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Compliance With Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest.

Abstract

The future of nano-food largely hinges on public perceptions and willingness to accept this novel technology. The present study utilizes the scientific literacy model and psychometric paradigm as the key theoretical frameworks to examine the factors influencing public support for labeling and banning of nano-food in Singapore. Using data collected from a nationally representative survey of 1001 respondents, the findings demonstrated that attitudes toward technology, preference for natural product, science knowledge, and risk perception were found to substantially affect public support for both labeling and banning of nano-food. Conversely, attention to food safety news on traditional media and attention to nano-news on new media were only associated with public support for labeling of nano-food. Similarly, benefit perception was only significantly associated with public support for banning of nano-food. Theoretically, these findings support the growing body of literature that argues for the significant role played by predispositions, media use, science knowledge, and risk and benefit perceptions on attitude formation toward nano-food. It serves as the pioneering piece to address the aspect of banning in the field of nano-food. Practically, insights drawn from this study could aid relevant stakeholders in enlisting effecting strategies to convey the benefits of nano-food while mitigating the risk perceptions among the public.

Keywords: nano-food; science knowledge; risk perception; benefit perception; media use; labeling; banning

Label It or Ban It? Public Perceptions of Nano-Food Labels and Propositions for Banning Nano-Food Applications

Nanotechnology is among a set of key enabling technologies that is revolutionizing the industrial and agricultural sectors by addressing security and sustainability issues (Parisi et al. 2015). Notably, among the key applications of nanotechnology is its ability to transform the production and distribution of food supplies (Moraru et al. 2009). Food products that either contain nanoparticle-ingredients or are produced using nanotechnology processes are commonly referred to as nano-food (Bieberstein et al. 2012). While currently not applied as ubiquitously in food as genetic modification, nano-food applications are being developed at an accelerated pace (Zhou 2013). Between 2008 and 2014, the global market for nano-food packaging has almost doubled from US$4.13 billion to US$7.30 billion (Smolander and Chaudhry 2010).

While such nano-food applications have been commended for their ability to improve food production, processing, shelf-life, product quality, and safety (Chaudhry et al. 2010; Weiss et al. 2006), they have generated considerable policy debates across multiple countries (Gruère 2011; Kalaitzandonakes et al. 2007; Monica Jr 2008). More specifically, those opposed to nano-foods have voiced concerns over the potential human health risks, long-term environmental impact, and value-based objections (Oberdorster et al. 2005; Rozin et al. 2004; Siegrist et al. 2009). Policy debates have fueled movements for mandatory labeling of nano-food products (European Commission 2013; Friends of the Earth 2008) and even call for a moratorium and ban on the use and distribution of nano-foods (Nanotechnology Industries Association 2010; Philips 2014). For instance, the Action Group on Erosion, Technology and Concentration (ETC Group), an organization recognized for its efforts to aid the conservation and sustainable advancement of cultural and ecological diversity and human rights, has called for a worldwide ban of nanotechnologies (Brumfiel 2003). Such a call has raised questions

about the safety of nanotechnology (Brumfiel 2003). The United States of America (USA) government has allocated more funding to investigate the ethical and societal impact of nanotechnology, and new nanotechnology-specific laws have been proposed (Brumfiel 2003; Rakhlin 2008).

Following these calls, scholars have conducted multiple studies aimed to improve understanding of public perceptions toward nano-food. However, existing literature mainly focuses on the effects of perceived benefits, perceived risks, and trust on public acceptance of nano-food (George et al. 2014). Given that food is an essential part of people's lives and culture, the public would form judgments about nano-food by comparing them to other food products. Public acceptance toward nano-food may also be influenced by other understudied factors, such as attitudes toward technology, preference for natural products, media attention, and science knowledge.

Past literature found that while consumers desired nano-food labeling, they were not necessarily opposed to all forms of nano-food technologies. There may be varying motivations behind people's support for labeling of nano-food products. Past studies have noted that for some consumers, nano-food labels serve as a sign of increased transparency and the affordance of greater personal control and choice for consumers in the purchasing process (Costa-Font et al. 2008; Frewer et al. 2004). However, for those strongly opposed to nano-food, such labels may serve as a warning to deter purchase (Brown and Kuzma 2013). Given the inconclusive findings surrounding factors influencing support for nano-food labeling, this study seeks to examine how factors such as institutional trust, attitudes toward technology, preference for natural product, media use, science knowledge, and risk and benefit perceptions influence support for the labeling of nano-food.

Noting the dual motivations for labels, desires for nano-food labeling are warranted by both those who hold positive and negative attitudes toward nano-food. However, support

for banning indicates strongly adverse attitudes toward nano-food to the extent that such products should not be made publicly available. Evaluation of support for the banning of nano-foods in conjunction with the support for labeling better assesses the intensity of opposition toward such food products. Currently, there is a dearth of research examining support for banning nano-food amid continued public calls for policy changes (European Parliament 2014; Philips 2014).

Most extant studies are also limited to countries in Europe (Chaudhry et al. 2008; Saher et al. 2006; Siegrist et al. 2008) and the USA (Brown and Kuzma 2013; Liang et al. 2015; Yue et al. 2015). There is scant research examining public perceptions of nano-food in Asia. Countries in this region will dominate the nanotechnology market in the coming years given the rising population count and inequality-adjusted human development index. The latter correlates with increased consumption of nano-engineered products (Keller and Lazareva 2013). Particularly, countries like Singapore, whose economy is fueled by technological innovations and development (Gupta et al. 2013), have invested substantially into the research and development in nanotechnology and its applications (Liu 2009; Yang et al. 2017). Given the controversy that continues to shroud nanotechnology applications in food, it is imperative to examine public support among the Singapore population for the labeling and banning of nano-food.

This study draws upon theoretical models such as the science literacy model and psychometric paradigm to understand public perceptions toward support for the labeling and banning of nano-food products. Practically, insights from this study can help to inform policymakers, communication practitioners, and the food industry players of effective communication strategies to shape and improve public outreach efforts.

Literature review

The application of nanotechnology in food is an emerging field that has garnered

significant scholarly attention over the years given its potential to alter the food industry. Studies have been conducted primarily to investigate public perceptions of nano-food (Rollin et al. 2011; Siegrist 2008) and public attitudes toward regulatory policies regarding nano-food products (Brown and Kuzma 2013; Coles and Frewer 2013; Siegrist and Keller 2011). Generally, consumers were found to be reserved and hesitant about purchasing nano-food products (Brown and Kuzma 2013).

Labeling of nano-food

In the USA, there are existing regulatory standards set by the Food and Drug Administration (FDA) to govern nano-food products in the market. However, most countries have not implemented mandatory laws to regulate the production and sale of nano-food. Thus, studies have been conducted to examine public support for regulatory policies, specifically regarding the labeling of nano-food (Brown and Kuzma 2013; Frewer et al. 2004; Yue et al. 2015). Public attitudes toward the labeling of nano-food product remain inconclusive due to the varying motivations behind people's support for the labeling of nano products. Some studies showed that consumers expressed support for labeling as it serves as a heuristic warning to deter purchase of such products (Brown and Kuzma 2013; Yue et al. 2015). Siegrist and Keller (2011) also adopted this view of the precautionary principle, arguing that mandatory labeling could be perceived by consumers as an enforcement by regulatory authorities to inform consumers of potential risks involved with such products, thus increasing risk perception and deterring purchase intentions.

However, other studies found that consumers support labeling as they perceive it as an indicator of transparency and an increased sense of personal control (Costa-Font et al. 2008; Curtis et al. 2004; Frewer et al. 2004). Dimara and Skuras (2005) suggested that consumers perceive food labeling to serve as a quality indicator and assurance of governmental regulation of the food products. The labeling of nano-food can also assure the public that the

government is protecting the consumers by “watching” over the food products (Dimara and Skuras 2005). Existing research on nano-food labeling also reveals a large disparity regarding the utile purpose of the label itself. In some studies, labels were associated with negative perceptions, serving as a warning sign that may deter purchase (Brown and Kuzma 2013; Yue et al. 2015). Other investigations roused positive perceptions, serving as an assurance of the quality and safety of the product (Dimara and Skuras 2005; Frewer et al. 2004). Given the ambiguity surrounding consumers’ attitudes toward labeling, this study seeks to illuminate the determinants of public support for labeling.

Banning of nano-food

Nanotechnology has entered our food system either as natural or designed materials (Shelke 2009). The impacts of nano-food on human health and environment remain controversial (Biello 2008; Chun 2009). Scientists argue that applying nanotechnology in food could lessen the amount of sugar, salt, and fat (Nature Nanotechnology 2010), as well as increase the amount of essential nutrients in food (Chun 2009). However, consuming the same amount of nano-food as normal food could be dangerous as a larger amount of nutrients will be absorbed by the body (Chun 2009). Nanoparticles may also cause harm to the human body as they have the potential to penetrate organs and cells (Biello 2008). Due to the uncertainty of the impact of nano-enabled products, several civil society groups and countries have called for the banning of nano-food. For example, Canada has banned methods involving nanotechnology and nanomaterials in organic food production (Nanotechnology Industries Association 2010).

A study conducted in the USA (Macoubrie 2006) found little support for the banning of nanotechnology products. Majority of the respondents perceived that banning nanotechnology is overacting (Macoubrie 2006). To the best of our knowledge, no study has investigated public support for banning of nano-food in Singapore. Existing studies show that

Singaporeans are supportive of government funding of nanotechnology (Ho et al. 2010). Singaporeans also perceive higher levels of benefits of nanotechnology as compared to the risks (George et al. 2014; Liang et al. 2015). These positive attitudes can be attributed to higher levels of familiarity regarding nanotechnology and higher levels of scientific knowledge than many other countries (Liang et al. 2015; Ho et al. 2010). However, it is well documented that greater familiarity does not equate to greater acceptance. Familiarity with nanotechnology may also result in negative attitudes given that people make judgments based on information from a variety of media platforms that may provide contrasting accounts (George et al. 2014).

Despite the support for government funding of nanotechnology (Ho et al. 2010), studies found that Singaporeans are concerned about the adoption of nano-food (George et al. 2014). Moreover, past studies tend to focus on public acceptance of nanotechnology in general and little attention has been devoted to the application of nanotechnology in food. There is a dearth of study investigating public support for the banning of nano-food. Therefore, this study seeks to fill the research gap by investigating factors influencing public support for the banning of nano-food. In particular, this study examines the influence of attitudes toward technology, preference for natural product, media attention, science knowledge, and risk and benefit perceptions on public support for labeling and banning of nano-food.

Predispositions

Attitudes toward technology. Attitudes refer to the psychological evaluation of the degree of favorability regarding a particular entity (Eagly and Chaiken 1993). While nanotechnology is viewed more positively than genetically modified (GM) products, public attitudes toward nano-food remain largely unfavorable (Cook and Fairweather 2007). Extant literature found that negative attitudes toward nanotechnology predicted support for nano-

product labeling (Brown and Kuzma 2013; Yue et al. 2015). Yue et al. (2015) attributed this to the perceived function of these labels that serve as heuristic warning indicators to deter purchase. This line of argument was supported by findings from Huffman et al. (2003), which showed that consumers who held negative attitudes toward GM technology were less likely to purchase food products with a GM food label. Hence, this study aims to understand the relationship between attitudes toward technology and support for labeling of nano-food by proposing the following hypothesis:

H1a: Attitudes toward technology are negatively associated with support for labeling of nano-food.

In other cases, negative attitudes toward novel food technologies have led to the outright ban of such products. For instance, various nationwide surveys and opinion polls revealed a strongly negative public perception of GM food among the Swiss (Bonfadelli et al. 2002; Siegrist 2003). This has resulted in the enactment of legislation banning GM organisms (Chandrasekhar 2016). Similarly, several European Union countries with low levels of public support for GM food have also banned GM crops (Gaskell et al. 2010). Although attitudes toward nano-food technologies have been found to influence consumers' willingness to pay for such products in the USA, there are no existing federal regulations regarding banning of nano-food products (Brown and Kuzma 2013; Katare et al. 2013). The National Organics Standards Board has also proposed a vote to ban the adoption of nano-food (Kessler 2011; Center for Food Safety 2009). Considering the above arguments, this study proposes that:

H1b: Attitudes toward technology are negatively associated with support for banning of nano-food.

Preference for natural products. Recent decades have witnessed a rise in consumers' desire for naturalness, particularly in the domain of food (Rozin et al. 2004). Naturalness is predominantly grounded in terms of the process through which a product is

being made as opposed to the actual substance the product is made up of (Rozin 2005, 2006). This preference for naturalness can be attributed to humans' desire to avoid interfering with nature, with the manipulation of an object at a molecular level being deemed as unacceptable (Siegrist 2008). Past studies showed that consumers generally prefer what they believe to be natural foods as opposed to foods they considered artificial, even when the benefits of the latter were clearly communicated to exceed that of the former (Rozin et al. 2004; Siegrist et al. 2009). For instance, Siegrist et al. (2009) found that consumers held negative perceptions and were reluctant to accept nano-food despite the clearly communicated health benefits. Similarly, Rozin et al. (2004) found consumer perceptions of naturalness to be based on the process of food production rather than the content of the food itself. This suggests that consumers perceive the quality of naturalness to supersede the benefits offered by nano-food. People with a pre-existing preference for natural products were found to possess higher levels of risk perception toward nano-food as compared to people who do not (Saher et al. 2006). Therefore, this study posits that people with a preference for natural products will support the labeling of nano-food to avoid choosing them or even support the outright banning of such food products (Yue et al. 2015).

H2a: Preference for natural products is positively associated with support for labeling of nano-food.

H2b: Preference for natural products is positively associated with support for banning of nano-food.

Media use

The media serves as the primary source of information regarding science and technology for the public (Gregory and Miller 1998). Scholars argue that information disseminated by media channels creates awareness and mental associations that can influence public opinion (Liu and Priest 2009) and shape subsequent policy decisions (Ho et al. 2011).

Given that science knowledge is low among the public for emerging science issues such as nanotechnology, the role of the media is especially important (Cobb and Macoubrie 2004; Lee et al. 2005). Particularly, science issues such as nanotechnology require domain-specific knowledge that is difficult to attain outside of formal classroom education. As such, traditional media such as newspapers and television, as well as new media, serve as alternative platforms that allow the public to engage in informal learning about science issues (Ho et al. 2010). Thus, attention to the media plays a significant role in educating the public to allow for the formation of attitudes toward such topics. Aside from the medium, it is also vital to understand if attention to different types of news content would affect attitude formation toward nano-food technology. The following sections will provide an in-depth review of the impact of media attention on food safety news and nano-news on support for the labeling and banning of nano-food.

Attention to food safety news on traditional media. Swinnen et al. (2005) claim that media coverage of food safety news tends to be negative in tone. For instance, media coverage of agricultural biotechnology was found to receive more negative reporting on the ethical issues as opposed to highlighting its benefits (Nisbet and Lewenstein 2002). Verbeke and Ward (2001) argue that this can be attributed to people's greater interest in negative news than positive news. Following this line of argument, food safety news coverage can be expected to be generally negative in tone. As such, greater attention to traditional news media can be expected to induce negative public perceptions of food safety. Thus, people who pay more attention to food safety news will be more likely to possess negative attitudes toward nano-food. Therefore, this study posits that greater attention to food safety news on traditional media will encourage support for food labeling. In more extreme cases, people who develop highly unfavorable perceptions of nano-food due to exposure to food safety news on traditional media will also support the banning of nano-food. Hence, this study

proposes:

H3: Attention to food safety news on traditional media is positively associated with (a) support for labeling of nano-food and (b) support for banning of nano-food.

Attention to food safety news on new media. Despite the dominance of traditional media in news reporting, new media has gained traction as an alternative source of news. The increased preference for new media sources can be attributed to the lack of traditional gatekeepers and censorship that govern traditional news media. Additionally, new media platforms provide unique affordances that encourage user contribution and interaction, enabling laypeople to serve as news contributors. In line with greater public scrutiny of contentious or negative news, food scandals are similarly more prevalent on new media due to the higher likelihood of generating online sharing and discussion. For instance, the video of China's toxic food scandal involving contaminated meat went viral and was highly debated among netizens (Jourdan 2014; Trefis Team 2014). Similarly, Tesco's horse meat scandal received widespread coverage after being circulated and retweeted via Twitter (Hough 2013). The widespread dissemination of such negative news could in turn induce negative perceptions of food safety. Yet, food companies that were able to effectively utilize new media in their favor were able to reap its benefits (Bhasin 2011). Given the inconclusive arguments, this study seeks to find out the relationship between attention to food safety news on new media and support for the labeling and banning of nano-food.

RQ1: To what extent does attention to food safety news in new media affects the support for (a) labeling of nano-food and (b) banning of nano-food?

Attention to nano-news on traditional media. In contrast to the negative tone of food safety news coverage, news coverages of nano-food across various countries in Europe (i.e., the UK, the Netherlands, and Denmark) and the USA were found to be positive in tone, emphasizing the benefits associated with the technology over its potential risks (Friedman

and Egolf 2005; Kjærgaard 2010; te Kulve 2006). This pattern of news coverage was demonstrated to be consistent even in the reporting of themes such as health and environmental risks, whereby both the benefits and the risks were equally discussed to provide a balanced argument (Friedman and Egolf 2005). The overall positive tone adopted by traditional news media can be attributed to the nascent stage of nanotechnology development. Scholars have observed similar patterns of news reporting when it comes to emerging science topics like biotechnology (Nisbet and Lewenstein 2002). As such, it can be expected that attention to nano-news on traditional media will encourage favorable perceptions toward nanotechnology. According to past literature, consumers expressed preference for the labeling of nano-food products in a bid to avoid the purchase of such products (Brown and Kuzma 2013; Yue et al. 2015). Thus, favorable perceptions toward nano-food can be expected to be associated with decreased support for labeling. Similarly, support for nano-food will reduce support for the banning of nano-food.

H4: Attention to nano-news on traditional media is negatively associated with support for (a) labeling of nano-food and (b) banning of nano-food.

Attention to nano-news on new media. However, the coverage of nano-news in new media remains relatively obscure, which could be attributed to the nature of the topic. Research has shown that the public is largely unaware about nanotechnology (Cobb and Macoubrie 2004), which makes it challenging for netizens to participate. There is also a dearth of literature that examined the coverage of nano-news on new media platforms. Thus, this study seeks to explore the relationship between attention to nano-news on new media and consumer support for the labeling and banning of nano-food.

RQ2: To what extent does attention to nano-news in new media affects the support for (a) labeling of nano-food and (b) banning of nano-food?

Science knowledge

Aside from predispositions and media effects, science knowledge also contributes to public attitudes toward nanotechnology and its applications. Relevant knowledge of science and technology aid people's understanding of the scientific processes behind the technology, which could help to reduce risk perceptions (Cobb and Macoubrie 2004). Indeed, according to the science literacy model, basic understanding of science is necessary for people to make decisions regarding science-related issues (Miller 1983). Therefore, science knowledge plays an important role in determining public attitudes toward nanotechnology.

There are two camps of research studying the effects of science literacy on public attitude toward science and technology (Lee et al. 2005). One camp examines the relationship between domain-specific knowledge and public attitudes, while the other looks at the relationship between general science knowledge and public attitudes. Despite numerous studies conducted to examine the effects of domain-specific knowledge on public attitude toward nanotechnology, the findings remain inconsistent. For example, Lee and Scheufele (2006) found that knowledge about nanotechnology predicted public attitude toward nanotechnology. However, other studies found no significant relationship between nano-knowledge and public attitude toward nanotechnology (e.g., Scheufele and Lewenstein 2005; Brossard et al. 2009).

Contrary to nanotechnology-specific knowledge, studies revealed general science knowledge to be a significant predictor of public attitudes toward nanotechnology (e.g., Ho et al. 2010; Lee et al. 2005). These contrary findings were ascribed to the early stage of nanotechnology development, whereby people lack nanotechnology-specific knowledge and thus, they rely upon their general science knowledge to make decisions regarding nanotechnology issues (Lee and Scheufele 2006). Although existing studies affirmed the role of science knowledge in shaping public attitudes toward nanotechnology, there is a dearth of

literature examining the relationship between science knowledge and support for labeling of nano-food, as well as the relationship between science knowledge and support for banning of nano-food. Hence, this study seeks to examine the role of science knowledge on public's support on labeling and banning of nano-food by proposing the following research question:

RQ3: To what extent does science knowledge affect the support for (a) labeling of nano-food and (b) banning of nano-food?

Risk and benefit perception

Existing literature emphasized the role of risk perception and benefit perception on attitudes and public acceptance of science and technology (e.g., Ho et al. 2010, 2011; Yue et al. 2015). According to the psychometric paradigm, individuals possess different perceptions toward different types of hazards or technologies (Siegrist et al. 2005). The psychometric paradigm has been widely applied in existing studies to explain the influence of risk perception and benefit perception on public attitudes toward nanotechnology (Siegrist et al. 2007a, b, 2008). It postulates that people possess different levels of risk perception toward different types of science and technology due to varying cultural, environmental, and governmental influences (Fischhoff et al. 1978; Sjöberg et al. 2004).

Risk perception refers to the subjective assessment of a possible occurrence of a hazard event and people's concern over its potential consequences (Sjöberg et al. 2004). Meanwhile, benefit perception is defined as the assessment of the positive consequences associated with performing a specific action. Although some researchers (e.g. Alhakami and Slovic 1994) assumed that risk and benefit perceptions are inversely and causally related, Siegrist et al. (2000) found that the relationship between risk perception and benefit perception was influenced by a third factor—social trust. The relationship between risk perception and benefit perception was not significant after controlling for social trust. Their findings demonstrate that high-risk perception does not indicate low benefit perception. A

new technology may be both very risky and very beneficial. As such, it is important to examine the influence of both risk and benefit perceptions on support for the labeling and banning of nano-food.

Drawing from the psychometric paradigm, scholars argue that people perceive the risk of hazardous activities and new technologies in terms of dread risk and unknown risk (Fischhoff et al. 1978). In other words, people are worried and fearful of the unknown dangers related to novel technologies, which subsequently contributes to a higher level of risk perception. More importantly, studies also showed that limited knowledge of nanotechnology amplifies risk perception and diminishes benefit perception of nanotechnology application simultaneously (Cobb and Macoubrie 2004). The psychometric paradigm is supported by later studies that demonstrated the significant association between risk perception, benefit perception, and attitudes toward science and technology (Ho et al. 2010; Siegrist et al. 2008). For instance, Ho et al. (2010) revealed that risk perception negatively affected public support for federal funding of nanotechnology, while benefit perception was positively associated with public support for federal funding of nanotechnology. Similarly, Siegrist and colleagues (2007a) found that risk perception of nanotechnology deterred people from buying nano-ingredient food and food with nano-packaging. However, limited studies have examined the effects of risk perception and benefit perception on support for the labeling and banning of nano-food.

In addition, Yue et al. (2015) revealed that attitudes toward GM food and nano-food, measured by the composite of the ease of consumption of GM/nano-food and risk-benefit comparison, affected consumers' preference for the labeling of GM food and nanotechnology food products. However, Yue et al. (2015) did not explicitly examine the relationship between support for labeling, risk perception, and benefit perception. To the best of our knowledge, other existing studies also have yet to investigate the effects of risk perception

and benefit perception on support for the banning of nano-food products. Thus, this study examines the relationship between risk perception, benefit perception, support for labeling of nano-food, and support for banning of nano-food, by proposing the following hypotheses and research questions:

H5: Risk perception of nano-food is positively associated with support for labeling of nano-food.

RQ4: To what extent does risk perception affects the support for banning of nano-food?

H6: Benefit perception of nano-food is negatively associated with support for labeling of nano-food.

RQ5: To what extent does benefit perception affects the support for banning of nano-food?

Method

Data in this study was collected from the general public in Singapore using an online survey (N = 1001). Given the poor response rate of computer-assisted telephone interview (CATI)[1] and coverage issues of door-to-door surveys[2] in the context of Singapore, this study employed an online survey to investigate public perceptions for the labeling and banning of nano-food. Many existing studies (Ho et al. 2017; Kim and Lwin 2016) have utilized online survey to gauge public perceptions and behaviors in the context of Singapore. Online surveys ease the data gathering process with minimal costs and improve ecological validity as respondents can answer the questionnaire according to their own pace and time, which may increase the response rates and improve the quality of data collected.

The survey was conducted online using Qualtrics over a period of 2 weeks. Respondents were recruited using a nonprobability quota sampling method. The survey

[1] The dismal response rate of CATI survey was due Personal Data Protection Act 2012 (PDPA), in which many phone users in Singapore have registered for the "Do Not Call Registry."

[2] Given that most of the Singaporeans above 21 years old are working adults, they are mostly not available during the day. Moreover, door-to-door surveys would miss out a specific segment of the population, that is, people living in private condominiums as they would not be able to enter. Therefore, door-to-door survey may have coverage issue and sample may not be representative.

company, Qualtrics, excluded respondents who did not respond every question in the questionnaire. The response rate was calculated by dividing the number of completed questionnaires by the number of qualifying panelists invited to participate. Respondents who provided consent to participate in this study were required to complete a questionnaire. The first section consisted of items measuring the factors influencing support for labeling and banning of nano-food products. Second, pictures of the front and back of a food packaging were shown to the respondents. The back of the food packaging stated general information about nanotechnology in the food product[3]. The food packaging was pretested prior to the online survey to ensure a balanced portrayal of risks and benefits. After viewing the food packaging, respondents were asked to complete the third section of the questionnaire which consisted of a list of items measuring the dependent variables of this study—support for labeling of nano-food and support for banning nano-food (Table 1). A response rate of 30.8% was achieved by dividing the number of completed questionnaires by the number of qualifying panelists invited to participate. Respondents who completed the survey were remunerated in the form of Qualtrics points which could be exchanged for various items, such as cash or gift cards.

Measures

Control variables

Demographic variables. Demographic variables were included in this study as control variables. These variables include gender[4] (51.6% of the respondents were female),

[3] 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."

[4] Gender refers to biological sex in the context of this study.

age (*M* = 37.92, *SD* = 10.68), race (86.9% of the respondents were Chinese[5]), education (*Mdn* = 8 or "degree" or equivalent of a bachelor degree in the USA), and monthly household income (ranged from S$6000 to S$6999 or equivalent to US$4300 to US$5000).

Institutional trust. Institutional trust was included in this study as control variables. It was measured by three items. The respondents were required to indicate on a 7-point scale (1 = "strongly disagree," 7= "strongly agree") how much they trusted the information about food safety provided by the following: (a) "regulatory bodies (e.g., Agri-food & Veterinary Authority [AVA] and National Environmental Agency [NEA])" (similar to the USA 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 institutional trust (*M* = 4.91, *SD* = 0.86, Cronbach's α = 0.69).

Independent variables

Attitudes toward technology. Attitudes toward technology were measured using two items on a 7-point scale (1 = strongly disagree, 7 = strongly agree) by asking the respondents how much they agree with the following statements: (a) "We should use technology to improve our daily life," and (b) "Our leaders should use technology to solve problems in society." These two items were averaged to create a composite index, with higher scores indicating more positive attitudes toward technology (*M* = 5.50, *SD* = 1.08, Pearson's *r* = 0.65).

Preference for natural products. Preference for natural products was measured by four items. Using a 7-point scale (1 = strongly disagree, 7 = strongly agree), the respondents were asked to indicate 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

[5] According to the latest Singapore statistic of composition (Department of Statistic Singapore 2017), the majority of Singaporeans are Chinese (74.3%), followed by Malays (13.4%), Indians (9.1%), and others (3.2%). The data that we have collected is comparable with Singapore's national ethnic statistic in which majority of the respondents are Chinese (86.9%), followed by Malays (5.2%), Indian (5.7%), and others (2.2%).

quality," (c) "I prefer to avoid food products with additives," and (d) "I do not mind paying a premium for natural products." These items were averaged to create a composite index, with higher scores indicating greater preference for natural products (*M*= 5.22, *SD* = 1.03, Cronbach's α = 0.83).

Attention to food safety news on traditional media. This variable was measured by asking respondent to indicate on a 7-point scale (1 = "no attention at all," 7 = "a lot of attention") how much attention they pay to the following: (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." These three items were averaged to create a composite index, with higher scores indicating greater attention to food safety news on traditional media (*M*= 5.19, *SD* = 1.13, Cronbach's α = 0.73).

Attention to food safety news on new media. This variable was measured by three items asking the respondents to indicate on a 7-point scale (1 = no attention at all, 7 = a lot of attention) how much attention they pay to the following: (a) "Information about food safety on blogs (e.g., Blogspot, Wordpress)," (b) "Information about food safety on Wikis (e.g., Wikipedia, Wiktionary)," and (c) "Information about food safety on social networking sites (e.g., Facebook, Twitter, YouTube)." These three items were averaged to create a composite index, with higher scores indicating greater attention to food safety news on new media (*M* = 4.19, *SD* = 1.34, Cronbach's α = 0.83).

Attention to nano-news on traditional media. This variable was measured by three items on a 7-point scale (1 = no attention at all, 7 = a lot of attention) by asking the respondents how much attention they pay to the following: (a) "New stories about nanotechnology on TV," (b) "New stories about nanotechnology on print newspapers," and (c) "News stories about nanotechnology on online news." All the items were averaged to create a composite index, with higher scores indicating greater attention to nano-news on

traditional media (M = 4.36, SD = 1.46, Cronbach's α = 0.90).

Attention to nano-news on new media. This variable was measured by three items on a 7-point scale (1 = no attention at all, 7 = a lot of attention) asking the respondents how much attention they pay to the following: (a) "Information about nanotechnology on blogs (e.g., Blogspot, Wordpress)," (b) "Information about nanotechnology on Wikis (e.g., Wikipedia, Wiktionary)," and (c) "Information about nanotechnology on social networking sites (e.g., Facebook, Twitter, YouTube)." These items were averaged to create a composite index, with higher scores indicating greater attention to nano-news on new media (M = 3.74, SD = 1.51, Cronbach's α = 0.91).

Science knowledge. Science knowledge was measured using five dichotomous items [1 = "true" (T); 2 = "false" (F)]. Respondents were required to answer 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 recorded into "0." Responses which fell into the "I don't know" categories were recorded as "0." Scores for all the items were summed, with higher scores indicating higher level of science knowledge (M = 3.05, SD = 1.40, KR-20 = 0.56).

Risk perception. Risk perception was measured using three items. Respondents were asked to indicate how much they agree with the following statements using a 7-point scale (1 = strongly disagree, 7 = strongly agree): (a) "Nano ingredients in food will lead to new human health problems," (b) "Nano ingredients in food will lead to new environmental problems," and (c) "Nano ingredients in food will lead to new food safety problems." These items were averaged to create a composite index, with higher scores indicating higher risk perception (M = 4.45, SD = 1.15, Cronbach's α = 0.92).

Benefit perception. Benefit perception was measured using three items on a 7-point scale (1 = strongly disagree, 7 = strongly agree) by asking the respondents to indicate how much they agree with the following statements: (a) "Nano ingredients in food will lead to better food safety," (b) "Nano ingredients in food will improve food quality," and (c) "Nano ingredients in food will lead to better nutrition." These three items were averaged to create a composite index, with higher scores indicating higher benefit perception (M = 4.12, SD = 1.11, Cronbach's α = .93).

Dependent variables

Support for labeling of nano-food. Support for labeling of nano-food was measured using a single item by asking the respondent how much they agree with the following statement using a 7-point scale (1 = strongly disagree, 7 = strongly agree): "The government should ensure that food products containing nano-ingredients are labeled." Higher scores indicated greater support for labeling of nano-food (M = 5.80, SD = 1.18).

Support for banning of nano-food. Support for banning of nano-food was measured using a single item by asking the respondent how much they agree with the following statement using a 7-point scale (1 = strongly disagree, 7 = strongly agree): "The government should ban the use of nano-ingredients in food." Higher scores indicated greater support for banning of nano-food (M = 3.95, SD = 1.33).

[Insert Table 1 about here.]

Analytic approach

This study conducted ordinary least squares (OLS) hierarchical regression analyses to test the proposed hypotheses and research questions. All demographic variables (gender, age, level of education, ethnicity, monthly household income, and institutional trust) were controlled and included in the first block. Predisposition variables (attitude toward technology, and preference for natural product) were entered into the second block.

Attentions to food safety news variables (attention to food safety news on traditional media and attention to food safety news on new media) were entered into the third block. Next, attentions to nano-news variables (attention to nano-news on traditional media and attention to nano-news on new media) were entered into the fourth block. Science knowledge was entered into the fifth block. Finally, perception variables (risk perception and benefit perception) were entered into the final block. All the variables were entered into the regression model according to their assumed causal order.

Results

Factors predicting support for labeling and banning of nano-food are reflected in Table 2. For the demographic variables, the results showed that gender was not significantly associated with both support for the labeling of nano-food and the support for banning of nano-food. In contrast, age was significantly associated with both support for labeling of nano-food ($\beta = 0.08$, $p < .01$) and support for banning of nano-food ($\beta = 0.07$, $p < .05$). Ethnicity was a significant predictor for only for labeling of nano-food ($\beta = -0.07$, $p < .05$). The results showed that other minorities such as Malays, Indians, and Eurasian were more likely to support labeling of nano-food. Educational level, monthly household income, and institutional trust were not related with any of the dependent variables. The demographic block accounted for smaller variances of support for labeling nano-food (4.4%) and support for banning of nano-food (2.8%).

Meanwhile, attitude toward technology was positively associated with support for labeling of nano-food ($\beta = 0.21$, $p < .001$) and negatively associated with support for banning of nano-food ($\beta = -0.08$, $p < .05$). Thus, *H1a* was rejected while *H1b* was supported. The results showed that preference for natural products was positively associated with both dependent variables, support for labeling of nano-food ($\beta = 0.12$, $p < .001$) and support for banning of nano-food ($\beta = 0.09$, $p < .01$). Therefore, *H2a* and *H2b* were supported. The

predisposition block accounted for much more variances for both the support for labeling of nano-food (6.8%) and the support for banning of nano-food (3.7%).

Among the attention to food safety news variables, attention to food safety news on traditional media was positively associated with support for the labeling of nano-food (β = 0.10, $p < .05$), but it has no significant relationship with support for the banning of nano-food. Hence, *H3a* was supported while *H3b* was rejected. For *RQ1a* and *RQ1b*, the results revealed that attention to food safety news on new media was not significantly related to both support for labeling of nano-food and support for banning of nano-food. This blocks account for little variances for support for labeling of nano-food (1.9%) and support for banning nano-food (0.2%).

Likewise, attention to nano-news on traditional media was not significantly associated with support for labeling and banning of nano-food. Therefore, *H4a* and *H4b* were rejected. To answer *RQ2a* and *RQ2b*, attention to nano-news on new media was entered in the fourth block. The result of the analyses showed that attention to nano-news on new media was negatively associated with support for labeling of nano-food ($\beta = -0.13$, $p < .05$), but it had no significant relationship with support for banning of nano-food. The fourth block accounted for lesser variance for both dependent variables—support for labeling of nano-food (0.5%) and support for banning of nano-food (0.2%).

Similarly, to answer *RQ3a* and *RQ3b*, science knowledge was entered into the fifth block. The results showed that science knowledge was positively associated with support for labeling of nano-food (β = 0.13, $p < .001$) but negatively associated with support for banning of nano-label ($\beta = -0.11$, $p < .001$). Science knowledge accounted for very little variance for support for labeling of nano-food (1.8%) and lesser variance for support for banning of nano-food (0.2%).

In the final block, the result showed that risk perception was positively associated

with support for labeling of nano-food ($\beta = 0.20$, $p < .001$). Therefore, *H5a* was supported. Notably, benefit perception was not significantly related to support for labeling of nano-food. Therefore, *H6a* was rejected. To answer *RQ4* and *RQ5*, the results showed that risk perception was positively associated with support for banning of nano-food ($\beta = 0.39$, $p < .001$), but benefit perception was negatively associated with support for banning of nano-food ($\beta = -0.20$, $p < .001$). This block accounted for much variance for support for labeling of nano-food (3.3%). It also accounted for the largest variance for support for banning of nano-food (22.2%).

In total, all the variance explained 18.6% of the variance for support for labeling of nano-food and 29.3% of the variance for support for banning of nano-food.

[Insert Table 2 about here.]

Discussion

Developments in the science and production of nano-foods have raised public concerns and debates about how nano-food will be compatible with other food products in terms of governance. Prior to decision-making about mandatory labeling of nano-foods or implementing a ban altogether on the use of nano-foods, it is crucial for policymakers and stakeholders to understand public perceptions toward nano-food and the policy desires. This includes important governance decisions such as the labeling and banning of nano-food. This study examines the associations between predispositions, media attention, science knowledge, risk and benefit perceptions, and support for these critical policy implementations.

Overall, the findings demonstrate that risk and benefit perceptions play significant roles in influencing public support for the labeling and banning of nano-food. Predispositions such as attitudes toward technology and preference for natural food also effect public support for the labeling of nano-food. Contrary to prior studies, higher levels of science knowledge

are associated with increased support for nano-food labeling, but not banning.

Consistent with the psychometric paradigm, increased risk perception is associated with increased support for the labeling and banning of nano-food. Drawing on the psychometric paradigm, risk perceptions of nano-food could be exacerbated by the uncertainty and potential repercussions of nano-food technology, in turn inhibiting purchase intentions (Siegrist et al. 2007a). To elaborate, consumers who perceive nano-food as risky would prefer them to be clearly labeled to serve as a heuristic function and cautionary label that can aid them in the avoidance of such products. Consumers who feel strongly against nano-food technology would prefer such products to be removed from the market completely, and they would support the banning of nano-food. Conversely, increased benefit perceptions are associated with lower levels of support for the banning of nano-food. These findings are in line with previous studies (Ho et al. 2010; Siegrist et al. 2008; Yue et al. 2015) which found risk and benefit perceptions to be significant factors predicting public support for nanotechnology and nano-food. Benefit perceptions had no significant influence on support for labeling.

This study also examines the impact of attention to food safety news and nano-news on support for nano-food labeling and banning. With regard to food safety news, results show a positive association between attention to food safety news on traditional media and support for labeling of nano-food, albeit having a small effect size. However, attention to food safety news on new media is not associated with support for labeling of nano-food. In terms of nano-news, attention to nano-news on traditional media is not significantly related to support for labeling of nano-food, but attention to nano-news on new media is found to be negatively associated with the support for the labeling of nano-food. This can be ascribed to three possible reasons—media platforms, news content, and tone of coverage.

Traditional media platforms, such as TV news and print newspaper, are limited to

one-way and top-down communication, whereas new media platforms allow for more dialogic and interactive communication between content providers and consumers. On traditional media platforms, newsmakers and gatekeepers possess autonomy over news content, while many new media platforms encourage information seeking and sharing among users. Notably, food safety news coverage on traditional media is predominantly negative in tone (Swinnen et al. 2005) due to the public's interest in negative or controversial issues (Verbeke and Ward 2001). People who pay attention to food safety news on traditional media are primed to envision nano-food as risky. As such, they tend to support the labeling of nano-food. However, given that Singapore is still at the initial stages of nano-food development, the coverage of nano-news on traditional media is likely to be quite limited. This is a likely explanation for why there was no significant relationship between attention to nano-news on traditional media and support for labeling of nano-food.

New media provide users with a multiplicity of platforms (e.g., blogs, Wikis, and social networking sites), and information sources (e.g., consumers, manufacturers, scientists) to acquire and validate information about nanotechnology (Brossard 2013; Lozano and Lores 2013). Consumers are afforded opportunities to assess the risks and benefits associated with nano-food through a variety of information sources on new media (Rutsaert et al. 2013). People who pay attention to nano-news on new media can easily seek nano-related information on new media and therefore, they may not support the labeling of nano-food that serves as warning to deter purchase (Brown and Kuzma 2013). In comparison to the nano-news on new media platforms, food safety news on new media includes a wide range of food-related news stories that may not necessarily be related to nanotechnology. As such, it is likely that attention to food safety news on new media is not associated with support for labeling of nano-food.

Attention to food safety news and nano-news on both traditional and new media does

not impact public support for the banning of nano-food. This may be due to the small degree of media coverage. Although Singaporeans are familiar with nanotechnology in general (Liang et al. 2015), they may not be familiar with the application of nanotechnology in food products. Thus, the public may prefer nano-food labeling to gain a better understanding of such products and keep their purchasing options open while they monitor the development of nano-food, as opposed to a complete ban at this point in time.

Congruent with findings from existing studies, the results show that consumers who prefer natural products support the labeling and banning of nano-food. It can be expected that consumers with a pre-existing preference for natural product would be more conscious of food labels, and use them as guides for purchasing decisions. Thus, they would prefer having labeling to serve as a "do-not-buy" marker to avoid buying such products. Moreover, those who prefer natural food were found to possess greater risk perceptions of nano-food (Saher et al. 2006) and would be more likely to resist it on the grounds of "unnaturalness." Thus, they are more likely to support the banning of nano-food.

One of the most interesting findings from this study is the relationship between attitudes toward technology and support for the labeling of nano-food. The results found attitudes toward technology to be positively associated with support for labeling. These findings are congruent with a body of literature which argues that support for nano-food labeling may not necessarily point to negative attitudes toward nano-food. For instance, some scholars suggest that food labels reassure consumers of the checks and balances that have been conducted by the relevant governing bodies and the safety of these food products for consumption (Dimara and Skuras 2005). These labels could also serve to enhance positive attitudes toward nano-food by displaying transparency and boosting consumers' sense of control during the purchasing process (Costa-Font et al. 2008; Curtis et al. 2004, Frewer et al. 2004). The negative relationship between attitudes toward technology and support for the

banning of nano-food found in study was in line with findings demonstrated in Siegrist's study (2003), in which people who dislike technology tend to support the banning of nano-food.

The findings from this study also demonstrate that people with higher levels of science knowledge are more likely to support the labeling of nano-food and less likely to support the banning of nano-food. Consistent with previous studies (Ho et al. 2010; Lee et al. 2005), the results show that people rely on their preexisting science knowledge to evaluate and make nanotechnology-related decisions. Science literate individuals express support for labeling as it provides them the ability to make informed purchasing decisions after interpreting and analyzing the information on the label provided. Due to an inherent desire for personal control in the purchasing process, consumers would prefer making their own decisions based on the labels and keep their purchasing options open rather than the banning of these food products.

Findings from this study suggest that labels serve distinct functions for different audiences. Nano-food labels serve as symbols that become inscribed with meaning by consumers who hold distinct motivations that range from labels serving as cautionary markers to labels promoting assurance that the product is appropriately governed by authorities. The results show that for people who prefer natural product, food labels serve more as a cautionary label while for people with positive attitude toward technology and those with higher level of science knowledge, nano-food labels are more closely aligned to a right to be informed function. Future research may further segment samples of the public to provide even more nuanced population-based identification of public desires for labels and support for banning nano-food.

Similar with other existing studies, this study has its limitations. First, this study used a cross-sectional sample and thus, we are unable to infer causality. Second, as this study was

conducted in Singapore, the findings of this study may be transferable to other similar populations, but should not be considered generalizable to other contexts. However, we note that this study adds valuable theoretical and practical contributions that will be of value to scholars and policymakers.

Theoretical and practical contributions

This study provides several theoretical and practical contributions. In terms of theoretical contributions, this study serves as the pioneering piece that sought to investigate the factors influencing public support for the banning of nano-food. Understanding attitudes toward the banning of nano-food technology is crucial as it indicates the degree of acceptance of nano-food products. Moreover, support for labeling has been found to stem from an assortment of reasons and relates to both positive and negative attitudes. It serves as either a cautionary signal or the right to be informed function for people with different attitudes toward nano-food. Contrastingly, the support for the banning of nano-food indicates only negative attitudes related to this novel technology. Future research can delve further to understand the variance in intensity of negative perceptions regarding nano-food technology that distinguishes individuals who support labeling of nano-food from those who support banning of nano-food. Furthermore, it may be worthwhile to investigate the overlap between support for the labeling and banning of nano-food.

This study also marks one of the initial nano-food technology studies in the context of Singapore. Singapore serves as a unique study context as compared to existing studies that were conducted in the USA and European countries due to the high science literacy rate. This would provide an alternative lens to understanding perceptions toward nano-food technology among a population who possess sufficient levels of knowledge to determine and weigh the benefits and risks incurred from such a technology. Additionally, the cultural differences may also contribute to acceptance of nano-food technology. For instance, Asians were found to be

more risk adverse than their western counterparts (Cheng 2010). Future studies can investigate the cultural impact on public support for the labeling and banning of nano-food.

Besides, this study contributes by offering practical insights for policymakers and communication practitioners. Our findings suggest that there may be lack of sufficient news coverage of nano-food. As such, the public may possess basic knowledge of nanotechnology but lack the expertise to form judgment about the application of nanotechnology in food products. Thus, the government can inform the public by utilizing both traditional media and new media platforms to disseminate information about nano-food. More importantly, newsmakers should provide a balanced argument of the advantages and disadvantages to allow the public to arrive at an informed conclusion regarding their stance on nano-food products. Furthermore, given the prominence and popularity of social influencers in the contemporary online sphere, the government can engage their help to create bite-sized information expressed in layman terms to help people learn about nano-food in a light-hearted and passive manner. Campaigns and media messages can be crafted to appeal to different segments of the public who hold varying intensities of attitudes toward nano-food technology. By engaging in audience segmentation, it is possible to address differing concerns and maximize the effect of media messages.

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Tables

Table 1. Descriptive statistic of independent and dependent variables.

	M	*SD*
Control variables		
Gender	51.6% female	-
Age	37.92	10.68
Race	86.9% Chinese	-
Education	Median = 8.00	1.32
Household income	Median = 7.00	3.01
Institutional trust	4.91	.86
Independent variables		
Attitude toward technology	5.50	1.08
Preference for natural product	5.22	1.03
Attention to food safety news on traditional media	5.19	1.13
Attention to food safety news on new media	4.19	1.34
Attention to nano-news on traditional media	4.36	1.46
Attention to nano-news on new media	3.74	1.51
Science knowledge	3.05	1.40
Risk perception	4.45	1.15
Benefit perception	4.12	1.11
Dependent variables		
Support for labeling of nano-food	5.80	1.18
Support for banning of nano-food	3.95	1.33

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

Table 2. Hierarchical regression models predicting support for labeling of nano-food and banning of nano-food.

	Zero-order Correlations	Support for labeling nano-food	Zero-order Correlations	Support for banning nano-food
Block 1: demographics				
Gender (1=male; 0=female)	0.22	0.01	-0.04	0.02
Age	0.10**	0.08**	0.12***	0.07*
Ethnicity (1=Chinese; 0=Others)	-0.05	-0.07*	-0.04	-0.03
Education	0.11***	0.03	-0.00	0.05
Household income	0.09**	0.02	-0.03	0.00
Institutional trust	0.12***	0.04	-0.09**	-0.02
Incremental R^2 (%)		4.40***		2.80**
Block 2: predispositions				
Attitude toward technology	0.27***	0.21***	-0.10**	-0.08*
Preference for natural product	0.22***	0.12***	0.15***	0.09**
Incremental R^2 (%)		6.80***		3.70***
Block 3: media use (food safety news)				
Attention to food safety news on traditional media	0.18***	0.10*	0.06	-0.01
Attention to food safety news on new media	0.02	-0.06	0.05	0.05
Incremental R^2 (%)		1.90***		0.20
Block 4: media use (nano-news)				
Attention to nano-news on traditional media	0.10**	0.02	0.07*	0.03
Attention to nano-news on	0.00	-0.13*	0.05	0.04

new media				
Incremental R^2 (%)		0.50		0.20
Block 5: science literacy				
Science knowledge	0.17***	0.13***	-0.07*	-0.11***
Incremental R^2 (%)		1.80***		0.20
Block 6: perceptions				
Risk perception	0.20***	0.20***	0.47***	0.39***
Benefit perception	0.00	0.03	-0.31***	-0.20***
Incremental R^2 (%)		3.30***		22.20***
Total R^2 (%)		18.60***		29.30***

*Significance at the $p < .05$ level; **significance at the $p < .01$ level; ***significance at the $p <.001$ level.