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Perceived familiarity or factual knowledge? Comparing operationalizations of scientific understanding

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This study compares two frequently used operationalizations of understanding: factual knowledge and perceived familiarity. The authors argue that these measurements—which have been used interchangeably in past research—are conceptually distinct and should be treated as such. Using hierarchical linear ordinary least squares regression, this study provides evidence that factual knowledge and perceived familiarity are only slightly correlated and are influenced differently by predicting variables, such as media use and cognitive processing variables. As a result, the use of these measures may result in different assessments of the levels of public understanding, which has important implications for future policy decisions.

Keywords: nanotechnology; knowledge; familiarity; understanding; media; science.

1. Introduction

Over the last decade, the policy and media debate surrounding the funding and use of emerging technologies, such as nanotechnology, has gradually intensified. Much of the discussion so far has been characterized by competing arguments related to the possible economic benefits of continued research and the social concern regarding tentative environmental and health risks related to these technologies (Anon. 2003; Scheufele and Lewenstein 2005). Although expert opinion regarding nanotechnology has remained relatively high over the years, levels of public support are a constant concern of nano-researchers.

Previous research on public attitudes and understanding of new technologies has predominantly been driven by the knowledge deficit model, which suggests that low levels of public understanding about science and new technologies in the USA may negatively influence levels of support among citizens (Miller 2004; Scheufele and Lewenstein 2005). Unfortunately, due to the use of conflicting measures of scientific knowledge, there is still considerable debate over the accuracy of aggregate assessments of public understandings of science (Miller et al. 2006; Sturgis and Allum 2004; Weiss 1983; Weld 1991). Specifically, the difficult task of creating an appropriate balance of quick and reliable knowledge measures that also have high validity has caused many scholars to rely on the use of factual knowledge questions, which are ideal for aggregate level survey research because of their simplistic nature.

Similarly, some scholars have argued that measures of 'perceived familiarity', which have also been referred to as 'self-reported knowledge' and 'perceived knowledge', with science topics may reflect a better assessment of an individual's knowledge (Kahan et al. 2009; Satterfield et al. 2009). This argument is founded in the meta-cognition literature, which suggests that knowledge about one's knowledge plays an important role in a variety of processing tasks, including problem solving (Metcalfe 1986). Supported by the familiarity hypothesis (which argues that an individual's familiarity with a topic increases their support of that topic) nanotechnology scholars have come to rely heavily on measures of self-reported knowledge as a replacement to measures aiming to assess an individual's factual knowledge (Cobb and Macoubrie 2004; Hart Research Associates 2006, 2007; Kahan et al. 2009; Macoubrie 2006; Satterfield et al. 2009). Advocates of the familiarity hypothesis have, therefore inserted perceived familiarity into the traditional knowledge deficit model as a substitute for factual science knowledge. Health and educational research, however, suggests that factual and perceived knowledge measures may be assessing two very different knowledge constructs. This implies that using these measures interchangeably as assessments of knowledge may produce less accurate results than was originally thought (Chermers et al. 2001; Crosby and Yarber 2001; Hansford and Hattie 1982). Subsequently, the creation of science education policy based on these assessments of knowledge may have drastically different effects depending on which measures were used. For example, science educators may focus learning efforts on a certain subset of the population that is more likely to claim familiarity with emerging technologies or a subset that is more likely to have factual knowledge about the technology at hand, depending on which measurement was used in research relevant to educational implementation.

The purpose of this study, therefore, is to examine the unique relationship between measures of perceived familiarity and factual science knowledge. Considering recent scholarly and scientific discussions regarding emerging technologies (Scheufele et al. 2007), the topic of nanotechnology is a perfect issue for examining the ways in which citizens acquire knowledge and how current measures of science knowledge differ in their representativeness of an individual's understanding of science issues. In fact, the literature regarding the influence of knowledge on support of, and opinions toward, nanotechnology often use factual and self-reported knowledge interchangeably when reporting results, which suggests that these measures are the same construct (Satterfield et al. 2009). Therefore, the following will address both the appropriateness of self-reported and factual measures of science knowledge and will also argue that these two types of measures are conceptually unique and have very different patterns in terms of construct validity tests. As mentioned above, this may have important implications for education and policy decisions based on past survey research that used respondents' self-reported familiarity as a proxy for factual science knowledge.

2. Assessing public understanding of science

The argument for the importance of a public understanding of science is founded upon an underlying normative belief that scientific knowledge is necessary for individuals to go about their daily lives. Similarly, as regulations applied to new technologies such as nanotechnology continue to be scrutinized at the federal level, scholars have begun to argue that an understanding of science may not only help individuals in their day-to-day life, but may also help encourage positive and productive democratic behaviors such as voting or engaging in political discussion (Satterfield et al. 2009). Recent research, however, has suggested that an understanding of emerging technologies may not result in optimal policy choices. For example, even adults who are highly educated about the effects of global warming may show little or no concern for policy implementation meant to address the issue (Sterman and Sweeney 2007). Although this discrepancy may highlight a shortcoming of the argument that science knowledge is an essential tool in decision-making processes, this finding may also point toward a much larger issue regarding the presence of inaccurate measures of public understanding in current social research.

Discrepancies such as those discovered by Sterman and Sweeney (2007) are what have led to what many now call the 'science wars' between various interest groups invested in the promotion of an understanding of science (Bauer et al. 2000). Specifically, Laugksch (2000) establishes that in the attempt to promote a better public understanding of science, several interest groups consistently differ in both their views related to the purpose of advocating scientific understanding as well as in their attempts to operationalize the construct. As a result a number of models and measurements have been proposed and used interchangeably in studies investigating public levels of science knowledge.

Scholarship examining public understanding of science was established based on the results of the Bodmer Report (1985) and British attempts at scientific public outreach. Particularly, one area of research related to public understanding of science focuses on the 'deficit model', which describes a one-way, top-down approach to learning about science where scientists are responsible for communicating to the public, at which time the public listens and learns about science, thereby increasing public support (Miller and Kimmel 2001; Miller et al. 1997; Wynne 1991). The establishment of this model led to some of the more notable and widely used measures of scientific knowledge, which employ reliable and cost-effective true or false factual science questions (Miller 1998, 2004; Miller et al. 1997, 2006). Some qualitative researchers have argued that the public may not be acquiring knowledge through formal educational experiences, however, but rather through less structured, daily experiences (Epstein 2009; McKechnie 1996; Roth and Lee 2002; Wynne 1996). Our research acknowledges the epistemological debate surrounding the definition of knowledge (see Brossard and Shanahan (2006) for a more extensive discussion of alternative measures of science knowledge), and our study builds upon this discussion by focusing on the specific areas of research that rely upon perceived familiarity as a proxy for factual science knowledge, which may be an indicator of public support of science, and a tool for science policy-makers (Kahan et al. 2009; Satterfield et al. 2009).

As previously mentioned, research supporting the use of self-reported measures of knowledge are based on the 'familiarity hypothesis', which argues that an individual's familiarity with a science topic may serve as a substitute for factual science knowledge and that familiarity is positively related to support for technology (Cobb and Macoubrie 2004; Hart Research Associates 2006, 2007; Kahan et al. 2009; Macoubrie 2006; Satterfield et al. 2009). In this sense, the familiarity hypothesis mirrors the deficit model in that scientific understanding begets science support, but employs self-perceived instead of factual knowledge measures. As a result, more than 22 risk perception surveys in the last six years have inserted familiarity measures in their cross-sectional surveys, suggesting that familiarity and factual knowledge indeed measure the same constructs (Satterfield et al. 2009).

Although using a measure of perceived familiarity allows for a short and succinct assessment of an individual's understanding of science, research points to several problems related to relying solely on such measures. For instance, scholars have argued that self-perceptions of knowledge may be too susceptible to personal preferences, emotion, or prior attitudes when gathering information about a science (Park et al. 1988). As a result, these factors may differ in their effects on information processing, subsequently skewing self-perceptions of knowledge (Park et al. 1988).

Similarly, the public's reliance on cognitive shortcuts may lead to an overestimation of one's perceived knowledge. Research has consistently indicated that we rely on personal heuristics when processing information that may seem difficult to understand (Delli Carpini and Keeter 1996; Kahneman 2003; Marcus and MacKuen 1993; Popkin 1991). Although these shortcuts allow individuals to form opinions and gather a sense of self-awareness, they may not allow one to acquire the information that is necessary to make sense of science and scientific issues. As a result, reports of self-perceived knowledge may be greater than an individual's factual knowledge or even unrelated to scientific understanding altogether.

Above and beyond the general literature referring to the pitfalls of perceived familiarity, empirical studies across several fields of research have proved its inaccuracy in reflecting factual knowledge. For example, Hansford and Hattie (1982) found that perceived intelligence only correlated at a coefficient in the range 0.2–0.3 with actual performance on tests. Similarly, individuals' perceptions in lie detection only correlated at 0.04 with real detection results (DePaulo et al. 1997). Finally, in a meta-analysis that reviewed 55 studies that observed perceived assessments versus objective performances, the average correlation coefficient was found to be 0.29, indicating low construct validity between the two types of measures (Mabe and West 1982). Clearly this past literature and research analyses from these multiple domains have shown that self-perceived assessments do not accurately reflect objective measurements. This study endeavors to find a connection in the realm of nanotechnology research.

2.1 Public understanding of nanotechnology

Similar to research regarding public levels of science knowledge, recent research has illustrated that the majority of the American public does not have a clear understanding of nanotechnology terms or concepts (Waldron et al. 2006). In fact, a 2005 study examining levels of understanding about nanotechnology among Wisconsin teachers and students, discovered that while 41% of the participants said that they had heard of nanotechnology, only 42% of those participants could correctly define the subject (Castellini et al. 2007). This lack of understanding of the basic elements of nanotechnology presents a roadblock in communication between researchers and the public.

This issue is further complicated by research examining public understanding and perceptions of nanotechnology, which rely on measures of perceived familiarity as an assessment of knowledge (Hart Research Associates 2006; Priest 2006; Sheetz et al. 2005). As previously mentioned, perceived familiarity with a topic may not be a reliable indicator of factual understanding. This argument is reinforced by political communication research, which indicates that internet use can lead users to subjectively believe they have greater political knowledge without any significant change in levels of understanding (Nisbet et al. 2002). Similarly, research has shown that individuals do not feel limited by understanding when making judgments about the risks and benefits of new technologies (Cacciatore et al. 2011). Although, scholars have discovered that perceived familiarity with nanotechnology is positively related to support of the technology, the link between support of nanotechnology and factual knowledge is heavily mediated by heuristic variables (Brossard and Nisbet 2007; Hart Research Associates 2006; Kahan et al. 2009). This research clearly indicates that while measures of perceived familiarity may provide a simpler method for assessing science understanding, self-reported measures may not assess the same constructs as factual knowledge measures. Considering this, we pose our first research question:

RQ1: What is the relationship between an individual's factual knowledge of nanotechnology and their perceived familiarity with nanotechnology?

3. Acquiring knowledge: Systematic and heuristic processing

The heuristic–systematic model, which theorizes decision-making through cognitive processing, suggests two separate but related information processing methods that enable one to make a judgment about an issue (Eagly and Chaiken 1995). Systematic processing involves scrutinizing information and facts in order to reach a well thought-out decision. Although this leads to a comprehensive understanding of an issue, it requires a large amount of cognitive capacity and effort (Chaiken 1980). Conversely, heuristic processing relies on less information uptake and requires less cognitive effort. Instead of fully understanding the many facets of an issue, one uses heuristics, or simple decision rules, to gain understanding and formulate an opinion (Tversky and Kahneman 1974). These shortcuts include relying on experts' opinions and past observations (Smith 1984).

Although heuristic processing of one set of issues can free time and cognitive effort to process another set more systematically, this model allows the two forms of processing to co-occur when there is both motivation to learn and when heuristic cues are readily available, leaving the processor to find a balance between the two modes of processing (Chaiken 1987). Past research has found that this balance is not always the same among individuals and heuristic processing depends on factors such as past schema, personal interest, and levels of anxiety about the issue (Cacioppo and Petty 1982; Chen et al. 1999). As a result, some individuals may rely more heavily on heuristics, while others spend more time systematically processing information before making a decision or forming an opinion.

Perhaps unsurprisingly, research in the fields of political science, sociology, psychology, and communication has recognized that individuals are more likely to rely on heuristics rather than systematic processing. In fact, much research suggests that people can usually be thought of as 'cognitive misers', meaning that they process only enough information to make an immediate judgment (Fiske and Taylor 1991; Popkin 1991). In an effort to save on cognitive capacity and effort, these misers use heuristic cues to gain information and make decisions especially when an issue has little importance to the processor. When an issue does have personal importance, one may have the determination to rely on systematic processing in order to gain a more in-depth understanding of the topic (Kahlor et al. 2006).

Considering the possible ways that the public may process science information, it is important to consider the possible effects of heuristic versus systematic processing on the acquisition and retention of general science and/or nanotechnology knowledge. Based on the literature presented above, it is likely that people who are interested in science will be more likely to seek out that scientific information, systematically process it, and retain more in-depth scientific understanding. However, individuals with lower levels of interest in science and emerging technologies will not make the cognitive effort to fully understand related issues and information. Instead they will be more likely to rely on heuristic processing and, although they may perceive that they have a high level of understanding of science, they may merely have a superficial understanding of the topic.

4. Media use and understanding of nanotechnology

Considering the finding that most Americans obtain general science knowledge from mass media (Nelkin 1990; Nisbet et al. 2002), it is necessary to question the possible effects that the mass media may have on both the acquisition and processing of scientific information. Science topics have always been present in media news coverage, however, as the public is continually offered new options for media access, individuals are more likely to encounter science in a more diverse environments. For example, a 2006 study discovered that although 14% of Americans obtained most of their general science news from newspapers, 20% turned to the internet and 41% preferred the television for science information (Horrigan 2006). However, understanding of science issues can vary across these media outlets and should, therefore, be examined by the type of medium.

4.1 Newspapers

The least common informational science media source in America attracts the oldest readership, with users over 55 years old most likely to utilize newspapers as their primary source for science news and information (Anderson et al. 2010). Although newspapers may be becoming a dated form of media communication, past research has shown a positive correlation between newspaper use and public understanding of the scientific process (Nisbet et al. 2002). Science newspaper use has also been related to increases in nanotechnology knowledge and support for the technology (Lee and Scheufele 2006). Nanotechnology news coverage has been on the rise for the last two decades in mass media, and it has been most salient in newspapers over the last 10 years with 84% of stories occurring in print (Dudo et al. 2009). Additionally, people who claim familiarity with nanotechnology frequently cite newspapers as one of their main informational sources (Hart Research Associates 2007). Considering these trends, we pose our first hypotheses:

H1a: Attention to science coverage in newspapers will be positively related to factual knowledge about nanotechnology.
H1b: Attention to science coverage in newspapers will be positively related to general factual science knowledge.
H1c: Attention to science coverage in newspapers will be positively related to perceived familiarity with nanotechnology.

4.2 Television

Although most Americans use television as their primary source of science information, past research has shown that general television use has negative or no effects on science knowledge because time spent watching television displaces time that could be spent on better learning outlets (Nisbet et al. 2002; Shanahan et al. 1997). Consistent with these findings, general television use does not affect nanotechnology knowledge either (Lee and Scheufele 2006). Other research, however, has found that science television use is a positive predictor of general science knowledge (Brossard and Nisbet 2007). Although there are mixed findings concerning television use and science knowledge, this media channel may not be a strong predictor of nanotechnology knowledge simply because nanotechnology news is not covered on television. However, 7% of news coverage on nanotechnology over the last 10 years has been covered on television (Dudo et al. 2009). Those that say they are familiar with nanotechnology cite science television coverage as a helpful source of information (Hart Research Associates 2007). Considering these mixed findings regarding the effects of television use on public understandings of science, we propose the following research questions and hypothesis:

RQ2a: How does attention to television science coverage influence levels of factual knowledge about nanotechnology?
RQ2b: How does attention to television science coverage influence levels of general factual science knowledge?
H2: Attention to science coverage on television will be positively related to perceived familiarity with nanotechnology.

4.3 Internet

For many Americans, gaining knowledge about any topic is as simple as typing a few keywords in a search engine such as Google. Science media use on the internet attracts a wide range of ages in its users, whereas television and newspapers primarily attract older adults (Anderson et al. 2010). Searching for information online may be an excellent way to learn more about emerging technologies: 67% of people search online for specific scientific queries such as stem cell research (Horrigan 2006). Like stem cell research, nanotechnology is another specific, emerging science that can be easily found online. Online nanotechnology news stories have considerably increased over the past ten years, but they still have only accounted for 9% of nanotechnology news coverage, considering newspapers and television (Dudo et al. 2009). Even though nanotechnology news coverage may not be as prominent in the online environment as in newspapers, people are increasingly turning to the internet to learn about specific science issues. This is reflected by results that indicate that individuals who primarily use the internet as a source for science information have higher levels of general science and nanotechnology knowledge (Anderson et al. 2010; Lee and Scheufele 2006). The internet has also been identified as a primary source of information for those who report higher levels of perceived familiarity with nanotechnology (Hart Research Associates 2007). Based on the increase in internet use as a source for information about science and its possible effect on levels of knowledge about nanotechnology, we pose the following hypotheses:

H3a: Attention to science online will be positively related to general factual science knowledge.
H3b: Attention to science online will be positively related to factual knowledge about nanotechnology.
H3c: Attention to science online will be positively related to perceived familiarity with nanotechnology.

Finally, based on past research of the heuristic–systematic model and the discussion of the effects of mass media on public levels of scientific understanding, this study proposes the following hypotheses, which apply to factual knowledge:

H4a: Systematic processing of science media is positively related to general factual science knowledge.
H4b: Systematic processing of science media is positively related to factual nanotechnology knowledge.

5. Methodology

In order to examine these hypotheses and research questions, we examined data from the 2007 Public Awareness of Nanotechnology Study, a study aimed at better understanding public attitudes and knowledge about nanotechnology. Data for this study was collected in the period

15 February–27 July 2007, using both a listed household phone survey and random digit dialing to identify respondents. The total sample consisted of 1,105 US adults with an American Association for Public Opinion Research (AAPOR 2011) response rate of 30.60% (calculated using Formula 3).

5.1 Demographic variables

Based on the previous research on science knowledge and understanding (Corley and Scheufele 2010; Hart Research Associates 2007; Scheufele et al. 2009), we included three demographic controls in our hierarchical regression model: age, gender, and socio-economic status (SES). *Age* was measured from 18 to 96 years, where M indicates the median and SD the standard deviation (M = 55 years; SD = 16.41). Approximately 52% of the respondents were female. Our variable for *SES* was created by compiling an index of two variables: level of education and family income variables. Education was measured on an 8-point scale with 1 coded as 'never attended school or only attended kindergarten' and 8 coded as 'graduate degree' (M = 5 'college 1–3 years'; SD = 1.47). Total family income was measured on an 8-point scale with 1 coded as 'less than $10,000' and 8 as 'over $100,000' (M = 6 '$50,000–75,000'; SD = 1.97).

5.2 Attention to science media

Our indicator of *attention to science online* was measured on a 10-point scale with 0 coded as 'no attention,' 1 coded as 'little attention,' and 10 coded as 'very close attention.' Specifically, respondents were asked to rate their attention to 'content related to science and nanotechnology,' and 'content related to the social or ethical implications of emerging technologies.' These measures (Cronbach's alpha = 0.96) were averaged together to create a 10-point index (M = 3.31; SD = 2.95). *Attention to science in newspapers* was asking the same questions ('attention to newspaper content related to science and nanotechnology', and 'attention to newspaper content related to the social or ethical implications of emerging technologies') with a Cronbach's alpha of 0.94 (M = 4.57; SD = 2.83). *Attention to science on television* was also measured using the two variables measuring attention to media use ('attention to television content related to science and nanotechnology', and 'attention to television content related to the social or ethical implications of emerging technologies' (Cronbach's alpha = 0.90; M = 5.27; SD = 2.32).

5.3 Information processing variables

To measure *heuristic information processing*, respondents were provided with the statements, 'When I read or watch science stories in the news, I focus only on a few key points', and 'The media contain far more information about scientific issues than I currently need'. Responses were coded as 1 = do not agree at all and 10 = agree very much. These two variables were averaged together to create a 10-point index (Cronbach's alpha = 0.38; M = 4.95; SD = 2.12). Although the Cronbach's alpha is low, past research gives theoretical reason to combine these measures based on extensive focus group research when creating indices that included these two items (Griffin et al. 2002; Kahlor et al. 2006).

To measure *systematic information processing*, respondents were asked how much they agree with the statements, 'After I encounter news about a scientific development, I am likely to stop and think about it', and 'If I need to act on science information, the more viewpoints the media give me the better'. Again, responses were coded as 1 = do not agree and 10 = agree very much. These measures were averaged together to create a 10-point index (Cronbach's alpha = 0.61; M = 6.70; SD = 2.28).

5.4 Dependent variables

Factual nanotechnology knowledge was measured by combining a battery of six true or false questions about nanotechnology with 1 coded as 'true' and 0 coded as 'false'. These questions were summed together to create a 6-point additive index [0 = no questions answered correctly, 6 = all questions answered correctly; M = 3.87; SD = 1.44; KR-20 (Kuder-Richardson Formula 20) = 0.49]. The questions used were: (1) 'Nanotechnology involves materials that are not visible to the naked eye', (2) 'U.S. corporations are NOT using nanotechnology yet to make products', (3) 'Experts consider nanotechnology to be the next industrial revolution', (4) 'A nanometer is a billionth of a meter', (5) 'Nanotechnology allows scientists to arrange molecules in ways that do NOT occur in nature', and (6) 'A nanometer is about the size of an atom'.

General factual science knowledge was measured using a list of five true or false questions about regarding individuals' understanding of science as a subject. These questions were summed together to create a 5-point additive index (0 = no questions answered correctly, 5 = all questions answered correctly M = 3.18; SD = 1.36; KR-20 = 0.47). The questions included in the general science knowledge battery were (1) 'Lasers work by focusing sound waves', (2) 'Antibiotics kill viruses as well as bacteria', (3) 'Electrons are smaller than atoms', (4) 'Ordinary tomatoes do not contain genes while genetically modified tomatoes do', and (5) 'More than half of human genes are identical to those of a chimpanzee'. Finally, *perceived nanotechnology familiarity* was measured using a 10-point scale where respondents were asked, 'How well informed you would say you are about nanotechnology' where 1 = not informed at all and 10 = very informed (M = 2.79; SD = 1.99).

6. Results

We tested our hypotheses using ordinary least squares (OLS) hierarchical regression with *general factual science knowledge, factual nanotechnology knowledge, and perceived familiarity with nanotechnology* as the dependent variables in three different models. The independent variables were entered into blocks in order to assess the relative influence of each variable block on our dependent variable, above and beyond previously entered blocks. The first block included the demographic variables of *age, gender, SES*. The second added the media use variables of *attention to science online, attention to science on television,* and *attention to science in newspapers*. The third block added the systematic processing variables of *systematic processing* and *heuristic processing*. Finally the fourth block compared each of the dependent variables of scientific understanding including *general factual science knowledge, factual nanotechnology knowledge,* and *perceived familiarity with nanotechnology*.

6.1 Model 1: Predicting general factual science knowledge

Overall, 24.5% of the variance for factual science knowledge was explained by this regression model. The demographic block of the model explained 16.7% of the total variance of this regression model. As shown in Table 1, younger adults ($\beta = -0.11$; $p < 0.001$) and individuals with higher socio-economic status ($\beta = 0.26$; $p < 0.001$) are more likely to have greater levels of general factual science knowledge. However, beta coefficients for both age and SES decreased slightly as variables were added to the model, suggesting possible mediating effects of media use and information processing.

Attention to science news in newspapers and online were the only media predictors of general factual science knowledge ($\beta = 0.08$; $p < 0.05$ and $\beta = 0.08$; $p < 0.05$), giving support to Hypotheses 1b and 3b. However, it should be noted that attention to science in newspapers and attention to science online became non-significant after the information processing and scientific understanding variables were added to the regression, respectively (see Table 1). Television was not a significant predictor of general factual science knowledge, answering Research Question 2b. Overall, the media use variables accounted for 2.3% of the total variance.

Both systematic ($\beta = 0.12$; $p < 0.001$) and heuristic processing ($\beta = -0.11$; $p < 0.001$) of science media were significant predictors of general factual science knowledge. Systematic processing was a positive predictor of general factual science knowledge, which indicates that individuals who process information systematically are more likely to have higher levels of factual science knowledge, and

Table 1. Predictors of general factual science knowledge

	Model 1	Model 2	Model 3	Model 4
Demographics	β	β	β	β
Age	−0.16 (−0.01)***	−0.16 (−0.01)***	−0.15 (−0.01)***	−0.11 (−0.01)***
Sex (female = 1)	0.03 (0.08)	0.02 (0.05)	0.02 (0.05)	0.01 (0.02)
SES	0.33 (0.31)***	0.28 (0.26)***	0.26 (0.24)***	0.26 (0.24)***
Incremental R^2 (%)				16.7
Attention to science in media				
Newspaper		0.08 (0.04)*	0.07 (0.03)	0.05 (0.03)
Television		0.03 (0.02)	0.00 (0.00)	−0.02 (−0.01)
Internet		0.10 (0.05)**	0.08 (0.04)*	0.04 (0.04)
Incremental R^2 (%)				2.3
Information processing				
Systematic			0.14 (0.08)***	0.12 (0.07)***
Heuristic			−0.09 (−0.06)**	−0.10 (−0.07)***
Incremental R^2 (%)				2.0
Scientific understanding				
General factual science				N/A
Factual nanotechnology				0.18 (0.17)***
Familiarity				0.06 (0.04)
Incremental R^2 (%)				3.5
Total R^2 (%)				24.5

Entries are standardized regression coefficients.
Unstandardized regression coefficients are in parenthesis.
***$p \leq 0.001$; **$p \leq 0.01$; *$p \leq 0.05$.

thereby supporting Hypothesis 4a. Oppositely, heuristic processing had a negative effect on the dependent variable, implying that individuals who rely more upon heuristics are less likely to be factually knowledgeable about science. Beta coefficients for systematic processing decreased slightly and coefficients for heuristic processing increased slightly as scientific understanding variables were added to the model, suggesting a possible mediating effect from other types of scientific understanding. Overall, the information processing variables accounted for about 2% of the total variance.

Finally, factual knowledge of nanotechnology was significantly related to general factual science knowledge ($\beta = 0.18$; $p < 0.001$) and the scientific understanding block accounted for 3.5% of the total variance.

6.2 Model 2: Predicting factual nanotechnology knowledge

This regression accounted for about 14.2% of the overall variance found in factual nanotechnology knowledge. As shown in Table 2, younger adults ($\beta = -0.15$; $p < 0.001$) were more likely to have higher levels of factual knowledge regarding nanotechnology. Similarly, *SES* was a positive and significant predictor of factual nanotechnology knowledge ($\beta = 0.11$; $p < 0.01$), but this result became non-significant once the media and knowledge variables were added to the regression. Overall, the demographic block of this model accounted for about 6.2% of the total variance in this regression.

Attention to science on the internet was positively related to factual nanotechnology knowledge ($\beta = 0.10$; $p < 0.05$), providing support for Hypothesis 3a. The internet beta coefficient decreased as the information processing and scientific understanding variables were added to the regression, again suggesting a mediating effect. Attention to scientific television and newspaper coverage, however, had no influence on factual levels of knowledge about nanotechnology, thereby causing us to reject Hypothesis 1a and providing subsequent insight into the relationship between television use and factual knowledge about nanotechnology (see Research Question 2a). Overall, the media use variable block accounted for 2.7% of the total variance.

Systematic processing of science media was a positive and significant predictor of factual nanotechnology knowledge providing support for Hypothesis 4b. However, it should be noted that this result became non-significant after scientific understanding variables were added to the model ($\beta = 0.09$; $p < 0.05$). Heuristic processing of science media became a significant indicator of factual nanotechnology knowledge after adding the

Table 2. Predictors of factual nanotechnology knowledge

	Model 1	Model 2	Model 3	Model 4
Demographics	β	β	β	β
Age	−0.20 (−0.02)***	−0.18 (−0.02)***	−0.19 (−0.02)***	−0.15 (−0.01)***
Sex (female = 1)	0.02 (0.05)	0.01 (0.03)	0.02 (0.05)	0.00 (−0.01)
SES	0.11 (0.10)**	0.04 (0.04)	0.03 (0.03)	−0.003 (−0.02)
Incremental R^2 (%)				6.2
Attention to science in media				
Newspaper		0.04 (0.02)	0.04 (0.02)	0.02 (0.01)
Television		0.02 (0.00)	0.00 (0.00)	−0.03 (−0.02)
Internet		0.15 (0.07)***	0.14 (0.07)**	0.10 (0.05)*
Incremental R^2 (%)				2.7
Information processing				
Systematic			0.09 (0.06)*	0.05 (0.03)
Heuristic			0.05 (0.03)	0.07 (0.05)*
Incremental R^2 (%)				1.0
Scientific understanding				
General factual science				0.21 (0.22)***
Factual nanotechnology				N/A
Familiarity				0.10 (0.07)**
Incremental R^2 (%)				4.3
Total R^2 (%)				14.2

Entries are standardized regression coefficients.
Unstandardized regression coefficients are in parenthesis.
***$p \leq 0.001$; **$p \leq 0.01$; *$p \leq 0.05$.

scientific understanding variables, also suggesting a mediating effect (β = 0.07; $p < 0.05$). Overall, the information processing variables accounted for 1.0% of the total variance.

Finally, general factual science knowledge (β = 0.21; $p < 0.001$) and perceived familiarity with nanotechnology (β = 0.10; $p < 0.01$) were both indicators of factual nanotechnology knowledge, and the scientific understanding block accounted for 4.3% of the total variance.

6.3 Model 3: Predicting perceived familiarity with nanotechnology

Our third regression model accounted for 27.8% of the variance in perceived nanotechnology familiarity. As shown in Table 3, gender is a positive and significant indicator of perceived familiarity. This result indicates that men's perceptions of their own familiarity about nanotechnology are higher than women's (β = 0.15; $p < 0.001$). *SES* was also a positive indicator of perceived familiarity (β = 0.11; $p < 0.01$), however, this result became non-significant after adding the subsequent blocks to the model. Overall, the demographic block of Model 3 accounted for 6.5% of the total variance in this regression.

All three media use variables were positive predictors of perceived familiarity about nanotechnology in the third regression model, which supports Hypotheses H1c, H2c, and H3c. Although attention to science in newspapers was initially significant upon entry (β = 0.07 in model 3; $p < 0.01$), it became non-significant after adding the scientific understanding variables to the model. Both attention to science on television (β = 0.27; $p < 0.001$) and attention to science online (β = 0.21; $p < 0.001$) were positively related to perceived nanotechnology familiarity. Overall, the media use variables accounted for 20.1% of the total variance.

Neither systematic nor heuristic processing of science media was a significant indicator of perceived familiarity with nanotechnology. Both of the information processing variables accounted for about 0.1% of the total variance in our dependent variable. Finally, factual knowledge about nanotechnology was a positive predictor perceived familiarity with nanotechnology (β = 0.08; $p < 0.01$), suggesting that individuals with higher levels of factual knowledge about nanotechnology were also likely to perceive their own familiarity as high. The scientific understanding variables accounted for an additional 1% of the total variance.

7. Discussion

The purpose of this study was twofold. First, we were interested in the continued use of measures of perceived

Table 3. Predictors of perceived familiarity with nanotechnology

	Model 1	Model 2	Model 3	Model 4
Demographics	β	β	β	β
Age	−0.04 (0.01)	−0.04 (−0.01)	−0.04 (0.00)	−0.01 (0.00)
Sex (female = 1)	0.17 (0.69)***	0.15 (0.59)***	0.15 (0.59)***	0.15 (0.58)***
SES	0.15 (0.21)***	−0.01 (−0.01)	0.01 (−0.01)	−0.03 (−0.01)
Incremental R^2 (%)				6.5
Attention to science in media				
Newspaper		0.07 (0.05)*	0.07 (0.05)*	0.06 (0.05)
Television		0.28 (0.23)***	0.27 (0.23)***	0.27 (0.23)***
Internet		0.23 (0.16)***	0.23 (0.16)***	0.21 (0.15)***
Incremental R^2 (%)				20.1
Information processing				
Systematic			0.04 (0.03)	0.02 (0.02)
Heuristic			−0.02 (−0.02)	−0.02 (−0.02)
Incremental R^2 (%)				0.1
Scientific understanding				
General factual science				0.06 (0.08)
Factual nanotechnology				0.08 (0.11)**
Familiarity				N/A
Incremental R^2 (%)				1.0
Total R^2 (%)				27.8

Entries are standardized regression coefficients.
Unstandardized regression coefficients are in parenthesis.
***$p \leq 0.001$; **$p \leq 0.01$; *$p \leq 0.05$.

familiarity and factual knowledge as proxies for one another within current social research regarding public attitudes toward science and emerging technologies. As argued earlier, using these measures interchangeably could have very important effects on science policy outcomes (Bauer et al. 2000; Laugksch 2000).

Our second goal, therefore, was to compare traditional measures of general factual science and factual nanotechnology knowledge to measures assessing perceived familiarity with nanotechnology. Based on the literature outlined earlier, it is reasonable to assume that although related, these two measurements are assessing two very different dimensions of scientific understanding and should be used independently in future research. Our results supported this argument in showing that measures of an individual's knowledge about nanotechnology and perceived familiarity with nanotechnology do not reflect the same underlying knowledge structures, as indicated by both a low correlation coefficient (Pearson's $R = 0.187$; $p < 0.01$) and differences between the predicting variables across our three models. Because this data found that perceived familiarity and factual knowledge fundamentally differ from each other and to clearly demarcate the line between the two measures, this discussion refers to self-reported measures of scientific understanding strictly as 'perceived familiarity' as opposed to 'self-reported knowledge' or 'perceived knowledge,' as seen in past research mentioned in the literature review.

However, before discussing these results in more detail, it is important to note some limitations of this study. As outlined earlier, we relied on the 2007 Public Awareness of Nanotechnology Study. Using a nationally representative survey allowed us to examine the relationships between different types of science understanding with a high degree of external validity. At the same time, however, using a secondary data set limited us with respect to the measures available for each of the concepts we were interested in.

First, we recognize that scholars across the fields of political science, sociology, and communication have criticized the use of factual knowledge questions as indicators of an individual's understanding of public issues (Brossard and Shanahan 2006). Specifically, researchers have argued that these types of factual knowledge questions can only assess a narrow scope of understanding and do not allow for an adequate representation of the variance in knowledge found in the actual population. Similarly, the true and false questions used in the survey were subjectively defined by a group of science experts and, therefore, reflect what the experts believe to be the required facts that public must understand in order to be scientifically literate. Alternatively, Miller (1998) contends that traditional, factual measures of scientific knowledge are preferable to other measures because of survey time and space constraints. A set of items examining core scientific constructs may have durability of validity over time, and such measures have been incorporated in many surveys examining scientific literacy (Laugksch and Spargo 1996; Miller 1998) Although use of these measures has been debated, the use of these survey items provided us with a unique opportunity to examine the continuing trend of using perceived familiarity measures as a replacement of more traditional factual knowledge questions in the context of the knowledge deficit model.

Second, as indicated in Table 2, our regression model predicting factual knowledge of nanotechnology only accounted for 14.2% of the variance in the dependent variable. This weak prediction may be explained by the unique nature of nanotechnology as both a new and difficult subject to discuss in the mass media. As a result, the public may not be as well informed about nanotechnology as other past emerging technologies. Future research should consider examining alternative predictors of factual knowledge about nanotechnology, such as interpersonal discussion or entertainment media. This inclusion of a wider variety of predictors in future models may shed light upon any alternative ways that individuals may be finding out about nanotechnology.

Keeping these limitations in mind, there are still a number of conclusions that can be drawn from our analyses. In regards to Hypothesis 1a, our results indicated that science newspaper use was not a significant predictor of factual knowledge about nanotechnology. This is a particularly interesting finding considering the extensive coverage that nanotechnology has received in daily newspapers over the last decade as opposed to other media outlets (Dudo et al. 2009). It is possible that this result is related to the roadblocks that readers may encounter when reading through a newspaper's more linear formatting. For instance, the dense nature of a newspaper page may cause readers to overlook information about nanotechnology, and instead rely on skimming through the headlines and lead paragraphs. Although previous studies have indicated that attention to science in newspapers is positively related to factual knowledge about nanotechnology (Lee and Scheufele 2006), our findings suggest that that relationship may be changing. This finding has particularly important implications for policy-makers, who must continue to engage newspaper audiences in order to encourage more active information seeking and decision-making.

Although television did not significantly predict factual knowledge about nanotechnology, it was a significant predictor of perceived familiarity with nanotechnology (supporting Hypothesis 2). As previously mentioned, people often believe that they know more about nanotechnology when they pay more attention to science stories from television (Hart Research Associates 2007). Looking at our results, television was also the strongest indicator of perceived nanotechnology familiarity. As mentioned earlier, people who have higher levels of perceived familiarity about nanotechnology often cite television as one of their main information sources, referencing science channels such as the Discovery Channel (Hart Research Associates 2007). Considering that attention to science on television only influenced perceived familiarity with nanotechnology and not factual nanotechnology knowledge, this finding supports previous research that argues that while television may be the most attention-grabbing medium, it may not be especially influential in informing the public about science issues (Gerbner et al. 2002; Shanahan et al. 1997).

As proposed by Hypothesis 3b, our results indicated that attention to science media online was a positive and significant predictor of factual knowledge about nanotechnology. Although online nanotechnology news has only comprised about 9% of total nanotechnology-related news in mass media over the last ten years (Dudo et al. 2009), this result confirms previous research arguing that attention paid to science on the internet is related to factual knowledge about nanotechnology (Anderson et al. 2010; Lee and Scheufele 2006). One possible explanation for this relationship may be related to the hyperlinked nature of the internet. In comparison to more traditional media, the interactive structure of the internet allows users to more easily connect bits of factual information together in order to create a more dense understanding of nanotechnology. These results support this argument and clearly indicate that the internet is an excellent resource for individuals who are trying to learn about science and nanotechnology. Considering this, as the topic of nanotechnology continues to be covered more extensively in the online environment, future research should focus more closely on its unique effect on knowledge acquisition.

Our findings also showed that systematic processing was positively related to general factual science knowledge and factual nanotechnology knowledge. This suggests that individuals who are more likely to scour news sources for science information are also likely to retain more factual knowledge. Oppositely, our result indicated that individuals who rely on heuristic processing through the use of cognitive shortcuts have lower levels of factual science knowledge (see Table 1). Interestingly, heuristic processing of science media was positively related to factual nanotechnology knowledge. This finding may be related to the newness of nanotechnology as an issue in media coverage. Because information regarding the risks and benefits of nanotechnology and related consumer products is still unclear, journalists may be relying heavily on facts provided by scientists and academic elites when covering nanotechnology-related issues. As a result, citizens who rely on media frames as cognitive shortcuts may be more aware of these bits of factual information, thereby increasing their ability to respond to factual knowledge questions more accurately.

Finally, and most importantly, our data analysis shows that measurements of perceived familiarity with nanotechnology and factual nanotechnology knowledge, although slightly correlated, do not measure the same underlying knowledge constructs (see Tables 2 and 3). Logically this finding makes sense: objective testing is employed throughout many facets in life because relying on an individual's self-assessment is insufficient. For instance, a student's self-reported familiarity about a class topic may not be an accurate assessment of how much that student learned in a class. Similarly, we employ driving tests as social requirements for eligibility to obtain a driving license as opposed to merely relying on an individual's word. Our analysis provides empirical support for these societal mores. Specifically, our findings indicated that a number of predictors varied in their effects on our three dependent variables. For example, television use and maleness were significant predictors of perceived familiarity with nanotechnology, but did not predict factual knowledge. Similarly, our results indicated that younger audiences were more likely to have higher levels of factual knowledge about nanotechnology, but age was not a significant predictor of perceived familiarity. Taking these predictors into account, factual nanotechnology knowledge can be thought of as a recollection of past knowledge based on age, attention to media, and information processing style. Alternatively, perceived familiarity with nanotechnology is a reflection of past knowledge augmented by other factors not necessarily related to nanotechnology knowledge acquisition, such as one's gender and attention to science on television.

Considering the heavy reliance on self-reported measures of science knowledge as a proxy of factual measurements of knowledge, as discussed above, our findings clearly indicate that these measures cannot be used interchangeably in survey research and scholars should refrain from using them in this manner. Additionally, our findings mirror results put forth in previous domains of research regarding measures self-assessment, including the areas of health, education, psychology, and sociology (DePaulo et al. 1997; Hansford and Hattie 1982; Mabe and West 1982). Therefore, our results not only support previous findings that claim that perceived familiarity provides inappropriate assessments of factual knowledge levels, but they also direct scholars to strengthen communication between fields and encourage interdisciplinary approaches to future investigations of public knowledge.

8. Conclusions

Our analyses show that mass media messages continue to influence individuals' underlying knowledge processes differently, which may subsequently influence levels of science understanding. Specifically, this study highlights the importance of the internet in disseminating information about nanotechnology and science. An analysis comparing identically worded survey data from 2004 and the 2007 data utilized in this study has shown that, although there is a widening gap in factual nanotechnology knowledge levels between those of high and low socioeconomic status, internet use among low-education individuals is closing that gap, allowing them to catch up to those with higher education (Corley and Scheufele 2010). This shows that even in the topic's early stages, it is clear that internet coverage of nanotechnology is resonating with individuals across social strata. Considering the reduction in spending on nanotechnology education by the US government, the internet could be a crucial tool in increasing the general public's level of science literacy (Corley and Scheufele 2010). This increase could then lead to better communication between researchers and the public, more substantive discussion, and more informed policy decision.

As mentioned before, the familiarity hypothesis echoes the knowledge deficit model with the exception that familiarity with nanotechnology, as opposed to factual knowledge, will lead to public support (Bodmer 1985; Cobb and Macoubrie 2004; Hart Research Associates 2006, 2007; Kahan et al. 2009; Macoubrie 2006; Miller 1998, 2004; Miller et al. 2006). Under this assumption, science education policy should focus on top-down education. However, past research has shown that this link between understanding and support of emerging technologies is mediated by various heuristics such as religiosity, political ideology, deference to scientists, and media frames (Brossard et al. 2009; Lee and Scheufele 2006; Nisbet et al. 2002). Additionally, research has shown that individuals in the USA are less likely to believe that nanotechnology is morally acceptable than Europeans, which is directly related to aggregate levels of religiosity among the various countries studied (Scheufele et al. 2009). These findings suggest that science education policy-makers need to reassess a uniform education policy and cater outreach to different social groups that are characterized by various heuristics (Brossard et al. 2009). Some sub-publics attitudes' concerning emerging technologies are shaped not merely by issue-specific knowledge, but by their defining value predispositions.

Considering the findings of this study—that perceived familiarity with nanotechnology is influenced by specific heuristics; and that those heuristics do not influence factual nanotechnology knowledge (i.e. gender and media frames of television and, to some extent, newspapers)—factual knowledge and perceived familiarity unmistakably tap into two distinct dimensions of understanding. And these constructs may subsequently have very different effects on public support. Taking these results into account, it is important that future research differentiates between these measures of knowledge in order to report more exact assessments of public levels of understanding science and nanotechnology. Similarly, policy-makers should consider the unique nature of each of these measures before implementing science or educational policy.

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