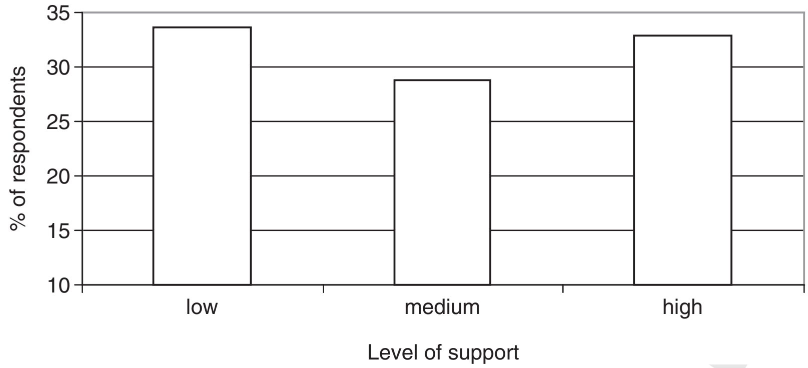

Figure 1. Levels of public support for the federal funding for nanotechnology.

Table 1. Predicting support for federal funding of nanotechnology

	Zero-order	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Block 1: Demographics							
Age	–.01*	–.07	–.05	–.07	–.04	–.05	–.05
Gender (female = 1)	–.18**	–.17***	–.16***	–.10**	–.10**	–.05	–.05
Education	.18**	.17***	.16***	.11**	.10**	.06	.06
Incremental R^2 (%)		6.7***					
Block 2: Value predispositions							
Religiosity	–.15**		–.10*	–.12**	–.11**	–.07*	–.07*
Incremental R^2 (%)			0.9*				
Block 3: Science media use							
Newspaper use	.30**			.13**	.12**	.11**	.11**
Television use	.36**			.27***	.26***	.20***	.20***
Incremental R^2 (%)				11.9***			
Block 4: Knowledge							
Factual nano knowledge	.20**				.11**	.05	.05
Incremental R^2 (%)					1.1**		
Block 5: Risk/ benefit information							
Perceived benefits	.42**					.35***	.35***
Perceived risks	.01					–.10**	–.10**
Incremental R^2 (%)						9.0***	
Block 6: Interactions							
Scientific knowledge* Religiosity	—						–.12***
Perceived risks* Religiosity	—						–.04
Perceived benefits* Religiosity	—						–.03
Incremental R^2 (%)							1.5**
Total R^2 (%)							29.8

Cell entries are final standardized regression coefficients for Blocks 1, 2, 3, 4 and 5 and before-entry standardized regression coefficient for Block 6.

*$p < .05$. **$p < .01$. ***$p < .001$.

As hypothesized (H1), we found a significant negative relationship between strength of religious beliefs and support for funding of nanotechnology ($\beta = -.07$, $p < .05$). Hypothesis 2, which predicted that the more people used science media, the more supportive they were of funding for nanotechnology, was also supported. Reading science news in the newspaper ($\beta = .11$, $p < .01$) and watching science news on television ($\beta = .20$, $p < .001$) were both significantly related to more support for funding of nanotechnology. Hypotheses 3a and 3b were also supported: we found a significant negative relationship between perceiving risks in funding nanotechnology and supporting it ($\beta = -.10$, $p < .01$), and a significant positive relationship between perceiving benefits in funding for nanotechnology and supporting it ($\beta = .35$, $p < .001$).

Research Question 1 was the following: does the link between levels of nanotechnology related knowledge and support for funding vary across different levels of religiosity? The answer is "yes." As Table 1 shows, there was a significant interaction effect between strength of religious beliefs and nanotechnology related factual knowledge ($\beta = -12$, $p < .001$). In other words, highly religious respondents also showed the lowest levels of support for funding for nanotechnology; and being more knowledgeable about nanotechnology

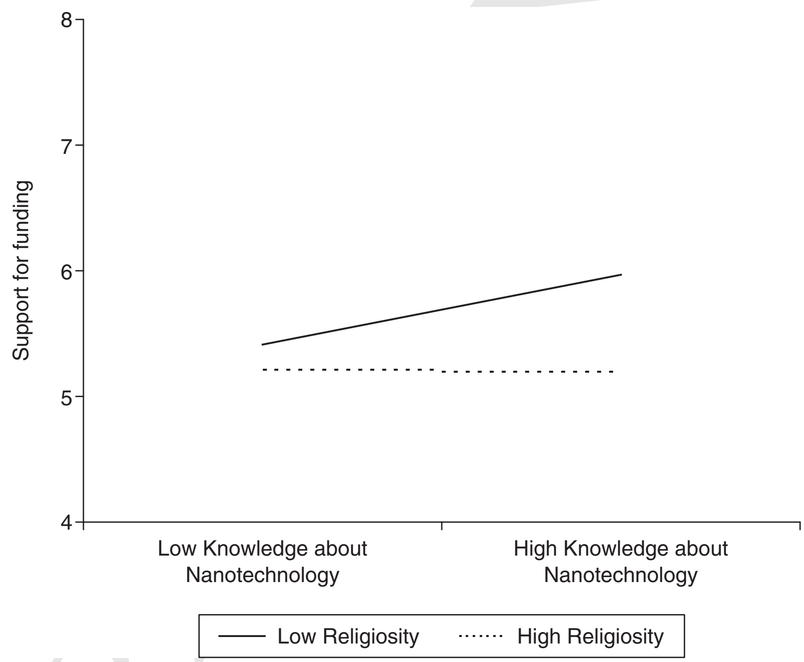

Figure 2. Interaction effect of religion and knowledge about nanotechnology on support for funding of nanotechnology.
Note: Y-axis scores based on 1–10 scale.

did little to influence their support for funding. For less religious individuals, however, our data showed a strong link between knowledge about nanotechnology and greater support for nanotechnology funding (Figure 2).

7. Discussion

As public levels of concern and awareness increase and as the public engages more and more in decision-making about new technologies, it is increasingly important for public officials and other stakeholders to develop a better understanding of how public opinion is formed and of how citizens make sense of information about nanotechnology. This paper used national survey data to assess the degree to which levels of religiosity, levels of science media use, factual knowledge related to the technology, and perceptions of its risks and benefits, help explain attitudes toward nanotechnology. As hypothesized, we found a direct and negative relationship between strength of religious beliefs and support for funding of the technology. Our findings also confirmed that science media use plays an important role in shaping positive attitudes toward a technology in its early stages of development. Until now, media have framed nanotechnology mostly in terms of economic benefits and scientific progress (Nisbet et al., 2002), and this kind of coverage has also shaped people's perceptions of nanotechnology (Scheufele and Lewenstein, 2005). And since media are likely to be the primary source of information about nanotechnology and its risks and benefits, it is not surprising that media use has a positive effect on public perceptions, at this point, both with respect to the use of nanotechnology in general, and funding for nanotechnology in particular.

Informing the ongoing academic and policy debates surrounding the cognitive deficit approach to public understanding of science, our study showed that factual knowledge about nanotechnology does play a role in shaping attitudes, although that role is not central. Most importantly, we provided initial evidence for the idea that religiosity serves as an interpretive tool for audiences when making sense of nanotechnology. As expected, levels of knowledge did interact with religiosity. Not surprisingly, highly religious respondents showed the highest level of opposition to federal funding for nanotechnology. But more importantly, the link between knowledge and support for federal funding was significantly weaker for highly religious respondents than it was for less religious respondents. Our data therefore suggest that factual knowledge can play a role in shaping attitudes, but that the effect differs depending on people's predispositions. And for highly religious respondents, their strong belief system can help suppress potentially positive effects of knowledge on support for nanotechnology.

Consistent with previous research on risk perceptions, we also found that acceptance of nanotechnology was negatively related to the perceived risks and positively related to the perceived benefits associated with the technology. This, of course, raises an important concern related to the criterion variables used in our study. Our dependent variable was a single-item measure, which obviously did not allow us to control or adjust for random measurement error. It is reasonable to assume, however, that any potential random error in this single measure would in fact attenuate the relationships that we identified. In other words, we expect that the strength of our relationships would increase if multi-item indicators were used to measure support for federal funding of nanotechnology.

With these considerations in mind, our study offers a new and more complex look at public perceptions of emerging technologies. Our findings show that factual knowledge does have an important role to play, as traditional models of public understanding of science would suggest. However, this effect is primarily present for people that do not have strong value predispositions such as religiosity.

In terms of policy implications of our findings, of course, however, it is important to keep in mind that overall public support for nanotechnology will depend not on levels of factual knowledge among the electorate, but on more applied heuristics, such as risk and benefits perceptions or other media frames. And as our study showed, factual knowledge tends to be interpreted through the lens of religious beliefs and potentially other predispositional factors not examined here (Scheufele, 2006b). Our data therefore clearly show that it is critical for policymakers and science communicators to understand the complex interplay of all of these factors when trying to understand public opinion formation about new technologies. Similarly, science communication and outreach efforts need to take these findings into account and replace one-size-fits-all modes of communication with tailored messaging for specific subgroups, based on their levels of information, risk and benefits perceptions, and belief systems.

Future research should explore these processes further, based on more reliable, multi-item operationalization of the dependent variable and based on a broader set of predispositional variables. In addition, controlled experimental designs will be valuable tools for examining the different mechanisms in more detail than we outlined here. This will be critical for developing the more refined, in-depth understanding that our study shows is necessary in order to understand the complex relationships between knowledge, predispositions, and different outcome variables outlined in this study.

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References

Bainbridge, W.S. (2003) "Religious Opposition to Cloning," *Journal of Evolution and Technology* 13 (October). URL: http://jetpress.org/volume13/bainbridge.htm

Besley, J.C. and Shanahan, J. (2005) "Media Attention and Exposure in Relation to Support for Agricultural Biotechnology," *Science Communication* 26: 347–67.

Bodmer, W. (1985) *The Public Understanding of Science*. London: Royal Society.

Brossard, D. and Nisbet, M. (2007) "Deference to Scientific Authority among a Low Information Public: Understanding U.S. Opinion on Agricultural Biotechnology," *International Journal of Public Opinion Research* 19(1): 24–52.

Brossard, D. and Shanahan, J. (2003) "Do Citizens Want to Have their Say? Media, Agricultural Biotechnology, and Authoritarian Views of Democratic Processes in Science," *Mass Communication and Society* 3(6): 291–312.

Cobb, M. (2005) "Framing Effects on Public Opinion about Nanotechnology," *Science Communication* 27(2): 221–39.

Cohen, J. and Cohen, P. (1983) *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*, 2nd edn. Hillsdale, NJ: Erlbaum.

Covello, V. and Sandman, P. (2001) "Risk Communication: Evolution and Revolution," in A. Wolbarst (ed.) *Solutions to an Environment in Peril*, pp. 164–78. Baltimore, MD: Johns Hopkins University Press.

Dunwoody, S. and Neuwirth, K. (1991) "Coming to Terms with the Impact of Communication on Scientific and Technological Risk Judgments," in L. Wilkins and P. Patterson (eds) *Risky Business*, pp. 11–30. New York: Greenwood.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S. and Combs, B. (1978) "How Safe is Safe Enough? A Psychometric Study of Attitudes towards Technological Risks and Benefits," *Policy Sciences* 9: 127–52.

Frewer, L.J., Howard, C. and Shepherd, R. (1998) "Understanding Attitudes to Technology," *Journal of Risk Research* 1: 221–35.

Friedman, S.M. and Egolf, B.P. (2005) "Nanotechnology: Risks and the Media," *IEEE Technology and Society Magazine* 24: 5–11.

Gaskell, G., Allum, N., Bauer, M., Durant, J., Allansdottir, A., Bonfadelli, H., Boy, D., de Cheveigne, S., Fjaestad, B., Gutteling, J.M., Hampel, J., Jelsoe, E., Jesuino, J.C., Kohring, M., Kronberger, N., Midden, C., Nielsen, T.H., Przestalski, A., Rusanen, T., Sakellaris, G., Torgersen, H., Twardowski, T. and Wagner, W. (2000) "Biotechnology and the European Public," *Nature Biotechnology* 18(9): 935–8.

Gaskell, G., Einsiedel, E., Hallman, W., Priest, S.H., Jackson, J. and Olsthoorn, J. (2005) "Social Values and the Governance of Science," *Policy Forum* 310: 1908–9.

Gorss, J. and Lewenstein, B.V. (2005) "The Salience of Small: Nanotechnology Coverage in the American Press, 1986–2004," Paper presented at the annual conference of the International Communication Association, 26–30 May, New York, NY.

Hook, C.C. (2004) "The Techno Sapiens are Coming," *Christianity Today* January, pp. 37–40.

Jallinoja, P. and Aro, A.R. (2000) "Does Knowledge Make a Difference? The Association between Knowledge about Genes and Attitudes toward Gene Tests," *Journal of Health Communication* 5: 29–39.

Johnson, B.B. (1993) "Advancing Understanding of Knowledge's Role in Lay Risk Perception," *Risk: Issues in Health and Safety* 4: 189–212.

Johnston, I. (2006) "Kirk Seeks 'Superman' Technology Watchdog to Rein in Scientists," *The Scotsman* 5 August, p. 13.

Lee, C.J., Scheufele, D.A. and Lewenstein, B.V. (2005) "Public Attitudes toward Emerging Technologies: Examining the Interactive Effects of Cognitions and Affect on Public Support for Nanotechnology," *Science Communication* 27(2): 240–67.

Miller, J.D. and Kimmel, L. (2001) *Biomedical Communications: Purposes, Audiences, and Strategies*. New York: Academic Press.

Miller, J.D., Pardo, R. and Niwa, F. (1997) *Public Perceptions of Science and Technology: A Comparative Study of the European Union, the United Status, Japan, and Canada*. Chicago: Chicago Academy of Sciences.

Nisbet, M.C. (2005) "The Competition for Worldviews: Values, Information, and Public Support for Stem Cell Research," *International Journal of Public Opinion Research* 17(1): 90–112.

Nisbet, M.C., Scheufele, D.A., Shanahan, J., Moy, P., Brossard, D. and Lewenstein, B.V. (2002) "Knowledge, Reservations, or Promise? A Media Effects Model for Public Perceptions of Science and Technology," *Communication Research* 29(5): 584–608.

Petty, R.E., Cacioppo, J.T. and Goldman, R. (1981) "Personal Involvement as a Determinant of Argument-based Persuasion," *Journal of Personality and Social Psychology* 41: 847–55.

Popkin, S.L. (1994) *The Reasoning Voter: Communication and Persuasion in Presidential Campaigns*, 2nd edn. Chicago, IL: University of Chicago Press.

Priest, S.H. (2001a) *A Grain of Truth: The Media, the Public, and Biotechnology*. Oxford: Rowman and Littlefield.

Priest, S.H. (2001b) "Misplaced Faith: Communication Variables as Predictor of Encouragement for Biotechnology Development," *Science Communication* 23(2): 97–110.

Scheufele, D.A. (2006a) "Five Lessons in Nano Outreach," *Materials Today* 9(5): 64.

Scheufele, D.A. (2006b) "Messages and Heuristics: How Audiences Form Attitudes about Emerging Technologies," in J. Turney (ed.) *Engaging Science: Thoughts, Deeds, Analysis and Action*, pp. 20–5. London: The Wellcome Trust.

Scheufele, D.A. and Lewenstein, B.V. (2005) "The Public and Nanotechnology: How Citizens Make Sense of Emerging Technologies," *Journal of Nanoparticle Research* 7(6): 659–67.

Sententia, W. (2004) "Neuroethical Considerations: Cognitive Liberty and Converging Technologies for Improving Human Cognition," *Annals of the New York Academy of Sciences* 1013: 221–8.

Siegrist, M. (2000) "The Influence of Trust and Perceptions of Risks and Benefits on the Acceptance of Gene Technology," *Risk Analysis* 20(2): 195–203.

Siegrist, M., Cvetkovich, G. and Roth, C. (2000) "Salient Value Similarity, Social Trust, and Risk/Benefit Perception," *Risk Analysis* 20(3): 353–62.

Sjöberg, L. (2002) "Attitudes toward Technology and Risk: Going beyond What is Immediately Given," *Policy Sciences* 35: 379–400.

Sjöberg, L. (2004) "Principles of Risk Perception Applied to Gene Technology," *European Molecular Biology Organization Report* 5: s47–s51.

Sjöberg, L. and Winroth, E. (1986) "Risk, Moral Value of Actions, and Mood," *Scandinavian Journal of Psychology* 27: 191–208.

Slovic, P. (1992) "Perception of Risk: Reflections on the Psychometric Paradigm," in S. Krimsky and D. Golding (eds) *Social Theories of Risk*, pp. 117–52. Westport, CT: Praeger.

Slovic, P. (1999) "Trust, Emotion, Sex, Politics and Science: Surveying the Risk-assessment Battlefield," *Risk Analysis* 19: 689–701.

Starr, C. (1969) "Social Benefit versus Technological Risk," *Science* 165: 1232–8.

Sturgis, P. and Allum, N. (2004) "Science in Society: Re-evaluating the Deficit Model of Public Attitudes," *Public Understanding of Science* 13(1): 55–74.

Wynne, B. (2001) "Expert Discourses of Risk and Ethics on Genetically Manipulated Organisms: The Weaving of Public Alienation," *Politeia* 17(62): 51–76.

Authors

Dominique Brossard (Ph.D., Cornell University) is an assistant professor in the School of Journalism and Mass Communication, University of Wisconsin-Madison, USA, and a faculty affiliate of the UW-Madison Robert and Jean Holtz Center for Science and Technology Studies. Her research broadly focuses on the intersection between science, media and the public and on the understanding of public opinion dynamics in the context of controversial science. She has recently co-edited (with Jim Shanahan and Clint Nesbit) the book *The Media, the Public, and Agricultural Biotechnology* (CABI Publishing, 2007). Correspondence: Dominique Brossard, School of Journalism and Mass Communication, 821 University Avenue, Madison, WI 53706, USA; e-mail: dbrossard@wisc.edu

Dietram A. Scheufele is a professor in the Department of Life Sciences Communication and a member of the steering committee of the Robert F. and Jean E. Holtz Center for Science and Technology Studies at the University of Wisconsin. He is also Wisconsin PI (principal investigator) of the NSF-funded Center for Nanotechnology in Society at Arizona State University (CNS-ASU) and currently serves as a member of the Nanotechnology Technical Advisory Group to the US President's Council of Advisors on Science and Technology.

Eunkyung Kim (M.A., University of Wisconsin) is a Ph.D. student in the School of Journalism and Mass Communication at the University of Wisconsin and a research assistant for the Center of Health Enhancement System Studies at the University of Wisconsin. Her research interests include 1) the impact of interpersonal discussion and media use on information processing and behavioral outcomes in political and health communication, 2) the processes underlying opinion formation about science and politics, and 3) quantitative research methods in media and market research.

Bruce Lewenstein is Professor of Science Communication at Cornell University, and a former editor of *Public Understanding of Science*. From 2004 to 2006, he was the Social and Ethical Issues Coordinator for the National Nanotechnology Infrastructure Network. From 2006 to 2008, he was co-chair of a National Academy of Sciences study on Learning Science in Informal Environments.