Previous studies on public attitudes toward emerging technologies have treated cognitive and affective influences on public opinion as distinct, with little attention to the possible interaction between the two. Directly addressing this issue, we argue that cognitive and affective factors not only have important separate effects on public attitudes but also work in tandem to produce effects. In particular, it may be that affective variables shape the impact of cognitions and vice versa. We use data from a national telephone survey to test this interactive model of decision making about emerging technologies. Our analyses show that emotional heuristics moderate the effect that knowledge about nanotechnology has on people's overall attitudes toward nanotechnology, with knowledge having a weaker effect on attitudes for people who do show strong emotional reactions to the topic. The implications of these findings for future research and policy making in this area are discussed.

Public Attitudes Toward Emerging Technologies

Examining the Interactive Effects of Cognitions and Affect on Public Attitudes Toward Nanotechnology

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While nanotechnology may be one of the most significant scientific developments in decades, the U.S. public is largely unfamiliar with this new technology. The lack of concrete factual information on the part of citizens, however,

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does not necessarily mean that they will not form attitudes about these new technologies. Rather, citizens will use cognitive shortcuts or heuristics, such as ideological predispositions or cues from mass media, to form judgments about emerging technologies (Nisbet 2005; Scheufele and Lewenstein, forthcoming).

Unfortunately, social scientists are only now beginning to pay attention to the complex interplay among many of these heuristics and their influences on public opinion formation (e.g., Nisbet 2005). Understanding these dynamics of opinion formation, of course, also provides critical insights into the sociocultural contexts in which nanotechnology research is conducted, into the societal benefits that people expect from nanotechnology, and, ultimately, into the links between public attitudes toward nanotechnology and democratic decision making about science and technology (Roco and Bainbridge 2001).

At this stage of the issue cycle, public attitudes toward nanotechnology are generally positive, which is in line with Americans' attitudes toward science and technology in general (Miller 1998, 2004). Several surveys among the U.S. public have shown "a high level of enthusiasm for the potential benefits of nanotechnology and little concern about possible dangers" (Bainbridge 2002, 561; for similar conclusions, see also: Cobb and Macoubrie 2004; Gaskell et al. 2004; Scheufele and Lewenstein, forthcoming).

Unlike attitudes on issues such as agricultural biotechnology, public opinion on nanotechnology is in the early stages of the issue cycle and—as a result—still very much in flux. In other words, public perceptions and attitudes can be affected by a wide range of cognitive and affective variables at this point.[1] Nanotechnology, therefore, provides social scientists with a unique opportunity to examine public opinion formation on emerging scientific issues in the early stages of the issue cycle, when citizens are only beginning to make sense of the risks and benefits connected with a new technology.

Previous research in this area is often characterized by a basic distinction between more cognitive (Miller 1998, 2004) and more affective (e.g., Priest 2001; Priest, Bonfadelli, and Rusanen 2003; Siegrist 1999, 2000)

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explanations of people's decision making about scientific issues and emerging technologies. In fact, much previous research in this area has examined these two factors as distinct influences that have different effects on public understanding of and public attitudes toward scientific breakthroughs. Most previous research that has examined the cumulative or net effects of cognitive and affective factors has dealt little with how audiences use a *combination* of the two approaches to form attitudes about scientific issues.

Our study directly addresses this issue. In particular, we test both cognitive and affective decision-making pathways that may shape public attitudes toward nanotechnology. More important, however, is our examination of the interplay between cognitive and affective factors and their *combined* influences on public attitudes toward nanotechnology. Before outlining an integrated model in which affective factors moderate the effects of knowledge about nanotechnology on public attitudes toward nanotechnology, it is necessary to outline the two groups of influences separately.

Knowledge and Literacy: Cognitive Influences on Public Opinion Toward Nanotechnology

As outlined earlier, many studies on public attitudes toward science and technology have relied on cognitive explanations: that is, they have focused on the link between science literacy and attitudes toward new technologies. Studies following this model usually focus either on issue-specific knowledge or on more general scientific literacy.

The first category—studies of issue-specific knowledge about new technologies—is often conducted in the area of risk perceptions and risk communication. They share the assumption that (1) specific risks can be accurately and objectively calculated (Hornig 1993) and (2) individuals' risk perceptions are at least to some degree a function of preexisting levels of knowledge about the topic (Wildavsky and Dake 1990).

The second category of studies focuses on more general "civic science literacy," rather than on issue-specific knowledge about new technologies. Similar to the previous category, researchers in this area assume that knowledge of basic scientific ideas and concepts is a prerequisite for a range of science-related behaviors and attitudes, such as informed public decision making (Miller 1987, 1995, 1998, 2004) or support for science (Miller and Kimmel 2001; Miller, Pardo, and Niwa 1997; Shen 1975). In contrast to issue-specific knowledge, however, civic scientific literacy is based on the assumption that citizens have various levels of understanding when it comes to the scientific process, the idea of scientific inquiry, and related concepts. Such an understanding provides an important tool with which citizens can make sense of specific developments in the field of science or of the risks and benefits connected to emerging technologies.

The nature of this relationship, however, is still under debate. For example, Miller and his colleagues have shown that civic scientific literacy can exert a positive influence on support for scientific research and for federal funding for science (e.g., Miller 1995, 1998, 2004; Miller and Kimmel 2001; Miller and Pardo 2000; Miller, Pardo, and Niwa 1997). Consequently, it could be argued that low levels of scientific literacy among the U.S. public is at least in part responsible for the public's misperceptions of science and scientists and reservations about new scientific developments (Dawkins 1998; Miller and Kimmel 2001; Miller, Pardo, and Niwa 1997). Other researchers, however, have argued that knowledge about specific scientific issues has no measurable impact on public attitudes on those issues (Brossard, Lewenstein, and Bonney 2005) or that the link between scientific literacy and attitudes is much more complex than previously assumed. In fact, it may vary significantly, depending on the sociodemographic characteristics of citizens or on the particular issue that is being examined (e.g., Sturgis, Cooper, and Fife-Schaw 2005).

In examining public attitudes toward new scientific discoveries, such as nanotechnology, researchers have usually relied on two different outcome variables. The first outcome variable is a measure of general support for or opposition to the new technology; the second outcome variable is a measure of perception of risks versus benefits of the new technology (Nisbet et al. 2002), that is, respondents' judgments about its risks compared to its benefits. Studies on public reactions to nanotechnology have followed a similar distinction (e.g., Bainbridge 2002; Cobb and Macoubrie 2004). Likewise, this study adopts both *general support for nanotechnology* and *perception of risks versus benefits of nanotechnology* as criterion variables.

On the basis of these considerations, we put forth the following research questions:

Research Question 1-1. Will higher levels of knowledge about science in general be positively related to general support for nanotechnology?

Research Question 1-2. Will higher levels of knowledge about nanotechnology be positively related to general support for nanotechnology?

Research Question 1-3. Will higher levels of knowledge about science in general be negatively related to perception of risks versus benefits of nanotechnology?

Research Question 1-4. Will higher levels of knowledge about nanotechnology be negatively related to perception of risks versus benefits of nanotechnology?

Affective Influences on Public Opinion

As some of the recent research on biotechnology and its applications has suggested, cognitive influences compete with various affective variables in their influences on public perceptions of new technology (e.g., Nisbet 2005; Priest 2001; Priest et al. 2003; Siegrist 1999, 2000). Specifically, people are often influenced by more affective aspects, such as concerns or fears, which are more a function of the potential severe outcomes or of the vividness of potential risks rather than of objectively quantifiable probabilities or expectations. Even though cognitions, such as levels of scientific knowledge and education, are related to public support for new technologies, they alone cannot fully explain the variations of public opinion on these issues.

There is a significant body of literature that has empirically examined these competing influences in greater detail (e.g., Fischhoff et al. 1981; Loewenstein et al. 2001). This line of research has shown that (1) affective processes often precede cognitive evaluations and (2) people's judgments about science and technology are sometimes based not on analytical judgment but on a general feeling about science and technology.

Expanding on this work, we are interested in the *simultaneous* effects that cognitive and affective influences have on public opinion toward nanotechnology. Specifically, our study focuses on two aspects of affective factors: *negative emotion toward nanotechnology* and *trust in scientists*. In addition, we include *negative emotion toward science in general*, assuming that people make judgments about specific technologies—at least in part—by relying on their past experiences of scientific breakthroughs.

Negative Emotions

How do negative emotions toward science, in general, and toward nanotechnology, more specifically, affect perceptions among the public with respect to risk- versus-benefit assessments and general support for nanotechnology? Across different studies in the area of risk-perception research, three different explanations emerge. The first explanation is provided by "risk-as-feeling" researchers (e.g., Loewenstein et al. 2001), who assume that affect, such as worry, fear, dread, or anxiety, experienced at the moment of decision making, can serve as an important cue or heuristic when assessing potential risks. In other words, emotional reactions to potential risks will often produce significantly different reactions than purely cognitive assessments of those risks. In fact, in many cases these emotional, rather than cognitive, assessments of risk drive behavior. The second explanation follows Schwarz and Clore's (1983) "affect-as-information hypothesis" (for an overview, see Clore, Schwarz, and Conway 1994). This approach draws on very different types of evidence to reach a similar conclusion. For example, Clore (1992) shows that people often use emotional responses, such as fondness or dislike, when forming judgments of others. Finally, a third group of scholars, often labeled "affect heuristic theorists," assume that affect plays an important role as a heuristic, that is, as a shortcut for information processing when citizens have to form judgments on the risks connected to new technologies (e.g., Finucane et al. 2000; Slovic, Flynn, and Layman 1991).

While not denying the important role that positive emotions play as a potential influence on public opinion, most previous research in the area of science and technology has identified negative emotions, such as fear or worry, as the key influence on public attitudes and perceptions (e.g., Alhakami and Slovic 1994; Finucane et al. 2000; Lerner and Keltner 2000; Loewenstein et al. 2001; Lopes 1987; Raghunathan and Pham 1999). For example, Savadori et al. (2004) note that dread is a factor that, for both experts and the general public, shapes people's perceptions of risks related to biotechnology applications. Finucane et al. and Lopes contend that worry or fear is negatively related to benefit perceptions and positively related to risk perceptions of risky technologies. Similarly, Raghunathan and Pham and Lerner and Keltner report that induced fear and anxiety are positively related to individuals' preference for low-risk and low-reward options. Most recently, Cobb and Macoubrie (2004) report that feelings of worry are positively related to the public's perceptions of risks versus benefits about nanotechnology.

We therefore put forth the following hypotheses:

Hypothesis 1-1: Higher levels of negative emotion toward science in general will be negatively related to general support for nanotechnology.

Hypothesis 1-2: Higher levels of negative emotion toward nanotechnology will be negatively related to general support for nanotechnology.

Hypothesis 1-3: Higher levels of negative emotion toward science in general will be positively related to perception of risks versus benefits of nanotechnology.

Hypothesis 1-4: Higher levels of negative emotion toward nanotechnology will be positively related to perception of risks versus benefits of nanotechnology.

Trust in Scientists

As outlined earlier, trust is another key aspect of affective reactions toward science and technology (Priest 2001; Priest, Bonfadelli, and Rusanen 2003). Along with negative emotions, trust can significantly influence both perception of risks versus benefits of new technologies and public acceptance of new technologies (Earle and Cvetkovich 1995; Priest 2001; Priest, Bonfadelli, and Rusanen 2003; Siegrist 1999, 2000; Siegrist, Cvetkovich, and Roth 2000). Specifically, Priest (1995) and Robbins (2001) argue that public trust in the management of technology-related risks can be more important than beliefs in the technology itself. These researchers suggest that trust in business leaders or government is therefore an important factor because it helps people reduce their subjective uncertainty and makes information processing more efficient.

Empirical tests of the relationship between different types of trust and public attitudes toward science and technology have focused on trust in laws and regulations, in institutions (such as businesses, government agencies, citizen groups, and scientists), and in information sources. Siegrist (2000), for instance, argues that trust in companies and their scientists who perform gene manipulations is related to public perceptions of benefits and risks, which ultimately influence public acceptance of gene technology. Priest (2001) also shows that judgments about the levels of risk associated with new technologies, such as bioengineered foods, are to a significant degree a function of judgments about the trustworthiness of scientists and their employers.

However, the previous studies in this area have been somewhat inconsistent with respect to the specific trust measures they used. Some studies have used social trust as a generic construct that has limited relevance to a specific area of science and technology. In particular, the construct of social trust combines different subdimensions of trust, and this combination may make it difficult to examine the specific role of trust in public decision making about new technologies (e.g., Sjoberg 1998). The conceptual vagueness in some previous studies is exacerbated by the fact that various kinds of trust can have different influences on perceptions of science and technology. For example, Trumbo and McComas (2003) found that higher credibility ratings for industry and state agencies are negatively related to risk perceptions, whereas higher credibility ratings for citizen groups are positively related to risk perceptions.

Second, despite the strong *assumptions* made in previous research about the potential effect that people's trust in scientists has on people's attitudes toward new technologies, empirical tests of these claims have been somewhat limited. That is, previous studies have paid more attention to other kinds of trust, such as trust in government or companies, than to trust in scientists or the science community. Research on nanotechnology is no exception. Cobb and Macoubrie (2004), for example, report that respondents' lack of trust in business leaders is positively related to perception of risks versus benefits of nanotechnology. To address this gap, our research expands on previous studies that concern the trust effect by addressing the relationship between a specific measure of trust in scientists and attitudes toward nanotechnology.

Therefore, we put forth the following set of hypotheses:

Hypothesis 2-1: Higher levels of trust in scientists will be positively related to general support for nanotechnology.

Hypothesis 2-2: Higher levels of trust in scientists will be negatively related to perception of risks versus benefits of nanotechnology.

Simultaneous Effects of Cognitions and Affect: An Integrated Model of Public Attitudes Toward Nanotechnology

As outlined earlier, even researchers examining the combined effects of cognitive and affective factors have modeled these effects as cumulative—that is, they focused on the net effects rather than on a potential *interaction* between the two factors. In this study, we explore public opinion formation relative to nanotechnology by examining in detail how knowledge and affect *interact* to affect public attitudes toward nanotechnology.

Our approach is very consistent with the larger trends in research on attitude formation and attitude change in social psychology. As a result of the "cognitive revolution" in this area, researchers have focused mainly on cognitive processes, while ignoring affective and motivational ones. Since the 1990s, however, the field has been characterized by a more integrative approach to social judgment and behavior, an approach that mirrors researchers' greater consideration for both affective and cognitive mechanisms and—more importantly—the interplay between the two. In this respect, our integrated model of scientific decision making is consistent with Eagly and Chaiken's (1993) "synergistic model," which emphasizes that affect and cognition operate "jointly to produce effects that are more attributable to their combination than to either one alone" (p. 423).

Similarly, scholars in social psychology have suggested different versions of dual information-processing models. Among others, the distinction between "analytical thinking" and "experiential thinking" (Epstein 1994) is directly relevant to our argument. The theory of two modes of thinking posits that, although analytical information processing is important in social judgment and decision making, experiential thinking, depending on affect and emotion, plays a potentially more significant role because "it provides a quicker, easier, and more efficient way to navigate in a complex, uncertain, and sometimes dangerous world" (Slovic et al. 2004, 313).

Particularly noteworthy, in this context, is the fact that the analytical thinking mode and the experiential thinking mode work in tandem, with each one depending on the other. This is consistent with our argument that cognitive and affective influences on public attitudes toward science do not work through isolated pathways but are interconnected and produce combined effects.

As we mentioned earlier, since most people have only limited knowledge of science and technology (Gregory and Miller 1998; Miller 1998, 2004) and certainly not enough to directly assess the risks and benefits associated with different technologies (Siegrist, Cvetkovich, and Roth 2000), they naturally depend on their feelings as heuristic or cognitive shortcuts in order to make decisions that compensate for the lack of information. Holtgrave and Weber (1993) and Slovic, Fischhoff, and Lichtenstein (1986) provide at least indirect evidence for this interactive influence of cognitions and affective factors. They show that, even though affect explained some variance in attitudinal outcomes (even after probabilistic assessments of a wide variety of risks are controlled for), a hybrid model combining affective factors and cognitive ones obtained the best fits.

On the basis of these theoretical considerations and the empirical evidence presented here, we put forth the following hypotheses:

Hypothesis 3-1: Knowledge about science in general and negative emotion toward science in general will have an interaction effect on both people's perceptions of risks versus benefits of nanotechnology and people's general support for nanotechnology.

Hypothesis 3-2: Knowledge about nanotechnology and negative emotion toward nanotechnology will have an interaction effect on both people's perceptions of risks versus benefits of nanotechnology and people's general support for nanotechnology.

Applying a similar logic, research on the simultaneous relationship between science knowledge and trust in the context of public attitudes toward biotechnology (e.g., Siegrist, Cvetkovich, and Roth 2000) suggests that trust has an enhanced effect if individuals lack science knowledge (e.g., Earle and Cvetkovich 1995). As outlined earlier, people's reactions to and attitudes toward new technologies are also often guided in part by the trust and confidence they have in scientists, companies, and government agencies (e.g., Priest 1995, 2001; Robbins 2001; Siegrist 1999, 2000). However, trust may play a stronger role when individuals lack the cognitive frameworks necessary to form a judgment (Priest, Bonfadelli, and Rusanen 2003; Siegrist and Cvetkovich 2000; Siegrist, Cvetkovich, and Roth 2000).

On the basis of this research, we put forth the following hypotheses:

Hypothesis 3-3: Knowledge about science in general and trust in scientists will have an interaction effect on both people's perceptions of risks versus benefits of nanotechnology and people's general support for nanotechnology.

Hypothesis 3-4: Knowledge about nanotechnology and trust in scientists will have an interaction effect on both people's perceptions of risks versus benefits of nanotechnology and people's general support for nanotechnology.

Methods

In the fall of 2004, we conducted a representative national telephone survey with a sample size of *N* = 706. The cooperation rate (based on standard definitions developed by the American Association for Public Opinion Research) was 43 percent (AAPOR definition CR-1). The survey was based on a carefully constructed probability sample that minimizes sampling and nonresponse biases. In this survey, we were particularly concerned about systematic nonresponse as a result of the scientific nature and novelty of the survey topic. In other words, it is possible that the people who chose to respond to our survey were overall more interested in nanotechnology and related issues and that people who were less aware or less interested in the issue refused to participate in the survey. This would not only skew our descriptive statistics but also potentially introduce biases into the multivariate relationships reported here. We therefore invested significant amounts of resources in multiple call-backs for noncontacts and initial refusals in order to minimize potential nonresponse due to the survey topic.

Dependent Measures

We tapped public attitudes toward nanotechnology using two separate outcome measures that are consistent with previous research: *general support for nanotechnology* and *perception of risks versus benefits of nanotechnology.*

We measured *general support for nanotechnology* by asking respondents to present themselves on a ten-point scale (1 = "not at all," 10 = "very much") that tapped respondents' agreement with the statement: "Overall, I support the use of nanotechnology" (M = 5.98, SD = 2.75).

We measured *perception of risks versus benefits of nanotechnology* by subtracting benefit perceptions of nanotechnology from risk perceptions of nanotechnology (M = -7.54, SD = 9.80). First, *risk perceptions of nanotechnology* was an additive index of four ten-point items, and these items measured the respondents' agreement with the statements: "Because of nanotechnology, we may lose more U.S. jobs," "Nanotechnology may lead to an arms race between the U.S. and other countries," "Nanotechnology may lead to the loss of personal privacy because of tiny new surveillance devices," and "Nanotechnology may lead to the uncontrollable spread of very tiny self-replicating robots" (Cronbach's alpha = .71, M = 18.89, SD = 8.58). Second, *benefit perceptions of nanotechnology* was an additive index of four ten-point items, and these items measured respondents' agreement with the statements: "Nanotechnology may lead to new and better ways to treat and detect human diseases," "Nanotechnology may help us develop increased national security and defensive capabilities," "Nanotechnology may lead to new and better ways to clean up the environment," and "Nanotechnology may give scientists the ability to improve human physical and mental abilities" (Cronbach's alpha = .81, M = 26.27, SD = 8.89).

It should be noted that our measure of *perception of risks versus benefits of nanotechnology* is different from similar measures used by other previous studies: "To what extent do you believe that the risks of scientific research outweigh its benefits?" This traditional measure is limited in two ways. First, a self-reported measure of risk and benefit assessments is likely susceptible to order effects, as some previous studies on public understanding of biotechnology suggest (e.g., Nisbet 2004). Responses may differ depending on which response option is given first: that is, whether "the benefits of scientific research outweigh its risks" or whether "the risks of scientific research outweigh its benefits." Second, our new measure provides an objective assessment of people's perceptions regarding risks versus benefits by not forcing respondents to make subjective calculations about the relative importance of risks and benefits for their own attitudes on the topic.

In sum, a risk-benefit self-assessment may be too vague a measure for respondents with little science knowledge to offer accurate or reliable answers. The measure proposed here—while using more questionnaire space—offers a more objective assessment of the relative importance of various risks and benefits and ultimately is a more reliable indicator of the construct.

Cognitive Variables

We measured two groups of cognitive variables: *knowledge about science in general* and *knowledge about nanotechnology*. First, *knowledge about science in general* was an additive index of seven dichotomous items asking respondents whether (1) lasers work by focusing sound waves; (2) the center of the earth is very hot; (3) antibiotics kill viruses as well as bacteria; (4) electrons are smaller than atoms; (5) all radioactivity is man-made; (6) which travels faster: light or sound?; and (7) the earth goes around the sun or the sun around the earth? (KR-20 = .58, M = 5.09, SD = 1.59).

Second, *knowledge about nanotechnology* was operationalized as an additive index of six dichotomous items asking respondents whether (1) nanotechnology involves materials that are not visible to the naked eye; (2) U.S. corporations are not using nanotechnology yet to make products sold today; (3) experts consider nanotechnology to be the next industrial revolution of the U.S. economy; (4) a nanometer is a billionth of a meter; (5) nanotechnology allows scientists to arrange molecules in a way that does NOT occur in nature; and (6) a nanometer is about the same size as an atom (KR-20 = .56, M = 3.90, SD = 1.55). Given the dichotomous nature of these scaled items, the low reliability for these two variables is certainly acceptable.

Affective Variables

To explore the affective factors influencing public perceptions of emerging science, we included three affective variables. First, *trust in scientists* was an additive index of three ten-point items that measured agreement with the statements: "Scientists know best what is good for the public," "It is important for scientists to get research done even if they upset people by doing it," and "Scientists should do what they think is best, even if they have to persuade people that it is right" (Cronbach's alpha = .65, M = 14.67, SD = 6.13).

We measured *negative emotion toward science in general* by asking respondents on a ten-point scale whether they feared the potential effects of scientific research (M = 3.79, SD = 2.82). Similarly, *negative emotion toward nanotechnology* was measured by asking respondents on a ten-point scale whether they were worried about nanotechnology (M = 3.09, SD = 2.52).

Other Antecedent Variables

We controlled for a number of exogenous variables. Specifically, we included age (M = 50.02, SD = 17.72), gender (58.5 percent females), formal education (median: some college education), income (median household income between $30,000 and $50,000), ethnicity (86.6 percent white), and level of religiosity. We measured level of religiosity by asking respondents on a ten-point scale (1 = "no guidance," 10 = "a great deal of guidance") how much guidance religion played in their everyday lives (M = 6.39, SD = 3.44). All these controls have been shown to have an impact on attitudes toward scientific risks (e.g., Brody 1984; Flynn, Slovic, and Mertz 1994; Johnson

2004; Pilisuk and Acredolo 1988; Siegrist 1998, 2000; Sparks, Shepherd, and Frewer 1994; Stallen and Thomas 1988; Vleeming 1985) and nanotechnology (e.g., Bainbridge 2002; Cobb and Macoubrie 2004).

Our regression models also included two groups of communication variables that have been shown to precede and to influence the relationship between cognitive and affective variables and public attitudes toward science (e.g., Durant, Evans, and Thomas 1992; Nelkin 1995; Nelkin and Lindee 1995; Nisbet et al. 2002; Shanahan and Morgan 1999). The first group of communication variables is labeled *public affairs media use* and includes sixteen ten-point items tapping frequency of exposure (1 = "not very often," 10 = "all the time") and ten ten-point items tapping attention (1 = "little attention," 10 = "very close attention"): (1) the frequency of TV use for international affairs, national government and politics, news about politics, the economy, and social issues in your area; (2) the attention to TV international affairs, TV national government and politics, TV news about politics, TV economy, and TV social issues in your area; (3) the frequency of newspaper use for international affairs, national government and politics, news about politics, the economy, and social issues in your area; (4) the attention to newspaper international affairs, newspaper national government and politics, newspaper news about politics, newspaper economy, and newspaper social issues in your area; and (5) the frequency of Web use for news about international affairs, news about national government and politics, news about politics, the economy, social issues in your area, and other educational purposes (Cronbach's alpha = .57, M = 69.24, SD = 35.18).

The second group of communication variables is labeled *science media use* and includes eight ten-point frequency items and four ten-point attention items: (1) the frequency of television use for stories related to science and technology and stories about specific scientific developments, such as nanotechnology; (2) the attention to television stories related to science and technology and television stories about specific scientific developments, such as nanotechnology; (3) the frequency of newspaper use for stories related to science and technology and stories about specific scientific developments, such as nanotechnology; (4) the attention to newspaper stories related to science and technology and newspaper stories about specific scientific developments, such as nanotechnology; (5) the frequency of Web use for information related to science and technology, information about specific scientific developments, such as nanotechnology, information about scientific studies in new areas of research, such as nanotechnology, and information about the investment and market potential of specific technologies (Cronbach's alpha = .64, M = 49.62, SD = 29.20).

Analytic Strategies

We used hierarchical ordinary least squares (OLS) regression models to examine each of the two dependent variables separately. The research hypotheses in this study also state expectations about interactive effects, or more specifically, contributory conditions. In order to test these interactive relationships in a multivariate model, we built a hierarchical regression that enters demographic and communication variables first, followed by the main effects of science knowledge, nanotechnology knowledge, trust in scientists, negative emotion toward science in general, and negative emotion toward nanotechnology, and, finally, by the interaction terms. Therefore, in the final blocks for each of the regressions predicting our two dependent variables, four multiplicative terms were included, tapping (1) the interaction between science knowledge and trust in scientists, (2) the interaction between science knowledge and negative emotion toward science in general, (3) the interaction between nanotechnology knowledge and trust in scientists, (4) and the interaction between nanotechnology knowledge and negative emotion toward nanotechnology. To avoid multicollinearity problems between the product terms and their components, we standardized the main effect variables by translating them into z-scores before we formed the interaction term (Cohen et al. 2003).

Results

To test our research questions and hypotheses concerning the impacts of knowledge and affect on public attitudes toward nanotechnology, we constructed hierarchical OLS models predicting each criterion variable separately. These analyses provide a stringent test of relationships between cognitions and affect and public attitude toward the emerging technology after considering the contributions of important demographic antecedents and media-use variables.

General Support for Nanotechnology

As indicated in Table 1, demographics and media-use variables accounted for a sizable amount of variance in general support for nanotechnology (18.7 percent). Interestingly, only science media use had a direct influence on general support for nanotechnology (as indicated in the significant beta in the final equation). In fact, the effects of formal education on general support for

TABLE 1
Hierarchical Multiple Regression Predicting General Support for Nanotechnology (standard regression coefficients)

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Block 1: Demographics					
Age	–.01	–.02	.00	.02	.02
Gender (male=1, female=2)	–.21***	–.16***	–.14***	–.13***	–.12***
Education	.13***	.06	.02	–.00	.01
Income	.06	.03	.02	.01	.01
Ethnicity (white=1, non-white=2)	–.01	–.03	–.01	.00	.00
Level of religiosity	–.09*	–.11**	–.10**	–.06	–.06
Incremental R^2(%)	9.8***				
Block 2: Media uses					
Public affairs media use		.07	.08	.06	.06
Science media use		.27***	.23***	.21***	.21***
Incremental R^2(%)		8.9***			
Block 3: Cognitions					
Knowledge about science			.11**	.12**	.11**
Knowledge about nanotech			.06	.04	.05
Incremental R^2(%)			1.4**		
Block 4: Affect					
Trust in scientists			.22***		.21***
Negative emotion toward science				.01	.01
Negative emotion toward nanotech				–.11**	–.11**
Incremental R^2(%)				6.0***	
Block 5: Interactions					
Knowledge about science*					
Trust in scientists					–.01
Knowledge about science*					–.05
Negative emotion toward science					
Knowledge about nanotech*					–.08*
Trust in scientists					
Knowledge about nanotech*					
Negative emotion toward nanotech					
Incremental R^2(%)					1.0
Total R^2(%)					27.1***

NOTE: $N = 706$. Cell entries are before-entry standardized regression coefficient for Block 5 and final standardized regression coefficients for Blocks 1, 2, 3, and 4.
*p <.05. **p <.01. ***p <.001

nanotechnology were largely mediated by science media use. Similarly, the effect of level of religiosity was mediated by affective variables, such as trust in scientists and negative emotion toward nanotechnology.

With respect to the main effects of cognitive and affective factors, we found significant positive links between knowledge about science in general and trust in scientists and general support for nanotechnology. Consistent with previous research (e.g., Cobb and Macoubrie 2004), negative emotion toward nanotechnology was negatively related to general support for nanotechnology, even after all other controls were entered in the model.

Most interesting was the result for knowledge about science in general. Unlike the previous studies that had found interactive effects between knowledge and trust (e.g., Earle and Cvetkovich 1995; Siegrist 1999; Siegrist and Cvetkovich 2000), we did not find an interaction between the two, failing to support hypotheses 3-3 and 3-4. Also, inconsistent with the findings of Priest and her colleagues (e.g., Priest 2001; Priest, Bonfadelli, and Rusanen 2003), our findings suggest that the effect of science knowledge was hardly attenuated by trust in scientists. With regard to the explanatory power of trust, however, trust in scientists seems to be a better predictor of general support for nanotechnology than science knowledge in our models.

Hypothesis 3-2 predicted that knowledge about nanotechnology and negative emotion toward nanotechnology will have a significant interaction effect on general support for nanotechnology as the criterion variable. Our data supported this hypothesis. As illustrated in Figure 1, knowledge about nanotechnology had a significantly stronger influence on general support for nanotechnology for respondents who displayed low levels of negative emotion toward nanotechnology than for respondents who displayed high levels of negative emotion toward nanotechnology. Overall, the regression model accounted for 27.1 percent of the variance.

Perception of Risks Versus Benefits of Nanotechnology

The coefficients for the demographics were similar to those in the previous model, with gender, education, and income being significantly related to perception of risks versus benefits of nanotechnology (see Table 2). In line with previous research on public perceptions of risk about emerging technologies, females showed a higher level of risk perceptions (e.g., Brody 1984; Pilisuk and Acredolo 1988; Siegrist 1998, 2000; Sparks, Shepherd, and Frewer 1994; Stallen and Thomas 1988; Vleeming 1985). Similar to the OLS model for general support for nanotechnology, the influences of religiosity were largely mediated by other affective variables in the model. Also, consistent with previous research, science media use had a negative and robust effect on perception of risks versus benefits (e.g., Durant, Evans, and Thomas 1992; Nelkin and Lindee 1995).

Knowledge about science in general and trust in scientists showed a negative relationship with risks-versus-benefits perceptions, whereas negative

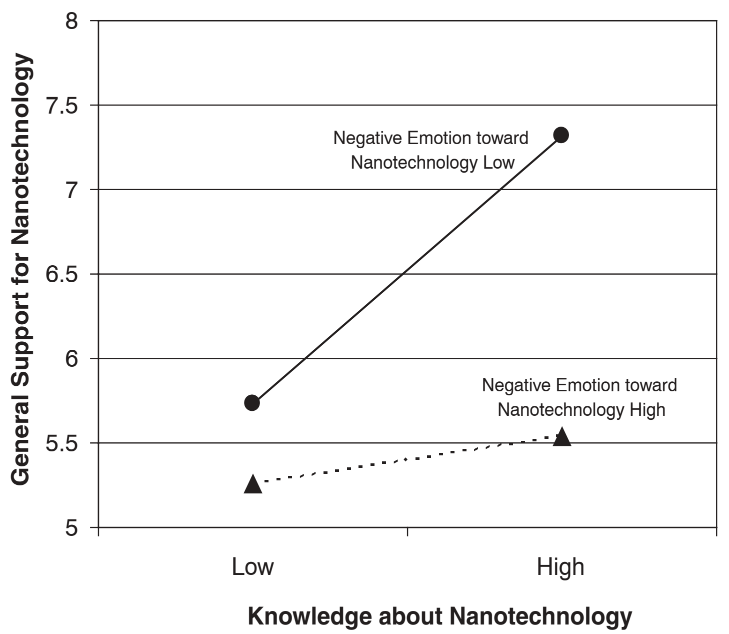

Figure 1: Predicting General Support for Nanotechnology: Moderating the Role of Negative Emotion toward Nanotechnology on Knowledge about Nanotechnology

NOTE: "Low knowledge about nanotechnology" represents the bottom 32.1% of respondents on the distribution of the knowledge-about-nanotechnology variable. "High knowledge about nanotechnology" represents the top 39.9 percent of respondents on the distribution of the knowledge-about-nanotechnology variable. Moreover, "Negative emotion toward nanotechnology low" represents the bottom 41.6 percent of respondents on the distribution of the negative-emotion-toward-nanotechnology variable. "Negative emotion toward nanotechnology high" represents the top 45.2 percent of respondents on the distribution of the negative-emotion-toward nanotechnology variable.

emotion was positively related. Confirming results from many previous studies, knowledge about science in general showed a negative link to perception of risks versus benefits (e.g., Bodmer 1985; Miller and Kimmel 2001; Miller, Pardo, and Niwa 1997). However, the relationships for affective variables were particularly interesting: (1) individuals who showed higher levels of trust in scientists were likely to perceive more benefits than risks, and (2) individuals who showed higher levels of negative emotion toward nanotechnology were likely to perceive more risks than benefits.

While there was a main effect between negative emotion toward nanotechnology and perception of risks versus benefits of nanotechnology (• = .25), the interaction between negative emotion toward nanotechnology and

TABLE 2
Hierarchical Multiple Regression Predicting Perception of Risks versus Benefits of Nanotechnology (standardized regression coefficients)

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Block 1: Demographics					
Age	.02	.02	–.02	–.04	–.04
Gender (male=1, female=2)	.17***	.15***	.13***	.10**	.10**
Education	–.21***	–.19***	–.15***	–.11**	–.12**
Income	–.13***	–.12***	–.11**	–.10*	–.08*
Ethnicity (white=1, non-white=2)	.07	.08*	.06	.02	.02
Level of religiosity	.09*	.10**	.09*	.02	.03
Incremental R^2(%)	15.4***				
Block 2: Media uses					
Public affairs media use		.04	.04	.04	.04
Science media use		–.15**	–.12*	–.11*	–.10*
Incremental R^2(%)		1.4**			
Block 3: Cognitions					
Knowledge about science			–.11**	–.11**	–.11**
Knowledge about nanotech			–.02	–.03	–.02
Incremental R^2(%)			1.0*		
Block 4: Affect					
Trust in scientists				–.18***	–.18***
Negative emotion toward science				.09**	.09**
Negative emotion toward nanotech				.24***	.25***
Incremental R^2(%)				11.0***	
Block 5: Interactions					
Knowledge about science* Trust in scientists					–.00
Knowledge about science* Negative emotion toward					.02
Knowledge about nanotech* Trust in scientists					.03
Knowledge about nanotech* Negative emotion toward nanotech					.07*
Incremental R^2(%)					.6
Total R^2(%)					29.4***

NOTE: *N* = 706. Cell entries are before-entry standardized regression coefficient for Block 5 and final standardized regression coefficients for Blocks 1, 2, 3, and 4. (2)
**p* <.05. ***p* < .01. ****p* < .001

knowledge about nanotechnology was also significant (• = .07). This suggests that knowledge about nanotechnology had a significantly stronger effect on risks-versus-benefits perceptions if individuals also had low levels of negative emotion toward nanotechnology (see Figure 2). In total, the regression model accounted for almost 30 percent of the variance.

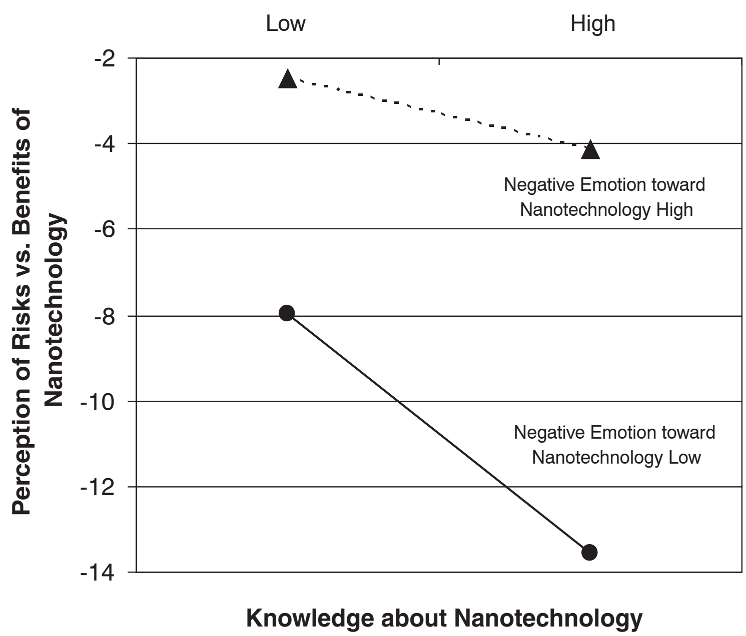

Figure 2: Predicting Perception of Risks Versus Benefits of Nanotechnology: Moderating the Role of Negative Emotion Toward Nanotechnology on Knowledge About Nanotechnology

NOTE:"Low knowledge about nanotechnology" represents the bottom 32.1 percent of respondents on the distribution of the knowledge-about-nanotechnology variable. "High knowledge about nanotechnology" represents the top 39.9 percent. Moreover, "Negative emotion toward nanotechnology low" represents the bottom 41.6 percent of respondents on the distribution of the negative-emotion-toward-nanotechnology variable. "Negative emotion toward nanotechnology high" represents the top 45.2 percent.

Discussion

As outlined earlier, previous research has identified a number of factors that explain the differences in perceptions of risks connected with various emerging technologies. Over the last two decades, the field has moved from a narrow focus on scientific literacy toward a broader focus that includes affective variables, such as negative emotions and trust, as alternative explanations. In this study, we examined the *interactive* effects of knowledge and affect on people's attitudes toward nanotechnology. In particular, we were interested in finding out how the influences of cognitive variables differ, depending on various affective reactions to new technologies.

Theoretically, people's gut reactions, or emotional responses, toward science and technology can be expected to have a significant impact on their attitudes toward these issues. This is, in part, a function of directing people's attention to certain aspects of scientific research or of leading them to selectively seek information consistent with their initial feelings, and thus preventing them from making analytical judgments about technology-related hazards, potentially caused by emerging technology (Slovic et al. 2004).

Empirically, however, there has been little research that has tested these simultaneous influences of cognitive and affective variables on public attitudes toward science and technology. Our study provides this test in the context of nanotechnology. We examined how knowledge about science or nanotechnology and affect interact with each other in the shaping of public attitudes toward nanotechnology.

Some Comments About Our Data

Our study utilized a national survey data set collected in fall 2004. This raises two issues that should be addressed at least briefly. First, our measures of negative emotion toward science in general and negative emotion toward nanotechnology are single-item variables. Single-item measures, of course, do not allow us to control for random measurement error, and we can, therefore, make no statement about the potential unreliability of this measure. It is reasonable to assume, however, that any potential random error in this measure would, in fact, *attenuate* the relationships reported here. In other words, the relationships identified in our OLS models would probably be stronger if we had been able to use multi-item measures of emotional responses to nanotechnology.

Second, we measured only trust in scientists and did not consider other kinds of trust. As outlined earlier, previous research has found differential effects on attitudes, depending on the type of trust that was examined. Many of these different types of trust were not available in our data set.

However, these potential limitations may be less a problem than they initially seem. Most important was that, according to our findings, we likely developed a set of robust, valid measures that, from a construct-validity perspective, are consistent with previous operationalizations. Our findings about the effects of cognitive and affective variables fit strongly with previous research in each area. And, as argued earlier, stronger and more reliable multi-item measures of cognitive and affective variables would likely *increase* rather than *decrease* the effect size in our study. Nonetheless, future research should continue to explore the effects that different aspects of both cognitions and affect have on public attitudes toward science and technology. In particular, among the elements of trust that need to be investigated are constructs that assess not just individual trust but also collective or socially mediated trust judgments.

Public Attitudes Toward Nanotechnology

With these considerations in mind, our study provided very important insights into the interactive influences of cognitive and affective variables on public attitudes toward emerging technologies. Consistent with the traditional cognitive approach, we found that people use their knowledge about science in general in order to evaluate the possible risks versus benefits of nanotechnology and to decide whether they support nanotechnology or not. Also, affective variables, such as negative emotion toward science in general and negative emotion toward nanotechnology, serve as important heuristic cues for risks-versus-benefits judgments and for general attitudes toward nanotechnology.

Three findings need to be highlighted in this context. First, affective variables played an important role in the shaping of perception of risks versus benefits of nanotechnology and of general attitudes toward nanotechnology. The significant main effects of trust in scientists and negative emotion toward nanotechnology suggest that these affective variables serve as important heuristics, regardless of people's level of knowledge about science in general or about nanotechnology. In other words, we found significant main effects for both of the variables, even after controlling for all the other variables in our OLS models. This is consistent with the findings from previous research that both experts and laypeople rely on affect heuristics in making risk decisions (Savadori et al. 2004). This might be due to the fact that the two thinking modes outlined earlier—analytical thinking and experiential thinking—are working not independently from each other but simultaneously (Epstein 1994; Slovic et al. 2004).

Second, we failed to find a main effect that knowledge about nanotechnology would have on both general support for nanotechnology and perception of risks versus benefits of nanotechnology. This may be due to the early stage of the issue cycle that nanotechnology is in (for an overview, see Nisbet, Brossard, and Kroepsch 2003). Nanotechnology knowledge levels among the general public are still reasonably low and mass media discuss the issue mostly in terms of economic benefits and scientific merits (Gaskell et al. 2004; Lewenstein, Gorss, and Radin 2005; Scheufele and Lewenstein, forthcoming). Accordingly, audiences rely on the heuristics provided by mass media rather than on nanotechnology knowledge that they simply do not have at this point.

Third, our study found that risk perceptions of nanotechnology were positively correlated with benefit perceptions of nanotechnology. This is inconsistent with some previous studies that reported an inverse relationship between risk perceptions and benefit perceptions (e.g., Alhakami and Slovic 1994; Siegrist 1999, 2000; Siegrist and Cvetkovich 2000; Siegrist, Cvetkovich, and Roth 2000).

Why is that? There are a number of explanations for this finding. First, it is reasonable to assume that people tend to perceive emerging technologies in their early stages of development in a fairly balanced manner by considering their benefits as well as their risks. While citizens are concerned about nanotechnology-related risks in the early stages of its development, they obviously also see the huge potential benefits of this new technology, leading to a positive correlation between the two.

The second explanation is based on the idea of issue cycles. As the issue develops, it will enter the political agenda where different political players will struggle to highlight the benefits over the risks or vice versa. At this stage, citizens will make a decision about whether they agree with the technology or not by paying selective attention to its positive or negative aspects, perhaps in part because of preexisting political allegiances or other social factors. As a result, we will see more and more of a negative correlation between risk perceptions and benefit perceptions as nanotechnology moves through the issue cycle. Yet, the debate about nanotechnology has, for the most part, not moved beyond the administrative policy arena at this point.

The Moderating Role of Negative Emotion Toward Nanotechnology

The most important contribution of our study is the examination of the *simultaneous* effects of cognitive and affective variables on public attitudes toward nanotechnology. As outlined earlier, we found a significant interaction between knowledge about nanotechnology and negative emotion toward nanotechnology for both of the criterion variables: general support for nanotechnology and perception of risks versus benefits of nanotechnology. That is, the key assumption behind the science literacy model—that people will be more open toward new technologies if they know more about them—holds only for respondents whose cognitive considerations are not overridden by emotional heuristics.[2]

TABLE 3
Predicting Negative Emotion toward Nanotechnology

	Negative Emotion toward Nanotech
Age	.10*
Gender (male=1, female=2)	.09*
Education	–.04
Income	–.07
Ethnicity (white=1, non-white=2)	.08*
Level of religiosity	.04
Media use for public affairs	.03
Media use for science	.01
Knowledge about science	.00
Knowledge about nanotech	.05
Negative emotion toward science	.28***
Negative emotion toward nanotech	—
Total R^2 (%)	41.4***

NOTE: *N* = 706. Cell entries are final standardized regression coefficients.
**p* <.05. ***p* <.01. ****p* <.001

This, of course, has important implications for how we think about public decision making about emerging technologies. Good examples are public meetings on technological issues and their implications for communities. Our findings suggest that the influence of new information on attitudes toward nanotechnology may be minimal if people rely on strong emotional heuristics to process this information. That raises the question of how useful public meetings really are, given that they are often attended by citizens who have strong positive or negative feelings toward the issue in the first place (McComas 2001). Our findings, therefore, suggest that the deliberative exchange of information may really have minimal effects on these people because of their prior strong emotional reactions to the issue. This point also highlights the importance of well-planned and moderated consensus conferences or “Citizens’ Technology Forums” (e.g., Macoubrie 2002) that maximize the range of viewpoints represented and also control the emotional involvement of the participants in the issue.

This leaves us with one important question: Where does this negative emotion toward nanotechnology come from? To be more specific, who are the people for whom their strong affective responses minimize the knowledge-attitude link? We conducted an additional OLS analysis, shown in Table 3. Age, gender, and ethnicity showed a significant relationship to negative emotion toward nanotechnology. That is, older people, females, and ethnic minorities were more likely to feel negative toward nanotechnology. This finding is very consistent with the previous studies about the effects of demographic variables on public perceptions of and attitudes toward technology-related issues, highlighting the importance of demographically defined social groups in the creation of public perceptions and attitudes. Furthermore, Table 3 shows a strong link between negative emotion toward science in general and negative emotion toward nanotechnology. In other words, people's emotional reactions to nanotechnology as one of the most recent technological breakthroughs seem to be at least, in part, influenced by their experiences with and perceptions of previous scientific controversies. This finding clearly shows the importance of effective public communication and public involvement in scientific decision making. Recent controversies, such as the ones surrounding genetically modified organisms or stem cells, have certainly shaped some long-lasting affective responses toward the scientific establishment among the public. As our analyses show, these emotional responses may spill over into new issue realms, such as nanotechnology, and may ultimately prevent informed decision making among parts of the American public. Effective public communication and outreach on the part of scientists and governmental agencies, therefore, are more important than ever.

References

Alhakami, A. S., and P. Slovic. 1994. A psychological study of the inverse relationship between perceived risk and perceived benefits. *Risk Analysis* 14: 1085–1096.

Bainbridge, W. S. 2002. Public attitudes toward nanotechnology. *Journal of Nanoparticle Research* 4: 561–570.

Bodmer, W. 1985. *The public understanding of science*. London: Royal Society.

Brody, C. J. 1984. Differences by sex in support for nuclear power. *Social Forces* 63: 209–228.

Brossard, D., B. Lewenstein, and R. Bonney. 2005. Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education* 27 (9): 1099–1121.

Clore, G. L. 1992. Cognitive phenomenology: Feelings and the construction of judgment. In *The construction of social judgments*, edited by L. L. Martin and A. Tesser, 133–163. Hillsdale, NJ: Lawrence Erlbaum Associates.

Clore, G. L., N. Schwarz, and M. Conway. 1994. Affective causes and consequences of social information processing. In *Handbook of social cognition*, *Vol. 1*, edited by R. S. Wyer and T. K. Srull, 323–417. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cobb, M., and J. Macoubrie. 2004. Public perceptions about nanotechnology: Risks, benefits, and trust. *Journal of Nanoparticle Research: An Interdisciplinary Forum for Nanoscale Science and Technology* 6 (4): 395–405.

Cohen, J., P. Cohen, S. G. West, and L. S. Aiken. 2003. *Applied multiple regression/correlation analysis for the behavioral sciences. 3d ed. Hillsdale, NJ: Lawrence Erlbaum Associates.*

Dawkins, R. 1998. *Unweaving the rainbow*. Boston: Houghton Mifflin.

Durant, J., G. Evans, and G. Thomas. 1992. Public understanding of science in Britain: The role of medicine in the popular representation of science. *Public Understanding of Science* 1:161–182.

Eagly, A. H., and S. Chaiken. 1993. *The psychology of attitudes*. Belmont, CA: Wadsworth.

Earle, T. C., and G. T. Cvetkovich. 1995. *Social trust: Toward a cosmopolitan society.* Westport, CT: Praeger.

Epstein, S. 1994. Integration of the cognitive and the psychodynamic unconscious. *American Psychologist* 49:709–724.

Eysenck, M. W. 1992. *Anxiety: The cognitive perspective*. Hove, England: Lawrence Erlbaum Associates.

Finucane, M. L., A. S. Alhakami, P. Slovic, and S. M. Johnson. 2000. The affect heuristic in judgments of risks and benefits. *Journal of Behavioral Decision Making* 13:1–17.

Fischhoff, B., S. Lichtenstein, P. Slovic, S. L. Derby, and R. L. Keeney. 1981. *Acceptable risk*. Cambridge, England: Cambridge University Press.

Fiske, S. T., and S. E. Taylor. 1991. *Social cognition*. 2d ed. New York:McGraw-Hill.

Flynn, J. H., P. Slovic, and C. K. Mertz. 1994. Gender, race, and perception of environmental health risks. *Risk Analysis* 14(6): 1101–1108.

Gaskell, G., T. Ten Eyck, J. Jackson, and G. Veltri. 2004. Public attitudes to nanotechnology in Europe and the United States. *Nature Materials* 3(8): 496.

Gregory, J., and S. Miller. 1998. *Science in public: Communication, culture, and credibility.* New York and London: Plenum Press.

Holtgrave, D., and E. U. Weber. 1993. Dimensions of risk perception for financial and health-and-safety risks. *Risk Analysis* 13:553–558.

Hornig, S. 1993. Reading risk: Public responses to print media accounts of technological risk. *Public Understanding of Science* 2:95–109.

Izard, C. E. 1977. *Human emotions*. New York: Plenum Press.

Johnson, B. B. 2004. Arguments for testing ethnic identity and acculturation as factors in risk judgments. *Risk Analysis* 24(5): 1279–1287.

Lerner, J. S., and D. Keltner. 2000. Beyond valence: Toward a model of emotion-specific influences on judgment and choice. *Cognition and Emotion* 14: 473–494.

Lewenstein, B. V., J. Gorss, and J. Radin. 2005. The salience of small: Nanotechnology coverage in the American press, 1986–2004. Paper presented at the annual convention of the International Communication Association, New York, May.

Loewenstein, G. F., E. U. Weber, C. K. Hsee, and E. S. Welch. 2001. Risk as feelings. *Psychological Bulletin* 127(2): 267–286.

Lopes, L. L. 1987. Between hope and fear: The psychology of risk. In *Advances in experimental social psychology, Vol. 20*, edited by L. Berkowitz, 255–295. San Diego, CA: Academic Press.

Macoubrie, J. 2002. True deliberation in technology mediated group communication. Paper presented at the International Symposium on Technology and Society: Social Implications of Information and Communication Technology, Raleigh, NC, June.

McComas, K. A. 2001. Public meetings about local waste management problems: Comparing participants to non-participants. *Environmental Management* 27(1): 135–147.

Miller, J. D. 1987. *Scientific literacy in the United States: Communicating science to the public*. New York: John Wiley.

———. 1995. Scientific literacy for effective citizenship. In *Science/technology/society as reform in science education*, edited by R. E. Yager, 185–204. New York: State University of New York Press.

———. 1998. The measurement of civic scientific literacy. *Public Understanding of Science* 7: 203–223.

———. 2004. Public understanding of, and attitudes toward, scientific research: What we know and what we need to know. *Public Understanding of Science* 13:273–294.

Miller, J. D., and L. Kimmel. 2001. *Biomedical communications: Purposes, audiences, and strategies*. New York: John Wiley.

Miller, J. D., and R. Pardo. 2000. Civic scientific literacy and attitude to science and technology: A comparative analysis of the European Union, the United States, Japan, and Canada. In *Between understanding and trust: The public, science, and technology,* edited by M. Dierkes and C. von Grote, 81–129. Amsterdam: Harwood Academic Publishers.

Miller, J. D., R. Pardo, and F. Niwa. 1997. *Public perceptions of science and technology: A comparative study of the European Union, the United States, Japan, and Canada*. Madrid: BBV Foundation.

Nelkin, D. 1995. *Selling science: How the press covers science and technology.* New York: W. H. Freeman.

Nelkin, D., and S. M. Lindee. 1995. *The DNA mystique: The gene as a cultural icon*. New York: W. H. Freeman.

Nisbet, M. C. 2004. The polls-trends: Public opinion about stem cell research and human cloning. *Public Opinion Quarterly* 68(1): 131–154.

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., D. Brossard, and A. Kroepsch. 2003. Framing science: The stem cell controversy in an age of press/politics. *The Harvard International Journal of Press/Politics* 8(2): 36–70.

Nisbet, M. C., D. A. Scheufele, J. Shanahan, P. Moy, D. Brossard, and B. V. Lewenstein. 2002. Knowledge, reservation, or promise? A media effects model for public perceptions of science and technology. *Communication Research* 29(5): 584–608.

Pilisuk, M., and C. Acredolo. 1988. Fear of technological hazards: One concern or many? *Social Behavior* 3:17–24.

Priest, S. H. 1995. Information equity, public understanding of science and the biotechnology debate. *Journal of Communication* 45(1): 39–54.

Priest, S. H. 2001. Misplaced faith: Communication variables as predictors of encouragement for biotechnology development. *Science Communication* 23(2): 97–110.

Priest, S. H., H. Bonfadelli, and M. Rusanen. 2003. The "trust gap" hypothesis: Predicting support for biotechnology across national cultures as functions of trust in actors. *Risk Analysis* 23(4): 751–766.

Raghunathan, R., and M. T. Pham. 1999. All negative moods are not equal: Motivational influences of anxiety and sadness on decision making. *Organizational Behavior and Human Decision Processes* 79:56–77.

Robbins, R. 2001. Overburdening risk: Policy frameworks and the public uptake of gene technology debate. *Public Understanding of Science* 10:19–36.

Roco, M. C., and W. S. Bainbridge, eds. 2001. *Societal implications of nanoscience and nanotechnology.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Savadori, L., S. Savio, E. Nicotra, R. Rumiati, M. L. Finucane, and P. Slovic. 2004. Expert and public perception of risk from biotechnology. *Risk Analysis* 24:1289–1299.

Scheufele, D. A., and B. Lewenstein. Forthcoming. The public and nanotechnology: How citizens make sense of emerging technologies. *Journal of Nanoparticle Research*.

Schwarz, N., and G. L. Clore. 1983. Mood, misattribution, and judgments of well-being: Information and directive functions of affective states. *Journal of Personality and Social Psychology* 45: 513–523.

Shanahan, J., and M. Morgan. 1999. *Television and its viewers: Cultivation theory and research*. Cambridge, UK: Cambridge University Press.

Shen, B. S. P. 1975. Science literacy and the public understanding of science. In *Communication of scientific information*, edited by S. B. Day, 44–52. Basel: Karger.

Siegrist, M. 1998. Belief in gene technology: The influence of environmental attitudes and gender. *Personality and Individual Differences* 24: 861–866.

———. 1999. A causal model explaining the perception and acceptance of gene technology. *Journal of Applied Social Psychology* 29:2093–2106.

———. 2000. The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis* 20:195–203.

Siegrist, M., and G. T. Cvetkovich. 2000. Perception of hazards: The role of social trust and knowledge. *Risk Analysis* 20:713–719.

Siegrist, M., G. T. Cvetkovich, and C. Roth. 2000. Salient value similarity, social trust, and risk/benefit perception. *Risk Analysis* 20:353–362.

Sjoberg, L. 1998. Risk perception: Expert and the public. *European Psychologist* 3:1–12.

Slovic, P., M. L. Finucane, E. Peters, and D. G. MacGregor. 2004. Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Analysis* 24(2): 311–322.

Slovic, P., B. Fischhoff, and S. Lichtenstein. 1986. The psychometric study of risk perception. In *Risk evaluation and management*, edited by V. T. Covello, J. Menkes, and J. Mumpower, 3–24. New York: Plenum Press.

Slovic, P., J. H. Flynn, and M. Layman. 1991. Perceived risk, trust, and the politics of nuclear waste. *Science* 254:1603–1607.

Sparks, P., R. Shepherd, and L. J. Frewer. 1994. Gene technology, food production, and public opinion: A UK study. *Agricultural and Human Values* 11:19–28.

Stallen, P. J. M., and A. Thomas. 1988. Public concern about industrial hazards. *Risk Analysis* 8:237–245.

Sturgis, P., H. Cooper, and C. Fife-Schaw. 2005. Attitudes to biotechnology: Estimating the opinions of a better-informed public. *New Genetics and Society* 24(1): 31–56.

Tomkins, S. S. 1981. The quest for primary motives: Biography and autobiography of an idea. *Journal of Personality and Social Psychology* 41:306–329.

Trumbo, C. W., and K. A. McComas. 2003. The function of credibility in information processing for risk perception. *Risk Analysis* 23(2): 343–353.

Vleeming, R. G. 1985. Factors affecting attitudes toward nuclear power in the Netherlands. *Journal of Social Psychology* 125:119–125.

Wildavsky, A., and K. Dake. 1990. Theories of risk perception: Who fears what and why? *Daedalus* 119:41–50.

Zajonc, R. 1980. Feeling and thinking: Preference needs no inferences. *American Psychologist* 35: 151–175.

Notes

1. We adopted the definition of "affect" outlined by Fiske and Taylor (1991) to refer loosely to a variety of emotions. However, "affect" has often been used more restrictively in psychological literature (e.g., Izard 1977; Tomkins 1981; Zajonc 1980). For example, Zajonc argues that affect, while encompassing such concepts as preferences and feelings, excludes specific emotions, such as surprise, anger, and guilt.

2. It is possible that a third variable, such as education, affects the interactive effects between knowledge and negative emotion. It could be assumed that the moderating effects of emotional factors work only for people with lower levels of education, but not for highly educated respondents. When we tested this assumption empirically, however, we did not find a significant three-way interaction between knowledge, negative emotion, and education.

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