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Protection Motivation and Communication through Nano-Food Labels: Improving Predictive Capabilities of Attitudes and Purchase Intentions toward Nano-Foods

Christopher L. Cummings¹, Agnes S. F. Chuah¹ and Shirley S. Ho¹

Abstract

The development and use of nanotechnology in the food industry (nano-food) has grown steadily. While visions for nano-food suggest that the applications will improve quality and safety, they are also controversial for several reasons, including potential health risks coupled with difficulty in assessing low-dosage nanoparticle risks, as well as value-based objections. In recent years, debate over nano-foods has led to inquiry of many factors that seek to predict public attitudes and purchase intentions. Such studies have investigated the roles of demographics and sociographics, value predispositions toward science and technology, preferences for natural products, trust in regulatory agencies, science knowledge, and media attention. This study assesses the role of each of these factors and improves the predictive models by evaluating concepts from Protection Motivation Theory. Findings demonstrate that the incorporation of threat- and coping-appraisals provide the most predictive models to date with regards to attitudes and purchase intentions of nano-food products.

Keywords: Nano-food, food labels, risk, protection motivation

¹ Wee Kim Wee School of Communication and Information, Nanyang Technological University, Singapore, Singapore

Corresponding Author:

Christopher L. Cummings, Wee Kim Wee School of Communication and Information, Nanyang Technological University, Singapore, Singapore.

Email: ccummings@ntu.edu.sg

When applied to food, the use of emerging technologies often evokes controversy with regard to safety and ethical standards of application (Yue, et al. 2015). The development and use of various nanotechnology applications in the food industry (nano-food) have been growing steadily in recent years (Zhou 2013). Globally, the food industry is worth well over US\$4 trillion annually (Murray 2007), and efforts to improve the quality and safety of food through the use of nanotechnology is significant. The global market value for nano-enabled food products was estimated to be around US\$20 billion in 2010, and nano-food developments are led by the USA, followed by Asian countries who are expected to be the biggest future market for such food products (Helmut Kaiser Consultancy 2004). In its entirety, nanotechnology is projected to have a global impact of around \$1 trillion by 2020 (Roco et al. 2010).

Nanotechnology is the application of engineered particles that fall within 1 to 100 nanometers in at least one dimension. These particles are included into consumer goods to serve potentially useful purposes. While not as prevalent as the use of genetic modification in food, nano-food applications are developing rapidly and have been proposed for use or are currently being used to improve food production, food processing, food packaging, shelf-life, nutrition, and taste (Shi et al. 2005; Chaudhry, Castle and Watkins 2010; Chaudhry et al. 2008; Smolander and Chaudry 2010; Chaudry and Castle 2011; Weiss, Takhistov and McClemens 2006). While visions for nano-food suggest that the applications will improve product quality and safety, such food technologies are also likely to be controversial for several reasons, including potential long-term environmental and human health risks coupled with difficulty in assessing low-dosage nanoparticle risks, as well as value-based objections (Oberdörster, Oberdörster and Oberdörster 2005; Besley et al. 2008; Bouwmeester et al. 2009; NRC 2009).

Background and Literature Review

While nano-foods are being developed for use around the world, media coverage of nanotechnology and public understanding of nanotechnology remain low, with a majority (62%) of Americans reporting they have only heard the term “nanotechnology” or knowing nothing about nanotechnology at all (Dudo et al. 2011; Harris 2012). Yet, even without a high-level of understanding about science or nanotechnology, consumers are faced with making potential health decisions about the products they consume (Berube et al. 2010).

Studies have been conducted to assess risk perceptions of nanotechnology and nano-foods in order to better prepare for future health and risk communication and governance. Berube et al. (2011) found that nanoparticle risk perceptions are low when compared to other potential health and safety risks, placing 19th out of 24 hazards ranging from nuclear waste, chemical pollution, to drinking alcohol, blood transfusions, and cell phone use. Stampfli et al. (2010) noted that willingness to buy (WTB) nano-food was more strongly influenced by perceived benefits and lesser so by perceived risks of the product. Yue et al. (2014) noted that US consumers are generally willing to pay (WTP) more to avoid nano-foods, but there is a higher premium in avoiding GM foods than avoiding nano-food. Some studies have also noted that consumers often make use of values-based judgments when considering nano-food products and that a majority of consumers are reluctant to consume nano-foods but support greater information about nano-foods and would also favor labelling initiatives (Brown and Kuzma 2013).

Nucci and Hallman (2015) noted that while nanotechnology is revolutionizing food packaging, the success of such promising technologies hinge upon public perceptions and concerns, and that communication about new developments are likely to play a significant role in public support for legislation and policy regarding the future of nano-food applications. Others have echoed a similar sentiment that individuals make risk decisions

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about nanotechnology even without a great of knowledge in the area and that scholarly understanding of perceptions and risk attitudes toward nanotechnology products are crucial for future health and risk communication initiatives and can inform health campaigning, public engagement initiatives, and decision-making (Berube et al. 2010).

It is from this premise that the current study seeks to expand on previous findings and evaluate how people come to make decisions about nano-foods; both in forming attitudes about nano-food applications, and regarding their intentions to purchase nano-foods. We investigate the influence of many factors that have been previously examined, and we significantly improve upon previous predictive models by evaluating the role of the two major concepts from Protection Motivation Theory (PMT); threat- and coping- appraisal (Rogers 1975). Specifically, this study uses a representative sample of Singaporean adults to investigate the degree to which various antecedent personal characteristics, value predispositions, and motivations predict attitudes and purchase intentions of nano-food products.

The existing literature on public attitudes regarding nano-food is complex and includes a variety of investigated factors. We include these factors in our predictive models in order to granularly assess the role of each factor and to investigate their comparative influences. Following the review of previous used factors, we provide information about our novel addition of threat and coping appraisal into the predictive models.

Value Predispositions toward science and technology

Attitudes and purchase intentions of nanotechnology applications in the food industry are likely to be influenced by individual beliefs about the broader enterprises of scientific and technological application in general (Yue, et al. 2015). Technocratic beliefs refer to individuals' value predisposition toward the use of technology for improving daily life. Individual evaluations of emerging technologies seem to rely on such value predispositions in

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concert with other factors like personal knowledge about the technology itself (Siegrist, et al. 2007).

Similarly, publics' attitude toward nanotechnology is also affected by their personal values and knowledge. However, when there is a lack of knowledge about nanotechnology, the general technocratic belief could affect attitude toward nanotechnology (Siegrist, et al. 2007). Siegrist (2007) suggested that technocratic belief can be divided into two factors – technology benefits and technology fears. Studies found that technocratic belief affected nanotechnology risk perception among laypersons but not among experts (Siegrist 2007). In addition, Stampfli and colleagues (2010) revealed that perceived technocratic belief was positively associated with perceived benefit of nanotechnology application, predicting the willingness to buy nano-product. Based on the literature above, we propose that technocratic belief could predict attitude toward nano-food applications and intention to purchase nano-food.

H1a: Technocratic belief is positively associated with attitude toward nano-food applications.

H1b: Technocratic belief is positively associated with intention to purchase nano-food.

Deference to Scientific Authority

Deference to scientific authority refers to the trust in scientific leaders and institutions to make decisions that impact society (Ho, Brossard and Scheufele 2008). This trust in the scientific community notes that some members of society are likely to defer to domain-specific expertise with regard to the use of a particular technology (Lee and Scheufele 2006). Deference to scientific authority may function as a decision heuristic that causes individuals to swiftly process or disregard mediated information when judging the new technology (Kim, et al. 2014). Deference to scientific authority has been demonstrated to contribute to public

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support for nanotechnology (Ho, et al. 2010; Lee and Scheufele 2006, Liang, et al. 2015) as well as to influence risk and benefit perceptions of nano-foods (Siegrist, et al. 2008). It follows that this study would similarly expect to find deference to scientific authority is positively associated with attitudes toward nano-food applications and intentions to purchase nano-food. Our second set of hypotheses is as follows:

H2a: Deference to science authority is positively associated with attitude toward nano-food applications.

H2b: Deference to science authority is positively associated with intention to purchase nano-food.

Value Predispositions toward food

Besides deference to scientific authorities, previous studies have evaluated the role of trust in regulatory agencies with regard to public attitudes and intentions toward emerging science and technology (e.g. Brossard and Nisbet 2006; Stampfli, Siegrist and Kastenholz 2010; Siegrist, et al. 2007a; Siegrist, et al. 2007b; Siegrist, et al. 2008). For example, researchers found that trust in biotechnology sponsors, such as government officials, industry representatives, and university scientist, positively affected the support for agricultural biotechnology (Brossard and Nisbet 2006). In the context of nanotechnology, Yue and colleagues (2015) found that trust in governing agencies to manage food technologies did not influence labelling preferences for either nano-foods or genetically modified food products, but that it did influence risk attitudes about the food technologies themselves. These findings were in line with Stampfli and colleagues (2010) who they found that social trust was positively associated with perceived benefit of nanotechnology applications and negatively associated with perceived risk of nanotechnology applications. They illustrated that people who have little experience with nano-food are more likely to rely on information made by industry and regulatory agencies, especially when they are considering purchase intentions of

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nano-food (Stampfli, et al. 2010). Thus, we hypothesize that increased trust in information provided by regulatory agencies will be positively associated with attitudes and purchase intentions of nano-foods:

H3a: Trust in regulatory agencies is positively associated with attitude toward nano-food applications.

H3b: Trust in regulatory agencies is positively associated with intention to purchase nano-food.

Preference for natural products

Moral and ethical concerns about the use of technology in the food industry have led to growing preferences for natural and organic food products worldwide (Anderson, Wachenheim and Lesch 2006). Some researchers have found that individuals are more hesitant to purchase foods with health benefits due to nanotechnology additives (Siegrist et al. 2009). They argued that “perceived naturalness” of food products is a significant factor that influences willingness to purchase nano-foods. Studies have also noted that perceived naturalness affects the manner in which people perceived nanotechnology where those of have a pre-existing preference for natural products tend to have a higher risk perception of nano-food than those who report no preference (Stampfli et al. 2010). Extending previous results studies, we propose the following hypotheses:

H4a: Preference for natural products is negatively associated with attitude toward nano-food applications.

H4b: Preference for natural products is negatively associated with intention to purchase nano-food.

Science knowledge

In addition to values predispositions and preference of natural products, science knowledge has been previously considered as a factor contributing to attitudes and purchase intentions of nano-foods. Studies have noted that experts have significantly lower risk perceptions of nanotechnology as compared to nonexperts (Ho, Scheufele and Corley 2010; Siegrist, et al. 2007a) and this difference is likely to be due to the disparate levels of knowledge about nanotechnology (e.g. Lee and Scheufele 2006; Liang, et al. 2015). Liang and colleagues (2015) found that specific knowledge about nanotechnology positively predicted public support for nanotechnology funding in Singapore but not in United States. They found that Singaporeans are more knowledgeable and familiar with nanotechnology leading to higher support for nanotechnology funding as compared to Americans (Liang, et al. 2015). However, scant research focus on the effect of general science knowledge on the attitudes and toward nano-food applications and intention to purchase nano-food. Instead, Lee and colleagues (2005) found that science knowledge was associated with the support for nanotechnology. However, Ho, Scheufele, and Corley (2010) found that science knowledge did not predict the support for federal funding of nanotechnology. As nano-food is new in the food industry and public's acceptance remains an unknown, it is important to further examine the effect of science knowledge on the intention to purchase nano-food. Lee and Scheufele (2006) suggested that more studies should also be conducted to examine the change of the relationship between knowledge and attitude toward nanotechnology over time. Hence, the present study includes a general science knowledge block as a potential predictive factor of attitudes and purchase intentions by proposing the following hypotheses:

H5a: Science knowledge is positively associated attitudes toward nano-food applications.

H5b: Science knowledge is positively associated with intention to purchase nano-food.

Media Attention

Research has shown that media is the primary source of information about science and technology among the public (Friedman, Dunwoody and Rogers 1986; Gregory and Miller 1998). Based on the agenda-setting effect (McCombs 2013) and framing effect (Tewksbury and Scheufele 2009), media messages can influence the perceived importance of an issue among the audience as well as shape their attitudes toward the topic, respectively.

Results have indicated that newspaper coverage of nanotechnology has been predominantly positive in tone (Anderson, et al. 2009; Lewenstein, Gross and Radin 2010; Kjølberg 2009), in which its benefits were often highlighted as outweighing its risks (Anderson and Anderson 2009; Laing 2005; Stephens 2005). Other studies have demonstrated that nanotechnology is more often framed in terms of scientific discovery, science fiction, and business rather than in terms of risk (Anderson, et al. 2005; Faber, Mackinnon and Petroccione 2005; Te Kulve 2006).

Food packaging which utilises nanotechnology has frequently been reported in the media to be more beneficial than foods which similarly utilises nanotechnology (Siegrist, et al. 2007b; Siegrist, et al. 2008). In the U.K., media coverage of nanotechnology reports a mix of optimism about the benefits of nanoscience and anxiety about its potential risks associated with nano-food (Wilkinson, et al. 2007), while the U.S. coverage tends to be more positive in tone overall (Friedman and Egolf 2011; Gaskell, et al. 2005; Stephens 2005). Similarly, news stories in the Netherlands and Denmark has predominantly covered the positive and beneficial aspects of nano-food (Kjærgaard 2008; Te Kulve 2006). Given the fact that empirical studies have shown that the tone of media coverage of nano-food can shape public acceptance of nano-food (Gaskell, et al. 2005), public attitude to media messages might be a factor influencing consumers' attitude toward nano-foods in Singapore. Hence, we propose the following hypotheses:

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H6a: Attention to food safety news is positively associated with attitude toward nano-food applications.

H6b: Attention to food safety news is positively associated with intention to purchase nano-food.

H7a: Attention to nano news is positively associated with attitude toward nano-food applications.

H7b: Attention to nano news is positively associated with intention to purchase nano-food.

Protection Motivation and Nano-Foods

Protection motivation is the term used to refer to individuals' motivations to engage in protective, adaptive behaviours when confronted with messages that may put them at "dis-ease." PMT was developed to explain and predict the effects of potential threats on health attitudes and behaviors (Rogers 1975). PMT is organized along two cognitively mediated processes: threat appraisal and coping appraisal (Floyd, Prentice-Dunn and Rogers 2000). Each process is comprised of two components. Threat appraisal evaluates 1) severity of the potential threat; the degree to which an individual believes they will be harmed if they experience the threat, and 2) vulnerability to the threat; the perceived likelihood or Probability that the individual believes they will experience the potential threat. The process of threat appraisal is dependent upon both features: as both threat severity and vulnerability increase, there is an expected increase in the individuals' motivation to protect themselves from the potential threat.

Coping appraisal, often referred to as efficacy appraisal, is also comprised of two components. Coping appraisal evaluates 1) response-efficacy; the degree that a behavior would be efficacious in diminishing a potential threat, and 2) self-efficacy; the degree to which an individual feels capable of performing a behavior to diminish a potential threat.

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Like threat appraisal, coping appraisal is also dependent on these two components and PMT notes that as both response-efficacy and self-efficacy increase, so too should protection motivation. The culmination of both threat- and coping appraisals is referred to as “protection motivation” which is theorized as a primary antecedent of intention, and ultimately of behavior. Figure 1 below provides a visual organization of PMT.

Figure 1: Protection Motivation Theory

Previous studies have demonstrated that some members of the public are wary of nano-food and would place such consumer products somewhere between the range of “safe” and “unsafe.” This notes that some members of the public view nano-foods as a potential threat, while others do not. Similarly, coping appraisal regarding the response- and self-efficacious use of nano-labels is likely to be different among the population. While yet

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untested in this area, we believe that threat- and coping appraisal are likely to have significant bearing on how people come to feel about nano-food purchase intentions, as well as how they feel about labelling and governance options regarding nano-foods. We note that in this case, where the “jury is still out” regarding nano-foods and public sentiments, it is best to attempt to maximize our scholarly understanding on how people come to make sense of nano-foods, and thus we proposed a research question along with our hypotheses to guide our inquiry:

RQ: What influence does threat- and coping- appraisal have on (a) attitudes of nano-food applications and (b) purchase intentions regarding nano-food?

To date, this is the first study to evaluate the role of protection motivation toward nano-food purchase intentions and attitude toward nano-food applications. As we expect that individuals are likely to process threat and efficacy in distinct ways, we choose to maintain threat and coping appraisals as distinct concepts in order to evaluate their individual role in cognitive outcomes, as will be further explicated in the methods section of this paper.

Demographics and Sociographics

Past studies demonstrate inconsistent results regarding the influence of demographics and sociographics on attitudes and purchase intentions toward nano-foods and nanotechnology. Contextual and sample population differences differ drastically between studies and are likely to hold sway over the observed differences between similar measures. For example, Ho and colleagues (2010) found that age and gender did not predict public support for federal funding of nanotechnology, but religiosity was negatively associated with the public support of nanotechnology. Siegrist and colleagues (2008) similarly found that age and gender did not influence nanotechnology perceptions. However, in a cross cultural study, support for governmental funding of nanotechnology was negatively predicted by age and religiosity in the United States but not in Singapore (Liang, et al. 2015). With regard to food

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decisions, Worsley and colleagues (2013) found that women more consistently consider the nutritional and technological aspects of food products than men. Higher income has also been found to positively influence consumers' attitude toward nano-food (Yue, et al. 2015). Men have more positive attitude toward nano-food as compared to women (Yue, et al. 2015). Religiosity has also been found to negatively influence acceptance for uses of technology in food products while heightening desires for labelling of food technologies (Chern, et al. 2012; Yue, et al. 2015). In our study, demographic variables (such as age and gender) and sociographic variables (such as level of education, household income, and religiosity) are used as control variables.

Methods

A pretested survey questionnaire (N= 1,001) was conducted online through the professional survey company Qualtrics. Participants were asked to complete a short questionnaire evaluating antecedent items pertaining to various independent variables in this study detailed below. After completing this questionnaire, the participants were asked to view the front and back of a hypothetical food package, in this case a box of cereal. The back of the box of cereal contained general information about nanotechnology in food and was designed to be balanced in its risk and benefit portrayal², similar to other studies where individuals assess a product containing nanoparticles (Author, blinded). Following the viewing of the nano-food, respondents were asked to complete another short questionnaire that evaluated our dependent variables including perceptions of the nano-food, as well as cognitive outcomes including purchase intentions, nano-food labelling preferences, and governance options.

² Specifically the text read: "What is Nano? Recent developments are allowing food companies to make adjustment to products by using very small materials as food ingredients and additives. These materials are measured at the nanoscale (1 nanometer equals 1 billionth of meter) and are smaller than other ingredients. These smaller materials can show unique properties when their size is reduced far enough, which allows for new uses as food ingredients and additives. Why Nano? Nanoscale food ingredients and additives are believed to improve food products and enhance taste and colour, as well as improve the shelf-life and product safety. However, because such uses are fairly new, some experts believe that we need to carefully look at the potential".

Sample Measures

Respondents were recruited from all geographic regions of Singapore to provide a representative sample of the country's citizens based on quota-sampling using the demographic variables gender, age, and monthly household income. Our final sample matched well with recent census targets with respondents ranging from 21 and 64 years old ($M = 37.92$, $SD = 10.68$). Among them 51.6% were female, median education level was "Degree" (equivalent of a bachelor degree in the United States). The median monthly household income ranged from S\$6,000 to S\$6,999 (US\$4,300- US\$5000). Our response rate, defined by the number of completed questionnaires divided by the number of qualifying panelists invited to participate was 30.8 %, falling within respectable parameters for online surveys (Bosnjak, Das and Lynn 2015; Iyengar and Hann 2009). Attention filter questions were set within the survey questionnaire to ensure that respondents were attentive to questions and the associated response options before reporting their individual responses. Respondents who completed the survey were rewarded in kind by Qualtrics in the form of points in which they can exchange for various items, such as cash or gift cards.

Independent variables

Besides the aforementioned demographic and sociographics sample selection variables, we also included a host of independent variables that have been used in previous studies to predict how members of the public form attitudes and make purchase intentions regarding nanotechnology and nano-foods.

Religiosity, the degree to which people feel that religious beliefs guide their daily decision-making (Brossard, et al. 2009), was measured using one item in which respondents were asked to indicate on a 7-point scale (1 = "no guidance at all," 7 = "a lot of guidance") whether their religion prohibit them from eating food with nano ingredients ($M = 4.24$, $SD = 1.29$).

Technocratic Belief, the sentiment that technology is a means for improving society, was measured by asking respondents to indicate on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) how much they agree with the following statements: (a) “Technology should be used to increase food safety (e.g., shelf life);” (b) “Technology should be used to increase food quality (e.g., taste and color);” (c) “We should use technology to improve our daily life;” and (d) “Our leaders should use technology to solve problems in society.” The four items were averaged to create a composite index, with higher scores indicating higher technocratic belief ($M = 5.27$, $SD = 1.04$, Cronbach’s $\alpha = .82$).

Deference to Scientific Authority: Deference to scientific authority (Ho, Brossard, and Scheufele 2008), or trust in scientific uses for decision-making, was measured using 3 items on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) asking respondents how much they agree with the following statements: (a) “Scientists know best what is good for the public;” (b) Scientists should move ahead with research even if it displeases some people;” and (c) “Scientists should do what they think is best, even they have to persuade people that it is right.” The items were averaged to form a composite index, with higher scores indicating higher deference to scientific authority ($M = 4.60$, $SD = 1.19$, Cronbach’s $\alpha = .86$).

Trust in Regulatory Agencies was measured by asking respondents to indicate on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) how much they trust the information about food safety provided by: (a) “Regulatory bodies (e.g., Agri-food & Veterinary Authority [AVA] and National Environmental Agency [NEA])” (Similar to the US FDA and EPA respectively), (b) “Scientists,” and (c) “Food companies.” These three items were summed and averaged to form a composite index, with higher scores indicating higher trust in regulatory agencies ($M = 4.91$, $SD = .86$, Cronbach’s $\alpha = .69$).

Preference for Natural Products was measured by 4 items on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) asking respondents how much they agree with the following statements: (a) “I prefer to buy natural products;” (b) “To me the naturalness of the food that I buy is an important quality;” (c) “I prefer to avoid food products with additives;” and (d) “I do not mind paying a premium for natural products.” The four items were averaged to create a composite index, with higher scores indicating higher preference for natural products ($M = 5.22$, $SD = 1.03$, Cronbach’s $\alpha = .83$).

Science Knowledge was measured by five dichotomous items (1 = “true” (T); 2 = “false” (F)) asking respondent the following statements: (a) “Lasers work by focusing sound waves (F),” (b) “The center of the earth is very hot (T),” (c) “Antibiotics kill viruses as well as bacteria (F),” (d) “Electrons are smaller than atoms (T),” and (e) “All radioactivity is man-made (F).” For each item, the correct answer was recorded into “1,” while the incorrect answer was recoded into “0.” Responses which fell into the “I don’t know” categories were recoded as “0.” These scores for all the items were summed, with higher scores indicating higher level of science knowledge ($M = 3.05$, $SD = 1.40$, KR-20 = .56).

Threat Appraisal was measured by summing two variables – *threat severity* and *threat vulnerability*. *Threat severity* was measured using 2 items on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”): (a) “Nano ingredients in food are healthy,” and (b) “Nano ingredients in food are safe.” These items were reverse-coded. *Threat vulnerability* was measured by asking respondents to indicate on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) how much they agree with the following statements: (a) “New human health problems caused by nano ingredients in food will affect me,” and (b) “New environmental problems caused by nano ingredients in food will affect me.” All the four items were averaged to create a composite index, with higher scores indicating higher threat appraisal ($M = 4.22$, $SD = .80$, Cronbach’s $\alpha = .58$).

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Coping Appraisal was measured by summing two variables – *response efficacy that nano-labels are efficacious*, and *self-efficacy to be able to appropriately use nano-labels when making decisions*. *Response efficacy* was measured using 2 items on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) asking the respondents how much they agree with the following statements: (a) “Nano labels on food products show that the food is safe for consumption” and (b) “Nano labels on food products help me to make an informed decision.” *Self-efficacy* was measured by asking the respondent to indicate on a 7-point scale (1 = “strongly disagree”, 7 = “strongly agree”) how much they agree on the following statements: (a) “I am able to use nano labels on food products to make food choices” and (b) “It is easy to use nano labels on food products to make food choices.” These items were averaged to form a composite index, with higher scores indicating higher coping appraisal ($M = 4.47$, $SD = 1.06$, Cronbach’s $\alpha = .86$).

Attention to Food Safety News was measured by asking respondent to indicate on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) how much attention they pay to: (a) “new stories about food safety on TV;” (b) “new stories about food safety on print newspapers;” (c) “news stories about food safety on online news;” (d) “information about food safety on blogs (e.g., Blogspot, Wordpress);” (e) “information about food safety on Wikis (e.g., Wikipedia, Wiktionary);” and (f) “information about food safety on social networking sites (e.g., Facebook, Twitter, YouTube).” These 6 items were averaged to create a composite index, with higher scores indicating higher attention to food safety news ($M = 4.69$, $SD = 1.06$, Cronbach’s $\alpha = .81$).

Attention to Nano News was measured using 6 items on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) asking the respondents how much attention they pay to: (a) “new stories about nanotechnology on TV;” (b) “new stories about nanotechnology on print newspapers;” (c) “news stories about nanotechnology on online

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news;” (d) “information about nanotechnology on blogs (e.g., Blogspot, Wordpress);” (e) “information about nanotechnology on Wikis (e.g., Wikipedia, Wiktionary);” and (f) “information about nanotechnology on social networking sites (e.g., Facebook, Twitter, YouTube).” These 6 items were averaged to create a composite index, with higher scores indicating higher attention to food safety news ($M = 4.05$, $SD = 1.38$, Cronbach’s $\alpha = .92$).

Dependent variables

Attitude toward Nano-Food Applications was measured by asking the respondents to indicate on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) how much they agree with the following statements: (a) “Nanotechnology should be used to increase food safety (e.g., shelf life);” (b) “Nanotechnology should be used to increase food quality (e.g., taste and color);” and (c) “Nanotechnology should be used to increase food nutrition.” These items were averaged to form a composite index, with higher scores indicating favorable attitude toward nano-food applications ($M = 4.52$, $SD = 1.29$, Cronbach’s $\alpha = .92$). Table II summaries of means and standard deviation of the control, independent, and dependent variables.

Intention to Purchase was measured using 1 item on a 7-point scale (1 = “strongly disagree,” 7 = “strongly agree”) asking the respondents how much they agree with the following statement: (a) “I would be willing to buy food products with nano ingredients.” Higher scores indicate greater intention to purchase food products with nano ingredients ($M = 4.09$, $SD = 1.29$).

Table I. Descriptive statistic of independent and dependent variables.	<i>M</i>	<i>SD</i>
Control variables		
Age	37.92	10.68

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Sex	51.6% female	-
Education	<i>Median</i> = 8.00	1.32
Household Income	<i>Median</i> = 7.00	3.01
Religiosity	4.24	1.92
Independent variables		
Technocratic Belief	5.27	1.04
Deference to Scientific Authority	4.60	1.19
Trust in Regulatory Agencies	4.91	.86
Preference for Natural Product	5.22	1.03
Science Knowledge	3.05	1.40
Attention to Food Safety News	4.69	1.06
Attention to Nano News	4.05	1.38
Threat Appraisal	4.22	.80
Coping Appraisal	4.47	1.06
Dependent variables		
Attitude toward Nano-Food Applications	4.52	1.29
Intention to Purchase	4.09	1.29

Note: For reference, items appear in this table in the same order as in the Methods section.

Analytic Approach

Ordinary least squares (OLS) hierarchical regression analyses were conducted to test our hypotheses and research questions. The variables were entered into the regression model according to their assumed causal order, with the novel addition of protection motivation input as the final block. All control variables (demographic variables) were included in the first block, followed by the sociographic variables (educational level, household income, and religiosity) in the second block. Values predispositions of science and technology variables (technocratic belief and deference to scientific authority) were entered in the third block. Values predispositions of food variables (trust in regulatory agencies and preference for natural products) were entered in the fourth block and science knowledge was entered in the fifth block. Next, media attention variables (attention to food safety news and attention to nano news) were entered in the sixth block. Finally, PMT variables (threat appraisal and coping appraisal) were entered in the final block.

Results

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Table II reports the final models predicting the two dependent variables. Across all dependent variables, age was not significantly related with attitude toward nano-food applications; but negatively associated with purchase intention ($\beta = -.08, p < .001$). Likewise, gender was not significantly associated with any of the dependent variables. The demographic variables accounted for little of the total variance observed across dependent variables including attitude toward nano-food applications (0.7%) and intention to purchase nano-food (1.9%).

Among sociographics, educational level and household income were not related to any of the dependent variables. Religiosity was partially associated with attitude toward nano-food applications ($\beta = -.05, p < .1$) and negatively associated with the intention to purchase nano-food ($\beta = -.06, p < .05$). The sociographics block accounted for smaller variance for both the attitude toward nano-food applications (1.4%) and intention to purchase (1.0%).

Concerning value predispositions of science and technology, technocratic belief was positively associated with the attitude toward nano-food applications ($\beta = .30, p < .001$) and intention to purchase nano-food ($\beta = .10, p < .001$). Therefore, H1(a) and H1(b) were support. Meanwhile, deference to scientific authority was positively related to attitude toward nano-food applications ($\beta = .09, p < .01$); but did not display significant relationship with the intention to purchase nano-food. Therefore, only H2(a) was supported. The third block account for much more of the observed variance regarding attitudes toward nano-food applications (24.4%) but lesser regarding purchase intentions (11.6%).

For attitudinal predispositions variables of food, trust in regulatory agencies was not associated with any of the dependent variables, rejecting H3(a) and H3(b). Notably, preference for natural product was negatively related to the attitude toward nano-food applications ($\beta = -.09, p < .01$) and intention to purchase nano-food ($\beta = -.10, p < .001$).

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H4(a) and (b) were supported. This block accounted for lesser variance in attitude toward nano-food applications (1.6%) and purchase intention (4.0%).

Science knowledge was not related to intention to purchase nano food and attitude toward nano-food applications. Therefore, H5(a) and H5(b) were rejected. Science knowledge accounted for very little variance across all dependent variables: intention to purchase nano-food (0.6%) and attitude toward nano-food applications (0.1%).

For the media attention variables, attention to food safety news did not display any significant relationship with all the dependent variables. Hence, H6 (a) and H6(b) were rejected. Conversely, attention to nano news was positively associated with attitude toward nano-food applications ($\beta = .09, p < .01$) and intention to purchase nano-food ($\beta = .13, p < .001$), lending support for H7(a) and H7(b). The media attention block accounted for significant variance in attitude toward nano-food applications (1.4%) and intention to purchase nano-food (1.3%).

To answer RQ1, threat appraisal and coping appraisal were entered in the last block of the regression model. There result showed that threat appraisal was negatively related to attitude toward nano-food applications ($\beta = -.27, p < .001$) and the intention to purchase nano-food ($\beta = -.43, p < .001$). Coping appraisal was positively related to attitude toward nano-food applications ($\beta = .27, p < .001$) and intention to purchase nano-food ($\beta = .29, p < .001$). The protection motivation block accounted for the large variance in attitude toward nano-food applications (16%) and intention to purchase nano-food (28.5%).

Table II. Hierarchical regression models predicting the attitude toward nano-food applications and intention to purchase.

	Attitude toward nano- food applications (β)	Intention to purchase (β)
Block 1: Demographics		
Age	-.02	-.08***
Gender	.00	-.04
Incremental R^2 (%)	0.70*	1.90***
Block 2: Sociographics		
Education	.03	.04
Household Income	.02	.04
Religiosity	-.05#	-.06*
Incremental R^2 (%)	1.40***	1.00*
Block 3: Value Predispositions – Science and Technology		
Technocratic Belief	.30***	.10***
Deference to scientific authority	.09**	.05
Incremental R^2 (%)	24.40***	11.60***
Block 4: Value Predispositions – Food		
Trust in Regulatory Agencies	-.01	.04
Preference for Natural Product	-.09**	-.10***
Incremental R^2 (%)	1.60***	4.00***
Block 5: Knowledge		
Science Knowledge	.01	-.03
Incremental R^2 (%)	0.10	0.60**
Block 6: Protective Motivation		
Threat Appraisal	-.27***	-.43***
Coping Appraisal	.27***	.29***
Incremental R^2 (%)	16.00***	28.50***
Block 7: Media Attention		
Attention to Food Safety News	.07	.01
Attention to Nano News	.09**	.13***
Incremental R^2 (%)	1.40***	1.30***
Total R^2 (%)	45.60	48.90

Note: # denotes significance at the $p < .1$ level. * denotes significance at the $p < .05$ level. ** denotes significance at the $p < .01$ level. *** denotes significance at the $p < .001$ level.

Discussion

As nanotechnology-enabled food products continue to be developed and disseminated for public consumption, and as public awareness and concern increases, it is increasingly vital for stakeholders, risk communicators, and policy makers to maximize understanding of how public attitudes are formed and what factors influence decision-making. This paper used national survey data to improve the predictive capability of health and risk decisions among the public regarding attitudes and purchase intentions of nanotechnology enabled food

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products. Data were evaluated among Singaporeans, a group noted to be among the biggest future market for nano-foods (Helmut Kaiser Consultancy 2004). The empirical models reported in this paper provide valuable insights into factors influencing various aspects of how members of the public make decisions about nanotechnology-enabled foods. To date, our models provide the best predictive evaluations of purchase intentions regarding nano-foods (48.9%) and attitudes toward nano-food applications (45.6%) that we've seen when compared to previous models that have also attempted to explain and predict similar attitude and intention outcomes.

There results showed that age was negatively related to purchase intentions. This implies that younger generations have higher intention to purchase food containing nano ingredients. Gender and household income however, played no significant role across the board and all together, demographics and sociographics held little sway over explaining the variance observed within the sample. Education, household income, and religiosity also saw small influences. Together, both of these blocks provide for little explanation of the observed variance of dependent measures. This bodes well for sentiments in the field of health and risk communication to continue to move away from simple demographic predictions of cognitive outcomes to more robust and granular assessments of value predispositions and motivations as more influential factors.

Value predispositions to science and technology were much greater in their explanatory power regarding purchase intentions (11.6%) and attitudes toward nano-foods (24.4%). As hypothesized, technocratic belief was positively related to purchase intentions and attitudes toward nano-foods. However, deference to scientific authority positively related to attitude toward nano-food applications but not intention to purchase. Interestingly, trust in regulatory agencies to manage nano-food risks was not a significant factor for all dependent

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measures. As hypothesized, preference for natural products was negatively related to purchase intentions and attitudes toward nano-foods.

In the media attention block we noted that attention to food safety news bore no significant impact on any dependent measures. However, media attention to nanotechnology news was a significant factor for all dependent measures, being positively related to purchase intentions and attitudes toward nano-foods. Noting that attention to food safety was not a factor, but attention to nanotechnology news was impactful may note that the exotic character and novelty of the “nano” in nano-foods may trump typical predictors when it comes to health and risk decision making of consumer products that employ emerging technologies with low familiarity among the public.

In evaluating our research question, there is little doubt that the PMT concepts of threat- and coping-appraisal, are vital to maximizing the predictive capability of phenomena like nano-foods that members of the public may or may not view as a potential threat. Higher perceptions that nano-foods are a threat were coupled with strong negative purchase intentions, and also strong negative attitudes toward nano-foods. High threat appraisal of nano-foods also bore strong relation to all forms of labelling, support for government regulation, and very strong support for a full ban on the use of nano-foods, as will be further discussed in another paper. This may note that among those with high threat perception, nano-labels likely serve the precedent as a “do not buy” beyond a “right to be informed” function.

Coping appraisal proved to be potentially most interesting and demonstrative in this case of nano-foods. Those with high efficacy beliefs reported higher intentions to purchase nano-foods and held more positive attitudes toward nano-foods. This group is likely to feel that they have the personal means to use labels to make informed risk-decisions and are the most likely group to desire nano-labels as serving a “right to be informed” function and not a

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“do not buy” caution. Cumulatively, PMT concepts were the biggest influential factor on purchase intentions while attitudes toward nano-foods were best predicted by value predispositions about science and technology.

In the larger sense, we also note that there is value in assessing and identifying the influences of threat and efficacy appraisals as separate concepts, rather than conflating them into one “protection motivation” variable. Being able to granularly note the influence of coping appraisal as distinct from threat appraisal, provides greater opportunity to theorize about how the public comes to make sense and evaluate unfamiliar phenomena like nano-foods.

In the field of health and risk communication it is well documented that risk perceptions do not always reflect the actual risk of a potential hazard, and that risks are often communicated as social constructs that can be perceived even if there is little or no actual technical risk (Slovic, Fischhoff and Lichtenstein 1981; Sjöberg 2001). Given all of these considerations, this study offers a novel and more robust account of public perceptions of nano-foods. The findings we report demonstrate that to date, antecedent value predispositions of science and technology coupled with threat- and coping- appraisal may be the best indicators yet for evaluating how members of the public come to make sense of emerging technological products that are uncertain in their risk-profile.

As debates around labelling and governance of nano-foods continue around the world, it may be of value to further explore these themes, and triangulate such findings with other modes of social scientific inquiry. This will be critical for ensuring that health communication initiatives, and public engagement are appropriately informed with robust understanding of the complex relationships between values, knowledge, media attention, and protection motivation.

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Appendix

Figure 2. Cereal box.