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Knowledge, Reservations, or Promise?

A Media Effects Model for Public Perceptions of Science and Technology

This study introduces a media effects model specific to public perceptions of science and technology. Analysis of the National Science Board's Science and Engineering Indicators Survey provides evidence that different media—newspapers, general television, science television, and science magazines—do affect perceptions differently. These media effects are direct but also indirect, as mediated through effects on science knowledge. Although newspaper reading, science television viewing, and science magazine reading all promote positive perceptions of science, given the relative size of its audience, the impact of general television viewing remains the most compelling finding. The negative images of science on television appear to cultivate scientific reservations, whereas television's portrayal of science as sometimes omnipotent, and offering hope for the future, appears to also promote a competing schema related to the promise of science. Television's direct effect on reservations is reinforced through the medium's negative relationship with science knowledge.

The popular television series *The X-Files* features a Holmes and Watson duo of FBI detectives. Fox Mulder is a credulous Oxford-trained parapsychologist, and Dana Scully is a skeptical medical doctor with a background in physics. Mulder and Scully's cases, derived from a filing cabinet collection of leads designated "X" for "unexplained," takes them to the border of reality. From psychic phenomena to genetic mutation to alien abduction, examples

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of the paranormal reveal themselves in each episode, never to be wholly believed, captured, quantified, or proven.

The themes of the internationally syndicated television series have not escaped the watchful eyes of the science community. *The X-Files* has been characterized by prominent scientists and other critics as the latest example of entertainment television's continual depiction of science as failing and as incapable of offering satisfactory scientific explanations for extraordinary occurrences, as well as depicting rational and scientific efforts as subordinate to mystical speculation (Dawkins, 1998a).

Other examples of entertainment television programming also trouble scientists. In one instance, Lawrence M. Krauss, chair of the Physics Department at Case Western Reserve University, contributed an opinion-editorial to *The New York Times* in February 1999 that protested NBC's airing of the 2-hour television special "Confirmation: The Hard Evidence of Aliens Among Us?" Krauss (1999) criticized the producers of the special and the television network for blurring the lines between news and entertainment and for adopting a "pretense of journalistic integrity to promote alien abduction claims by interested parties" (p. A17). According to Krauss, NBC's actions highlighted the state of scant scientific literacy among the American public and the absence of a public ability to distinguish "charlatans from honest researchers."

Not all, however, agree with this characterization of the media. Well-known media producers respond that sensationalistic, inaccurate, and negative portrayals of science are inevitable and that they are merely part of the nature of popular fiction (Crichton, 1999). They also insist that their products are harmless (Carter, 1997). The editors of the journal *Nature* have contended that more troubling than dramatizations that distort science are media productions that dogmatically promote scientists and science "as truth's ultimate custodian" ("How Not to Respond to *The X-Files*," 1998, p. 815).

Although debate over the influence of dramatized depictions of science in television and film has been heated and visible, there is among the general scientific community as much, or perhaps even greater, concern over the influence of news reporting and other media on public attitudes toward science. In one survey, more than 75% of scientists believed that the media, when covering science, are more interested in sensationalism than truth; that media coverage concentrates too much on trendy discoveries rather than basic research and development; and that the media exaggerate risks, unduly alarming the public (Hartz & Chappell, 1997).

In summary, central to these criticisms of the media is the common assumption that the media foster negative perceptions of science and technology and that the public, because of a widespread lack of science literacy, is relatively defenseless to the media's influence. Despite these strong assertions, research in the social sciences has paid little attention to the relationship between media use and public perceptions of science and technology (Lewenstein, 1995b). To redress this gap, we present here a media effects model for science and technology. Specifically, we examine associations between media use and perceptions of science and technology across media channels, including general television viewing, general newspaper use, and different forms of science media. Within our media effects model, we highlight two links between different types of media use and perceptions: (a) media's direct association with perceptions of science and technology derived from content and (b) media's indirect association with perceptions of science and technology through media's relationship with science knowledge.

The Role of Media Content in Shaping Perceptions of Science

Concerns over media's role in promoting negative perceptions of science and technology have generated at least two major areas of research relevant to this study. The areas include (a) images of science, technology, and scientists in the media and (b) media effects on public perceptions of science and technology.

Images of scientists and science. How are scientists and science depicted in entertainment media? Although entertainment media do not present one common or unified description of the scientist, there are several representations or "clusters" of images that are seen across time period, medium, and genre. One commonly seen role for the scientist is that of an evil and violent figure, outside the rules of normal society. The sinister scientist is seen as socially irresponsible and mentally unstable (Basalla, 1976). These dangerous characters will kill if necessary (Lewenstein, 1989) but are ultimately headed for failure (Gerbner, Gross, Morgan, & Signorelli, 1981). This is the image of scientist as "Frankenstein," seen many times since the character was introduced by Mary Shelley in 1818. Most recently, the connection of evil science to occult phenomena, as in television programs such as *The X-Files*, disseminates this science-gone-awry perception to a very wide audience.

On the other hand, scientists are sometimes portrayed as "powerless" (Goldman, 1989). These individuals are easily manipulated or dominated (Basalla, 1976) and seen as pawns doing the dirty work for either big business or the military (Shortland, 1988). These stereotypes of scientists can be seen in movies such as *The China Syndrome* and *Silkwood*.

Several common images of scientists highlight the degree to which they differ from other people. Many depictions of scientists show them as eccentric and antisocial (Long & Steinke, 1996) and being so dedicated that they will spend most of a day at work (Basalla, 1976; Nelkin, 1995). This person is shown as deviating from the norm in dress and actions. This "geek" image is a very powerful and common one, epitomized in popular movies such as *Back to the Future*.

As part of the separation from the general public, scientists are also portrayed as an elite and privileged group (Long & Steinke, 1996), wearing white lab coats or suits to differentiate themselves (Shortland, 1988). It is their job to explain science, and so they are seen as having the answer to all the questions (Hornig, 1990). Thus, the separation of scientist from the public results in the portrayal of scientists as "priests."

Long and Steinke (1996) found that science in general is often depicted as mysterious, magical, or dangerous. In this context, it is the job of the scientist to construct, explain, and at least try to rationalize the mysteries of the world (Hornig, 1990). Oftentimes, scientists lose control of their research or their technology, to the detriment of society (Basalla, 1976). As such, scientific achievement and technology are distrusted because of possible unforeseen ramifications. Yet Long and Steinke also found instances where science and technology were shown as truthful, or as a solution to problems. Science is shown as a sacred field for which it is necessary to have qualified individuals as guides (Hornig, 1990). Relatedly, science and technology are seen as important weapons for solving problems (Nelkin, 1995). In these cases, the media portray scientists as having the ability to use science and technology to overcome social problems and to improve life.

Gerbner, Gross, Morgan, and Signorelli (1981, 1985) reported that entertainment television disseminates a full range of familiar and conflicting cultural myths of science and technology as weird and frightening; omnipotent but dangerous; always progressing boundlessly but out of control; offering hope for the future, or even salvation; but also perhaps society's annihilation. With similar complexity, scientists are shown as being important "authorities," yet working alone, socially isolated, very smart, often mad, and sometimes evil. Compared to other fictional professionals, more of them are of foreign (non-U.S.) nationality (which contributes to their "strangeness"), and they have a far higher failure rate. These studies found that proportionally more scientists are killed than any other occupational group featured on television—perhaps as a penalty for uncovering secrets better kept locked away or by their own investigations run amok (Shanahan & Morgan, 1999).

Obviously, previous research on the depiction of science and scientists on television or in film paints a somewhat self-contradicting picture. Science, technology, and scientists are sometimes depicted as malevolent and sometimes as powerful forces for good. What is clear is that when science and scientists do appear, they tend to be shown as unusual, whether in positive or negative ways. The implication is that science is not "common knowledge."

News Media, Entertainment Media, and Perceptions of Science

If the public is receiving inconsistent messages about science and technology across the media, then the likelihood that public perceptions will be influenced differentially across media channel and media content increases. How then do people (including media audiences) perceive science and technology? Relatedly, what does previous research suggest about how media are associated with these perceptions?

As early as 1963, Davis, in a study concerning the public's image of scientists, found that respondents held scientists in high regard. Scientists were described as intelligent, educated, and dedicated. Many thought that scientists were interested in discovery, derived satisfaction from work, and were concerned with the social value of their studies. Most respondents indicated that the world is better off due to science because of health improvements, a higher standard of living, and technological advancements.

Studies examining the image of science for teenagers and children also have found that both groups see scientists as good (Mead & Metraux, 1957; Potts & Martinez, 1994). High school students believe that scientists are essential, brilliant, and dedicated. In addition, respondents maintain that science is a source of unlimited power (Potts & Martinez, 1994).

Currently, the best available national assessment of American attitudes toward science and technology is the National Science Board's (NSB's) Science and Engineering Indicators Survey, conducted approximately every 2 years since 1979. The principal investigator for this project, Jon D. Miller, has previously identified two distinct attitude constructs related to science and technology emerging from this data (for an overview, see Miller, Pardo, & Niwa, 1997). The first attitude construct reflects "reservations concerning science and technology," reflecting concerns about the speed of change in modern life and a sense that science and technology pose conflicts with traditional values or belief systems. The second construct represents what Miller called "belief in the promise of science and technology," conceptualized as representing respect for the intentions of scientists, a sense that science and technology provide useful results and products for society, and the assumption that future benefits from science and technology are likely.

Miller et al. (1997) theorized that these two constructs represent competing schemas for interpreting new information related to science or technology. In the U.S. context, the two schema are strongly negatively correlated, suggesting that individuals who have a strong belief in the promise of science and technology are less likely to have concerns about potential negative impacts of science, whereas people who have strong reservations are less likely to acknowledge current or future benefits from scientific or technological developments. On standardized 100-point indices of "scientific promise" and "scientific reservation," Americans score relatively high on promise (68) and comparatively low on reservations (39), indicating a public on the whole that is fairly positive in its outlook. These scores have remained relatively consistent since 1992 (NSB, 2000).

In terms of possible media influences on the two schema, the published reports of the NSB surveys and Miller's subsequent analyses of the data (Miller et al., 1997; Miller & Kimmel, 2001) fall short of fully testing for media effects. After controls for demographics and science knowledge, Miller and his collaborators found that attentiveness promotes public estimations of promise but is unrelated to public reservations. This measure of attentiveness, however, does not account for expected differences in effects on perceptions across different media channels and across different content.

Support for the expectation that various media do influence perceptions of science and technology differently can be found in previous research both in communication and in the field of science and technology studies. In previous communication research, influences of media messages on science have mostly been theorized and measured in terms of the impact of journalistic or news messages. Most such studies have defined the issue in ways that focus on how journalists might distort or reframe scientific issues in ways that deviate from the scientific ideal (Ankney, Heilman, & Kolff, 1996; Dunwoody, 1982; Friedman, Dunwoody, & Rogers, 1999).

For example, certain characteristics of news media production specific to television might be expected to lead to audience confusion or uncertainty about science and technology–related issues. Iyengar (1991) described television media coverage as tending to focus on the episodic, taking the form of a case study or event-oriented report, and depicting public issues in terms of concrete incidents. Issues that cannot be reduced to specific events or occurrences, such as the history of regulatory development that might support the safety of controversial scientific research and technologies, are less likely to be covered. Iyengar's notion of episodic framing implicates television news in that 30- or 60-second news stories will present considerably less information than newspapers, which tend to frame stories more thematically. More important, because episodic frames are individual rather than system oriented, viewers treated to stories framed episodically are likely to attribute responsibility—and treatment of a problem—to the individual rather than the system. It is plausible then that people who get their science news on television will tend to believe the system (i.e., the scientific field) is not that important, or is not responding, and thus hold greater reservations about science and technology.

Another mechanism by which television can undermine public perceptions of science concerns Goffman's (1973) notion of "front regions" versus "back regions." By providing access to what was once restricted to elites and insiders, and shaping what the public learns from its coverage, television has opened up to its viewing audience private, not-to-be-seen areas, thereby eroding confidence in all societal institutions (Meyrowitz, 1985).

Recent work in science and technology studies, however, has questioned the impact of journalistic or news messages, advocating a more nuanced understanding of science journalism's role within science communication (Dornan, 1990; Hilgartner, 1990; Lewenstein, 1995a). The few newer studies looking at news images of scientific issues have suggested that journalists often construct scientists (or physicians, whom the public apparently associates with science) as important authority figures and often produce a strong protechnology bias in coverage, thereby reinforcing public trust in science and technology (Durant, Evans, & Thomas, 1992; Hornig, 1990; Nelkin & Lindee, 1995).

Few studies have examined the influence of entertainment media on perceptions of science. The research on cultivation by Gerbner et al. (1981, 1985) predictably showed that heavy viewers of television saw scientists and science as "strange" and mysterious, likely to do weird things, and to be outside of the social mainstream. On balance, the messages cultivated a fear and mistrust of science (for a fuller discussion of television's effect on science, see Shanahan & Morgan, 1999). These previous cultivation studies, however, do not account for other types of media use or levels of audience expertise or knowledge.

The Role of Science Knowledge in Shaping Perceptions of Science

Although the media may be associated with perceptions of science by virtue of their content, media effects may also be associated indirectly, working through the key concept of science knowledge. A common assumption among scientists, science educators, and policy makers is that greater science knowledge, or science literacy, enables individuals to sort through the misinformation, "bad" science, and extraordinary claims that emerge during science and technology disputes (Bodmer, 1985). It is believed that greater science literacy would ensure that the public makes "proper" risk judgments, that is, risk assessments in line with those of scientists or experts. This belief is supported by "knowledge theory," a framework commonly used in the perception of one's risk literature that assumes that individual response to risk is conditioned by level of knowledge (Widavsky & Dake, 1990). A scientifically literate public is also considered to be more appreciative of science and supportive of science as an institution. Support for science as a social institution, along with acceptance of science and technology, is considered paramount to the successful functioning of democracy (Bodmer, 1985).

The most commonly cited measure of general scientific literacy has been the NSB's Science and Engineering Indicators studies. With each survey's results, prominent members of the scientific community have turned an eye toward the dismally low scores for public science literacy and have responded with a chorus of alarm. Scientists have named scientific illiteracy as responsible in part for the public's inability to discern industry distortions of environmental issues (Ehrlich & Ehrlich, 1996), public misperception of science and scientists (Dawkins, 1998b), widespread belief in various paranormal claims (Sagan, 1995), and gullible acceptance of pseudoscientific gadgets, nostrums, and potions (Park, 2000).

Such warnings by scientists fit with the "civic science literacy" model that holds that knowledge of basic scientific ideas and concepts is required for civic participation, personal efficacy in the outcome of science and technology–related events, global economic competitiveness, individual preparation for employment (Einsiedel, 1990, 1994; Hirsch, 1988; Miller, 1987), and practical aspects of daily life (Shen, 1975). According to this model, the increasing complexity of society, and the increasing number of science and technology–related public controversies, makes general public science literacy an essential component of public participation, informed public policy, and support for science (Shen, 1975; see Miller et al., 1997, for an overview).

Specific to the relations between knowledge and perceptions of science and technology, Miller et al. (1997) and Miller and Kimmel (2001) found that knowledge is negatively related to reservations and positively related to promise. In other words, the scientifically literate within American society hold fewer reservations about the impact of science and technology on life and a greater belief in the promise of science and technology to improve life.

The media and science knowledge. The Miller research, however, does not account for the indirect role through knowledge that different forms of media and different types of media content might play in shaping perceptions of science and technology. Indeed, the significance of the media in informing the public about science cannot be overlooked. When formal education in science ends, media become the most available and sometimes the only source for the public to gain information about scientific discoveries, controversies, events, and the work of scientists. Science and scientists are portrayed in the mass media on a daily basis. It is through television and other mass media that individuals receive much of their knowledge about science and scientists (Gerbner et al., 1981; LaFollette, 1990; Nelkin, 1995).

Although there may be other important sources of scientific information—science classes, science museums, and interpersonal sources would be three examples—no other source offers as much access to scientific information as do the mass media. Newspapers and magazines, especially technical or scientific publications, even within the popular press, offer rich sources for learning about scientific practices and advances. Television, perhaps, offers the best possibilities for broad access to various publics; given that people are spending a significant amount of time with television compared to other media, one might expect television to provide the most opportunity for educational gains in terms of science knowledge. In the past, well-known scientists such as astronomer Carl Sagan (1995) and Nobel laureate Leon Lederman (Pollack, 1998) advocated that television holds vast potential for teaching mass audiences about science. In fact, some survey studies with children have shown television science programming to be effective in teaching children science content (Fortner, 1986; Gunter, Clifford, & McAleer, 1997; Mares & Cantor, 1999).

However, scientists may be hoping for too much in heralding television as a learning tool. Shanahan, Morgan, and Stenbjerre (1997) found that heavy viewers of television were less knowledgeable about scientific issues and concluded that the simple act of viewing television could displace opportunities for becoming involved in or learning about science.

This is consistent with much of the political learning literature. Newspaper readership consistently has been shown to be a better predictor of political learning than television (for an overview, see Chaffee & Frank, 1996; also McLeod, Scheufele, & Moy, 1999). This is not to say that television does not provide its viewers with any information. Watching television news is positively associated with certain dimensions of political sophistication such as political interest and active processing (Guo & Moy, 1998). But overall, the political learning effects—and perhaps the scientific learning effects—from television are weaker than for newspapers, controlling for variables such as age, education, or income (e.g., Eveland & Scheufele, 2000).

If print and broadcast media are associated differentially with the acquisition of science knowledge, these influences can very well carry over to perceptions of science. Although television may have popularized science, it may not necessarily be what Cloître and Shinn (1986) considered an efficient instrument for transmitting "better" knowledge. If anything, scholars have noted that increased familiarity with science has been accompanied by more frequent realizations that one cannot follow the complexities of scientific arguments. Put another way, "the democratization of science has . . . increased the remoteness and authority of science" (Felt, 2000, p. 7). A similar argument was raised in political communication research on media effects on trust in government. When Robinson (1976) found that people who watched "The Selling of the Pentagon" manifested lower levels of trust in the military, he placed responsibility on the format of television news. According to his line of argument, the format of television news made it inherently confusing for the viewer. Viewers who are confused will have lower levels of efficacy and believe that governmental activities are beyond their comprehension and, hence, will have lower levels of trust.

Finally, our study can be informed by recent research on media effects on trust in government. Moy and Pfau's (2000) extensive cross-comparison of media effects on confidence in democratic institutions indicates that different media have different effects: Print media enhance perceptions, whereas television news have both positive and negative effects. However, in 97% of all cases, increased expertise in a democratic institution led to increased trust in that institution. If science is a social institution and needs public trust (Bodmer, 1985), then science literacy is crucial, and the indirect association of the media with perceptions of science through knowledge becomes of critical importance.

Hypotheses and Research Questions

Our review of previous research leads us to expect (a) that media use at least partially mediates the relationship between demographic variables such as age, gender, and, most important, education on science knowledge variables and (b) that in turn these science knowledge variables partially mediate the relationship between media use and perceptions related to science and technology. These expected direct and indirect influences of mass media can be further specified as the following set of hypotheses and research questions:

Hypothesis 1: After demographic controls, exposure to general entertainment television is positively related to reservations about science and technology. This cultivation hypothesis has been previously supported (Gerbner et al., 1981; Shanahan & Morgan, 1999) but deserves replication.

Research Question 1a: Given previous research that has characterized some of entertainment television's depictions of science as a powerful and positive force, what association might television viewing have on public estimations of the promise of science and technology, separate from the cultivation of reservations?

Research Question 1b: After demographic controls, what is the direct association between perceptions and other media thought to portray science and technology in a more positive manner than entertainment television, including the general print media and the specialized science media?

Hypothesis 2: After demographic controls, general television viewing is negatively associated with science knowledge, which itself promotes belief in the promise of science and technology and decreases reservations (Miller et al., 1997; Miller & Kimmel, 2001). This indirect relationship between viewership and perceptions via knowledge is distinct from the direct relationship hypothesized by cultivation theory.

Research Question 2: After demographic controls, what are the indirect effects of using other media? Does exposure to general print media or science media influence science knowledge and, therefore, indirectly influence perceptions of science and technology?

Method

Data for our study came from the 1999 NSB Science and Engineering Indicators Survey, based on telephone interviews of a random-digit dialing sample of 1,882 respondents in the United States. The NSB survey offers the only publicly available source of national-level data for the United States that include indicators measuring perceptions of science, knowledge of science, various forms of media use, and basic demographic controls. Question wording for items used in this survey is publicly available through the NSB.[1]

The variables used for the study can be categorized into three groups: exogenous variables (those not influenced by other variables in the model), antecedent endogenous variables (those influenced by some variables in the model but that also influence other variables), and our two consequence endogenous variables.

Exogenous Variables

Respondents' ages were assessed by an open-ended continuous item (M = 46.25, SD = 17.00). Gender was coded with male = 0 and female = 1 (54%). General education was an ordinal-level measure with 10 categories that ranged from Grade 6 or less of education (coded 1) to graduate/professional degree (coded 10) (M = 5.27, SD = 1.84).

Antecedent Endogenous Variables

Media use was broken down by channel (television, newspaper, magazines) and by content (general television viewing, general newspaper, science television, and science magazines). General television viewing was measured by a question that asked respondents the average number of hours of television watched per day (M = 2.87, SD = 2.20). Our measure of television science use consisted of an additive index of three items that asked the monthly frequency of viewing up to three different science or nature programs (M = 2.43, SD = 4.22). Newspaper use was measured by a question that asked respondents how often per week they read the newspaper, with less than once a week coded 1, once a week coded 2, a few times a week coded 3, and every day coded 4 (M = 3.00, SD = 1.11). Science magazine use (M = 0.18, SD = 0.44) consisted of a constructed variable of five open-ended questions that asked respondents which magazines they read regularly. Because this question did not specify science magazines only, with responses ranging from arts and leisure to sports magazines, answers that accurately reflected magazines with a science focus were selected and totaled in the constructed measure. They included *Science*, *Scientific American*, *Discover*, and *National Geographic*.

In this article, we adopted a multidimensional conceptualization of science knowledge developed by Miller et al. (1997) that introduces two separate but related knowledge constructs. First is the understanding of factual terms and concepts within science. This measure represents a vocabulary of basic scientific constructs sufficient to read opposing views in a newspaper. Our measure of this factual knowledge concept consisted of 14 items (α = .75, M = 8.52, SD = 3.19). Questions tapping factual knowledge included true and false questions, such as "lasers work by focusing sound waves," "electrons are smaller than atoms," and "antibiotics kill viruses as well as bacteria." Multiple-choice questions included, "Does the Earth go around the Sun, or does the Sun go around the Earth?" and "Which travels faster: light or sound?"

The second knowledge construct measured knowledge of science as a process or mode of inquiry. Here, the nature of scientific inquiry is defined to be consistent with a Popperian paradigm: Scientific theories are propositions logically connected in a deductive manner, subject to empirical scrutiny, and able to be falsified (Miller et al., 1997). The measure of this "procedural knowledge" construct consisted of eight items (α = .68, M = 4.23, SD = 1.07). Items in this construct included an open-ended question that asked respondents to describe "what it means to study something scientifically," close-ended items that measured understanding of a control group or experiment, an open-ended measure that asked why a control situation was better in an experiment, close-ended items measuring understanding of probability posed in the context of the likelihood of inheritance of genetic traits, and a close-ended item measuring assessment of the scientific nature of astrology.

Consequence Endogenous Variables

Our two final consequence variables measuring perceptions of science are based on previous work by Miller et al. (1997) and Miller and Kimmel (2001) that identified two distinct attitude constructs emerging from the NSB surveys.

Reservations concerning science and technology consisted of a common factor of four standardized items (α = .54, M = –0.35, SD = 2.54). These four items measuring reservations concerning science and technology reflect agreement on a four-response category Likert-type scale with the following four statements:

- Science makes our way of life change too fast.
- On balance, the benefits of scientific research have outweighed the harmful results (reverse scored, a neutral response leads to five possible responses on this item).
- We depend too much on science and not enough on faith.
- It is not important for me to know about science in my daily life.

Belief in the promise of science and technology consisted of a common factor of four standardized items (α = .67, M = 0.05, SD = 2.83) also previously identified by Miller et al. (1997) and Miller and Kimmel (2001). These four items measuring belief in the promise of science and technology reflect agreement on a four-response category Likert-type scale for the following four statements:

- Because of science and technology, there will be more opportunities for the next generations.
- Science and technology are making our lives healthier, easier, and more comfortable.
- Most scientists want to work on things that will make life better for the average person.
- With the application of science and new technology, work will become more interesting.

We tested the relationships between independent and dependent variables employing structural modeling techniques, in this case, using LISREL

(Jöreskog, 1993). In contrast to other multivariate techniques, structural equation modeling allows for the simultaneous estimation of all parameters in a model. Any given coefficient therefore represents the relationship between two variables controlling for all other relationships and variables in the model. Structural equation models postulate "a pattern of linear relationships among these variables" (MacCallum, 1995, p. 18) and test these relationships against the data collected. By treating endogenous variables as both independent and dependent variables, structural equation modeling allows for the estimation of direct and indirect effects. An indirect effect is the influence of an independent variable on a dependent variable through one or more intervening or mediating variables (Bollen, 1987; Hoyle, 1995).

In this article, we follow a "model generating" approach (Jöreskog & Sörbom, 1996) where we develop an initial model based on prior theorizing and test the theorized relationships against the data. In estimating our model, based on previous research demonstrating the effects of media use on environmental knowledge (Shanahan et al., 1997) and previous research indicating the political learning effects of media use (for an overview, see Chaffee & Frank, 1996; Eveland & Scheufele, 2000; McLeod et al., 1999), we place demographics, including education as well as media use, as temporally and logically prior to the two knowledge constructs. Also, following from Miller et al. (1997) and Miller and Kimmel (2001), knowledge temporally and logically precedes our two attitude constructs. The model-generating approach proceeds in two steps. In the first step, an initial model is specified, based not necessarily on specific hypotheses about single paths between variables but on "at least some tentative ideas of what a suitable model should be" (Jöreskog, 1993, p. 313). In the second step, based on this core model, paths can be freed or fixed based on the so-called Lagrangian multiplier (LM) test (Bollen, 1987). All parameters that are added based on the LM test should be meaningful and substantively interpretable.

Standardized beta coefficients are presented to allow for the comparison of the relative influence of all the effects in the model. All coefficients are significant at the .05 level. Several measures of goodness of fit are provided to evaluate whether our model as theorized fits the data.

Results

Our final model (see Figure 1) fit the data very well. The chi-square (16, N = 1,882) is $\chi^2 = 19.81$, which translates into a Bayesian information criterion statistic (see Raftery, 1995) of –100.83. The goodness-of-fit index and the adjusted goodness-of-fit index—accounting for multivariate nonnormality—both indicate an equally excellent fit with coefficients of 1.00 and 0.99,

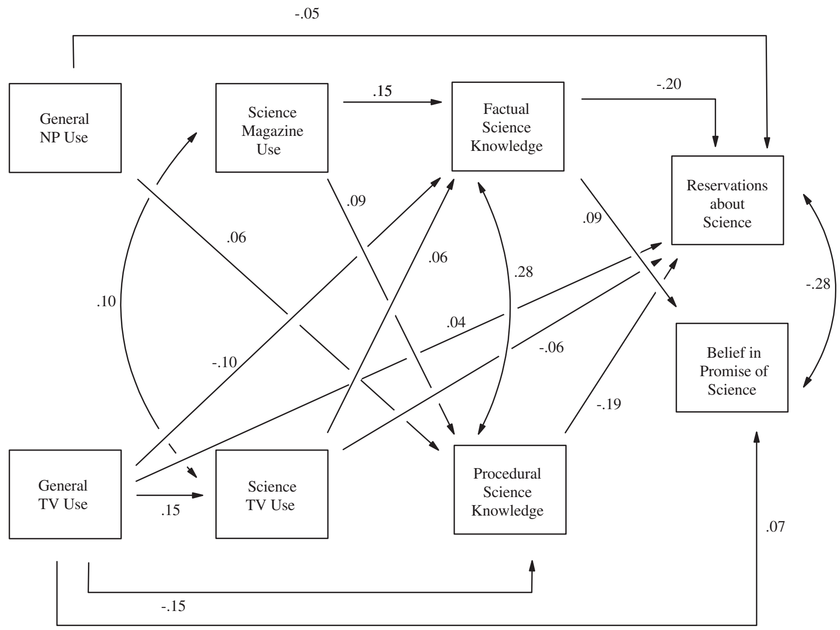

Figure 1. Media, Knowledge, Reservations, and Promise
Note. NP = newspaper.

respectively. The variables included in this model accounted for 34% of the variance in factual science knowledge, 22% in procedural knowledge, 23% in reservations about science and technology, and 4% of belief in the promise of science and technology.

Demographic effects. As outlined earlier, our model controlled for three exogenous variables: age, gender, and education. As Table 1 shows, older respondents are more likely to use newspapers, $\gamma = .26$, and to watch television, $\gamma = .16$. They were less likely, however, to watch science-related television programming, $\gamma = -.06$. Older respondents also hold lower levels of factual knowledge of science, $\gamma = -.14$, and lower levels of procedural knowledge of science, $\gamma = -.17$. At the same time, in a direct relationship, older respondents are more likely to hold reservations about science, $\gamma = .06$.

With the exception of general television viewing, $\gamma = .05$, women are less likely to use different types of media than men. This includes newspapers, $\gamma = -.09$; science magazines, $\gamma = -.19$; and science television, $\gamma = -.08$. Women also possess lower levels of knowledge of both factual and procedural aspects of

Table 1
Influence of Exogenous Variables on Other Variables in the Model

Variable	Age	Gender (Female)	General Education
General newspaper use	.26	–.09	.14
	—	—	—
	.26	–.09	.14
General television use	.16	.05	–.23
	—	—	—
	.16	.05	–.23
Science magazine use	—	–.19	.11
	—	—	—
	—	–.19	.11
Science television use	–.09	–.08	.09
	.02	.01	–.03
	–.06	–.08	.06
Factual science knowledge	–.12	–.19	.39
	–.02	–.04	.04
	–.14	–.23	.43
Procedural science knowledge	–.16	.06	.34
	–.01	–.03	.05
	–.17	–.03	.39
Reservations about science	–.11	—	–.18
	.06	.06	–.18
	.06	.06	–.35
Belief in promise of science	–.11	–.06	.11
	.00	–.02	.03
	.00	–.08	.14

Note. All coefficients are significant at $p \leq .05$. Coefficients in the first row indicate direct effects, coefficients in the second row indicate indirect effects, and coefficients in the third row indicate total effects. If the sum of direct and indirect effects is not equal to the total effect size, this is due to nonsignificant indirect effects that are not shown here or to rounding error.

science, total effects of –.23 and –.03, respectively. As a result, because they know less about science, women are more likely to hold reservations about science, total effects of .06. Women are also less likely to believe in the promise of science, with direct effects of –.06 and total effects of –.08.

Education is positively linked to newspaper use, $\gamma = .14$, as well as to science magazine and science television use, total effects of .11 and .06, respectively. Education, however, is negatively linked to general television viewing, $\gamma = -.23$. Direct effects of education on factual knowledge and procedural knowledge were .39 and .34, respectively. In regards to total effects on reservations about science, education was strongly negatively related at –.35. About half of this total influence, $\gamma = -.18$, was accounted for by indirect effects through knowledge and media use. To a lesser extent, education also promoted a belief in the promise of science, with total effects of .14.

Nondirectional effects. When specifying the relationships between the endogenous variables, we had to make a number of decisions regarding the directionality of links between several constructs. Specifically, we decided to open nondirectional correlational links between newspapers and general television use as well as between science magazines and science television use. Only the link between science magazine use and science television use was significant, $\Psi = .10$. This relationship is plotted in Figure 1.

For the two types of science-related knowledge and the two types of science perception measures, we also opened nondirectional links to account for potential covariation among the measures. The data show that individuals who have higher levels of factual science knowledge are also more knowledgeable about the procedural aspects of science, $\Psi = .28$. In agreement with previous findings by Miller et al. (1997) and Miller and Kimmel (2001), the two measures of science perceptions are negatively related, $\Psi = -.28$. These relationships are indicated in Figure 1.

Media effects. Although the relationships with general demographics are of interest, our main focus in this article, however, was directed more toward the links from different types of media use to perceptions of science and technology. Newspaper use, general television viewing, science magazine use, and science television use are all significantly related to reservations. The direction of these links, however, differed between media. Newspaper use, science magazine use, and science television use are related to fewer reservations regarding science and technology with total effects of –.06, –.05, and –.07, respectively. In contrast, frequent television viewers are more likely to hold reservations (total effects of .08) (see Table 2).

In regards to belief in the promise of science and technology, the dual nature of depictions of science and technology on television appear to play out. Although general television viewing cultivates reservations among viewers, this type of media use also cultivates a belief in the promise of science and technology, with a direct effect of .06. Other media, including science television use and science magazine use, are only slightly and indirectly related to a belief in promise, with total effects for both of .01.

Many of these total relationships for media use are a function of mediated links through factual science knowledge and procedural science knowledge. Both knowledge variables are related to fewer reservations with $\beta = -.20$ for factual science knowledge and $\beta = -.19$ for procedural science knowledge. In regards to the influence of knowledge on belief in the promise of science and technology, only factual knowledge was significantly related, $\beta = .09$.[2]

The overall association of general newspaper use with reservations about science is due to a direct link through content, $\beta = -.05$, but also to indirect

Table 2
Relationships Between Endogenous Variables

Variable	1	2	3	4	5	6
1. General newspaper use	—	—	—	—	—	—
	—	—	—	—	—	—
	—	—	—	—	—	—
2. General television use	—	—	—	—	—	—
	—	—	—	—	—	—
	—	—	—	—	—	—
3. Science magazine use	—	—	—	—	—	—
	—	—	—	—	—	—
	—	—	—	—	—	—
4. Science television use	—	.15	—	—	—	—
	—	—	—	—	—	—
	—	.15	—	—	—	—
5. Factual scientific knowledge	—	–.10	.15	.06	—	—
	—	.01	—	—	—	—
	—	–.10	.15	.06	—	—
6. Procedural scientific knowledge	.05	–.15	.09	—	—	—
	—	—	—	—	—	—
	.05	–.15	.09	—	—	—
Reservations about science	–.05	.04	—	–.06	–.20	–.19
	–.01	.04	–.05	–.01	—	—
	–.06	.08	–.05	–.07	–.20	–.19
Belief in promise of science	—	.07	—	—	.09	—
	—	–.01	.01	.01	—	—
	—	.06	.01	.01	.09	—

Note. All coefficients are significant at $p \leq .05$. Coefficients in the first row indicate direct effects, coefficients in the second row indicate indirect effects, and coefficients in the third row indicate total effects. If the sum of direct and indirect effects is not equal to the total effect size, this is due to nonsignificant indirect effects that are not shown here or to rounding error.

links through procedural science knowledge, β = .09. The pattern for science television use is similar. There is a direct link to reservations, β = –.06, but science television viewing is also related indirectly through factual science knowledge, β = .06. Science magazine use is only indirectly related to reservations. Its association is mediated by factual science knowledge, β = .15, and procedural science knowledge, β = .09. Newspaper use is unrelated to belief in the promise of science, whereas both science television use and science magazine use are only indirectly and slightly related both at .01.

The total effects of general television use on reservations about science are .08. In other words, people who watch television frequently are more likely to have reservations about science and technology. This is a combination of content effects, supported by a direct link of β =.04, and informational effects, mediated by the two knowledge measures. Frequent television viewing is associated with decreased objective levels of factual, β = –.10, and procedural,

$\beta = -.15$, knowledge that then is associated with an overall increase in reservations about science. For belief in the promise of science, television's association is predominantly direct and positive, $\beta = .07$, with only a slight indirect effect, $\beta = -.01$, mediated by television's promotion of reservations about science.

Conclusion

As outlined earlier, this study is based on cross-sectional survey data, which constrains the degree to which we can make inferences about the direction of causality between variables based on their observed relationships. However, given the scarcity of data sets that include measures of media use, perceptions of science, and knowledge variables, this study provides extremely valuable insights into a media effects model for public dispositions toward science and technology.

Naturally, using an existing data set places constraints on the indicators of media use and knowledge with which we were able to work. Specifically, different media measures of exposure and attention would have allowed us to explore the effects of different types of media use on knowledge gains and perceptions among audience members more carefully. As researchers have argued, measuring exposure to media content alone is insufficient and that attention to the corresponding content may be a far better predictor of cognitive outcomes (Chaffee & Schleuder, 1986). However, no measures for attention to specific types of content (an example might include attention to science coverage in newspapers or attention to entertainment programs on television) were available in this data set. Future research should explore the differences between news, entertainment, and science-specific coverage in greater detail. Finally, the level of measurement error in the model likely attenuates to a degree the strength of the media effects that we find. If measurement were improved, we expect that the strength of our relationships would increase.

Regardless of these constraints, our results offer valuable conclusions for understanding public perceptions of science and technology as well as the role of the media in shaping those perceptions in light of demographic influences. First, although the influence of gender on perceptions of science and technology is not a primary focus of our study, it should be pointed out that research in science education has consistently shown that gender is an important variable influencing perceptions (Shibeci, 1984). In this direction, our results confirm a significant gender gap in media use, knowledge of science, and perceptions of science. Women are less likely to use media that foster informal learning about science and hold comparatively lower levels of actual knowledge of science. As a result of their lower levels of knowledge, along with other possible social and cultural influences not examined in this study, women are more likely to have reservations about science and less likely to believe in the promise of science.

Our results also indicate an education gap in media use, knowledge of science, and perceptions of science. Individuals with higher levels of general education are more likely to read newspapers and use science media and are less likely to engage in general television viewing. They also hold comparatively higher levels of factual and procedural knowledge of science. As a partial result of these traits, society's best educated are less likely to hold reservations about science and are more likely to believe in the promise of science.

Even though these demographic characteristics are important to understanding public perceptions of science, our results demonstrate that above and beyond these demographic influences, the media do matter. In our study, we confirm the fears of scientists that some forms of media content could be doing damage to the public perception of science. Particularly, with television, it is fairly clear that there is a positive relationship between general television viewing and reservations about science. This is a two-part relationship in regards to the promotion of reservations: Part of the problem is that television exposure is associated with less scientific knowledge, and part of it is that heavy viewers simply absorb the images of science that are so frequently portrayed on television.

With respect to knowledge, our data are consistent with previous research showing that expertise leads to greater trust (Moy & Pfau, 2000). Moreover, knowledge in our study was negatively related only to general television use. This supports the notion that television viewing probably simply displaces opportunities to learn more about science. In this sense, television probably obstructs the development of appreciation for science that might occur for people who view less (Shanahan, 1995).

Concerning the direct relationship, general television viewing also seems to "cultivate" reservations about science and technology. Apart from the negative impact on knowledge, heavy viewers of television find that misconceptions of science are either confirmed or created anew. These results are well in line with earlier cultivation results (Gerbner et al., 1981; Shanahan et al., 1997). Part of the landscape of television's world is the strange and scary scientist and the nefarious nature of science. Our findings, however, add new results to previous cultivation research. If the negative images of science found on television cultivate reservations, television's portrayal of science sometimes as omnipotent, and offering hope for the future, appears to also directly promote belief in the promise of science and technology.

Our findings also show that other media appear to work at cross-purposes. Newspaper use and science television use decrease reservations directly. Also, in contrast to general television viewing, all other media variables are positively associated with increased factual and procedural knowledge. Thus, media effects on perceptions and understanding are not monolithic. But to the extent that general television viewing has increasingly come to dominate the attention of most members of the media audience, we would argue that the television results are the most compelling.

The results do not easily yield suggestions for policy. One might hope that the American science community in collaboration with media producers could make better use of television. And indeed, the National Science Foundation and other institutions have played some role, funding programs such as *Bill Nye the Science Guy*. Our results indicate that science-specific programming can have positive benefits for public understanding. Obviously, though, these programming efforts are overwhelmed by the massive popularity of science fiction, science fantasy, paranormal mystery shows, and other general television content that caters to a ready-made audience for storytelling that often distorts science as either scary or omnipotent, while apparently inhibiting public understanding. Our results, therefore, suggest that in matters of science education and appreciation, any policy efforts to use the media for public outreach should be focused within the realm of newspapers and magazines. Short of systemic changes in the forces that drive the production of broadcast content, science will always provide fodder for the sensationalized narratives of television, leaving news in print to continue as the prime vehicle for education.

Notes

1. Details on the public availability, survey design, and question wording can be found at http://www.nsf.gov/sbe/srs/seind00/start.htm.
2. Given the number of observations in our data set, we acknowledge that there is a possibility of Type I error in the interpretation of our findings. However, the fact that the coefficients in our results are all in a consistent direction and confirm our theoretical expectations reinforces our confidence that a Type I error is not a major problem in these analyses.

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