Nanotechnology in Food, Care Products, and Medicine:
Public Perception of Risks and Benefits

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Abstract

Nanotechnology is considered to be an enabling technology that is likely to have a great impact on our lives over the coming decades. This new technology could offer great benefits, but little is known about environmental or health hazards. The purpose of this study was to examine people's perceptions of trust, risks, benefits, control, and dread on food, care products, and medicine to which either natural or nano-additives were added for certain unique benefits for human health. Data was collected with two online surveys, both identical except for which additive was mentioned. Participants (*N* = 125) perceived risks and dread to be significantly higher for nano-additives than for natural additives for all product categories. Scores were significantly lower for nano-additives when measuring perceived trust, benefits, and control for food and care products. Medicine did not show any significant results for trust, benefits, and control. Calculations were also conducted to see whether there were any significant differences between nano-fortified products. Medicine scores were found to be significantly higher than food for benefit and control items, and medicine scores were also significantly higher than care products for control and dread items. The results suggest that the public may perceive nano-fortified food and care products differently from nano-fortified medicine.

Keywords: nanotechnology, risks, benefits, perception

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Nanotechnology in Food, Care Products, and Medicine: Public Perception of Risks and Benefits

Over the past few decades a new technology has emerged called "nanotechnology". It has entered the lives of millions of people already and is projected to keep doing so more and more. Nanotechnology is the manipulation of matter on a molecular or even atomic level (Drexler, 1992) and due to its wide range of possible applications in food and packaging for example, its use is likely to increase over the coming years (Kuzma & VerHage, 2008). Aside from food, nanotechnology can also add to care products (e.g. sunscreens) (Shatkin, 2013), or various types of medicine (Maynard, 2006). Public perception of new technologies can be influential for their application (Köhler & Som, 2008), and the sales of genetically modified (GM) foods, for example, were adversely affected by a negative outlook from the public (Ferber, 1999; Gaskell, Bauer, Durant, & Allum, 1999). Knowing the public's perception on nanotechnology's risks and benefits is therefore of great importance. This study was conducted to see whether nano-additives in either food, care products, or medicine were perceived differently from other additives. Using nano-additives in different product categories could also possibly unveil differences in perception among nano-products, so this was taken into account as well.

Nanotechnology can be used for a wide range of applications, e.g. military purposes, machinery, the environment, medical purposes, or food (Cacciatore, Scheufele, & Corley, 2011). Some current and proposed applications of nanotechnology include self-cleaning and air-purifying surface coatings, self-healing coatings, static and wrinkle-free fabrics, and contaminant detection in drinking water (Shatkin, 2013). However, these possible benefits do not exclude the possibility of accompanying risks, as several studies have pointed to potential risks from producing and using nano-materials (Arnall, 2004; Dreher, 2004; Hoet, Brüske-Hohlfeld, & Salata, 2004). It is likely that some nano-particles may be released into the environment during or after the production or consumption of products using nano-materials. By either inhalation, ingestion, or dermal penetration it is possible for nano-particles to get into the human body (Maynard, 2006, Oberdörster, Oberdörster, & Oberdörster, 2005). When considering medical devices and drugs there are two additional means of entry – injection (Oberdörster et al., 2005) and release from implants (Maynard, 2006). It is not yet possible to say what the actual effects of decades of using nanotechnology will or might be on human health and the environment, even if current tests deem it to be safe. The technology has not been in use long enough yet to gather enough data on this.

Nano-fortified Food, Care Products, and Medicine

Cobb and Macoubrie (2004) found that the most important potential benefit of nanotechnology to achieve was new ways to detect and treat human diseases. A total of 57.2% of respondents found this benefit preferable to cheaper and better consumer products, increased national security and defence, new ways to clean the environment, and physical and mental improvements for humans. When it came to the most important risk of nanotechnology to avoid, human health ("breathing nano-particles that accumulate in the body") came in at third place with 18.6% of respondents considering that a top priority. The most important risks to avoid were loss of personal privacy (31.9%) and an arms race (23.8%).

The most sought-after potential benefit for nanotechnology by far was improving human health. Some of the ways human health can be impacted greatly are with our food, care products, and medicine. Nanotechnology is already used, or can be used in the future, in those products and their packaging. In food nanotechnology can help fortify certain functional ingredients (Chen, Remondetto, & Subirade, 2006; Weiss, Takhistov, & McClemens, 2006). Nanotechnology in food packaging can for example be used to reduce ultraviolet light exposure or reduce microbial growth. Nano-packaging also allows for the detection of contaminants or pathogens (Weiss, Takhistov, & McClemens, 2006). These properties make nanotechnology interesting not just for everyday food consumption, but also for the use in care products and medicine. In the category of care products, sunscreen is known for containing nanotechnology (zinc oxide and titanium dioxide) for improving their efficiency and is deemed safe (Newman, Stotland, & Ellis, 2009). In medicine, nanotechnology is projected to revolutionize drug delivery, gene therapy, and diagnostics, among other areas.

Public Perception of Nanotechnology

Views on nano-food and nano-packaging can be specific to certain countries. Bieberstein, Roosen, Marette, Blanchemanche, and Vandermoere (2013) showed that although French as well as German consumers are both reluctant to accept nanotechnology in their food, the French consumers are more reluctant to accept nano-packaging, whereas German consumers are less favourable towards nano-fortified food. Consumers in general attribute a negative utility to nanotechnology foods, despite clear health benefits. Although they are interested in products with additional health effects, these effects have to be from natural additives and not from nanotechnology (Siegrist, Stampfli, & Kastenholz, 2009). A study in Switzerland, among consumers who found nano-packaging less problematic than nano-food, showed that affect and perceived control are important factors that can influence the perception of risks and benefits (Siegrist, Stampfli, Kastenholz, & Keller, 2008). Naturalness in food products and trust were significant factors affecting the perceived risks and benefits of nanotechnology foods and packaging.

Because of its wide range of possible applications, the use of nano-additives in food and food packaging is likely to increase over the coming years, despite the public’s uncertain stance towards this new technology (Kuzma & VerHage, 2006). Public perception about new technological advancements can be influential for their application (Köhler & Som, 2008), both in direct influences, e.g. a consumers’ unwillingness to buy (Siegrist, 2008), and indirect influences, e.g. public fears leading to more regulation and possibly higher production costs

(Ayers, 1998). The sales of genetically modified (GM) foods, for example, were adversely affected by a negative outlook from the public (Ferber, 1999; Gaskell, Bauer, Durant, & Allum, 1999).

If nanotechnology proves to be useful and safe, a positive public outlook on the technology could be decisive for its application. Being aware of public perception and their level of knowledge on the subject can help organizations change the public's attitude and help improve the adoption of nanotechnology.

Nano-Additives Versus Natural Additives

Besides nanotechnology there are several other types of additives that can improve our products. Siegrist, Stampfli, and Kastenholz (2009) found that consumers were more willing to buy food products with health benefits due to natural additives than the same products with the same benefits from nano-additives. The importance of perceived naturalness was also underlined in the same study with participants' higher appreciation of natural flavours compared with artificial flavours. Natural additives and flavours were attributed positive utility, unlike the nano-additives and artificial flavours. The benefits associated with the functional foods (cancer-combatting ice cream and cardiovascular disease reducing yogurt) on their own were not persuasive enough for consumers to buy the product. The naturalness of a product proved to be an important factor as well. These findings are consistent with the results of an earlier study in which nano-packaging was perceived as more beneficial than nano-food (Siegrist, Cousin, Kastenholz, & Wiek, 2007a). Rozin, Spranca, Krieger, Neuhaus, Surillo, Swerdlin, and Wood (2004) also demonstrated the importance of naturalness of food for their acceptance. Another study showed that nanotechnology used in lamb or beef was preferred to GM food (Cook & Fairweather, 2007), showing mixed results in the perception of nanotechnology.

Based on the previously mentioned studies, natural additives seem to be a good counter to nano-additives, so natural additives will also be used in this study as a counterpart to nano-additives. The first research question can then be formulated: how are nano-additives perceived in food, care products, and medicine compared to natural additives?

Risk Perception

Perceptions about risks and benefits, and subsequently the consumers' willingness to use nanotechnology, are influenced by several factors. Epstein (1994) distinguishes two separate ways in which people assess risk. One mode of thinking, the experiential system, bases its assessment on affect, associations and connections, past experiences, and encoding reality into images, metaphors, and narratives. This process is rapid and validated through "experiencing is believing". The other mode of thinking, the analytic system, is based on logic and reason, and encodes reality into abstract symbols, words, and numbers. It's a slower process and requires justification through logic and evidence. Finucane, Alhakami, Slovic, and Johnson (2000) show how affect comes before, and also directs, judgments of risks and benefits. For example: information stating that a risk his high for a certain technology or activity leads to a decrease in perceived benefits and vice versa. The same holds true when it is states that a technology or activity has low risk. The benefits will be inferred to be high. Information about high benefits also suggests low perceived risks.

People use trust as another shortcut when making decisions when they lack knowledge or information. People trusting the industry using and applying, and the agencies checking and regulating nanotechnology, assessed nano-applications more positively than the people lacking trust (Siegrist et al., 2007a; Siegrist, Keller, Kastenholz, Frey, & Wiek, 2007b; Siegrist et al., 2008). Cobb & Macoubrie (2004) found that amount of trust was not significantly related to knowledge about nanotechnology, but it was associated with perceptions of more specific potential risks and benefits. Less trust also resulted in more participants responding that risks would outweigh benefits. Nanotechnology has been considered to be more risky than more conventional ways of enhancing products. Granted that higher perceived risks is associated with lower trust, the first hypothesis will be: nano-additives will have lower perceived trust than nano-additives. Here, trust is defined as the confident expectation or reliance upon something with more trust, meaning being more hopeful or confident in a positive outcome.

Slovic (1987), discussing the psychometric paradigm, summarizes a few key qualitative characteristics that lead to specific evaluations of risk. People tend to be intolerant of risks they perceive to be uncontrollable, being potentially catastrophic, having fatal consequences, or showing an unfair distribution of risks and benefits. The public also tends to avoid risks that are unknown, new, and have a delayed delivery of harm. Since nanotechnology is new and we know little about long-term effects (unknown risks and possible delayed delivery of harm due to nano-particle build-up), hypothesis 2 was formulated as: nano-additives will have higher perceived risks than natural additives. With higher perceived risks also come lower perceived benefits, so hypothesis 3 reads: nano-additives will have lower perceived benefits than natural additives.

The degree to which a certain activity or technology is controllable and observable also plays a role in the perception of risk (Slovic, 1987). Activities and technologies that are perceived as controllable are also associated with being of a more voluntary nature, having less serious and fewer possible negative outcomes, and having lower risks overall. More observable activities and technologies are considered to be better known to both science and those exposed, and having more immediate effects. With the public's negative perception towards nanotechnology, lower perceived control may be a factor for this shyness, thus hypothesis 4 was formulated as: nano-additives will have lower perceived control than natural additives.

Even when groups of laypeople and experts disagreed on the riskiness of certain hazards, they agreed for the most part when it came to some of the characteristics of risks, such as knowledge, controllability, dread, and catastrophic potential (Slovic, Fischhoff, & Lichtenstein, 1982). Dread will be defined as great fear or uneasiness about something negative that will or might happen. When it comes to laypersons, the higher an activity or technology's score on dread risk, the higher its perceived risks, and the more people want its risks reduced (for example by regulation). Experts were not significantly influenced by dread risk. Since this study deals with laypeople dread may be a significant factor influencing risk and benefit perceptions, so hypothesis 5 is: nano-additives will have higher perceived dread than natural additives.

Slovic (1987) also mentions that even with so many variables (e.g. controllability, catastrophic potential, etc.), a large portion of risk perception is socially and culturally informed. A possible example of these social and cultural influences can be found in Bieberstein et al., (2013)'s study showing French and German consumers having different views on either nano-foods and nano-packaging.

While over the past decade more and more has become known about the public's perception of nano-fortified products, little research was done to identify differences in how nano-fortified products were perceived among one another. This study aims to shed some light on this aspect by checking whether different products show different results in the perception of risks and benefits, by trying to answer research question 2: how are different nano-fortified products (food, care products, medicine) perceived compared to each other?

Research Questions and Hypotheses

To summarize, this study will concern itself with the following research questions and hypotheses:

- Research question 1: how are nano-additives perceived in food, care products, and medicine compared to natural additives?

Accompanying research question 1 are five hypotheses:

- Hypothesis 1: nano-additives will have lower perceived trust than natural additives
- Hypothesis 2: nano-additives will have higher perceived risks than natural additives
- Hypothesis 3: nano-additives will have lower perceived benefits than natural additives
- Hypothesis 4: nano-additives will have lower perceived control than natural additives
- Hypothesis 5: nano-additives will have higher perceived dread than natural additives

The last research question was formulated as:

- Research question 2: how are different nano-fortified products (food, care products, medicine) perceived compared to each other?

Method

Participants

A total of 139 behavioural science university students participated in an online survey. Fourteen of these participants were not included in the analysis due to poor performance on the survey resulting in incomplete data. All students were given course credits for their participation.

The average age of the participants was 20.5 years (*SD* = 2.1). Twenty-six participants were male (20.8%) and ninety-nine participants were female (79.2%). Participants were either Dutch or German. It was assumed none of the participants had any problems expressing themselves in, or understanding Dutch, because all foreign students were obligated to pass a Dutch language course before starting their education. Due to this, Dutch was chosen as the language for the surveys.

Survey Design

Participants were randomly assigned to one of two possible surveys. Both surveys were identical. The only exception to this was which additive was mentioned. The items in the surveys were about products with either natural additives (N = 65) or nano-additives (N = 60). Natural additives were chosen to contrast the nano-additives to uncover whether some aspects of either additive were perceived differently (e.g. if one had higher perceived risks than the other).

The additives mentioned in each survey were added to three product categories, each product with its own added benefit from the additives. The products were orange juice (a food product), shower gel (a care product), and pain killers (a medicinal product). These products were presented in randomized order for every participant. Multiple product categories made it possible to see whether there participants perceived an additive differently from product to product. The benefits that were added by the natural ingredients or the nanotechnology were added vitamins and minerals for the orange juice, improved skin cleansing for the shower gel, and localized delivery of the active ingredients in the pain killers.

Task

Participants were assigned a random survey, with everything in it focused on either natural additives or nano-additives. After signing an informed consent form, participants received instructions for the survey. Subsequently they were given a brief overview of what either natural or nano-additives are and how they are made. After this information they viewed each of the three products one at a time and answered the corresponding items. The order in which participants viewed the products was randomized.

For every product, participants were asked to read about the product (e.g. orange juice), what type of additives was added (i.e. natural or nano-additives), and what benefit this additive yielded (e.g. more vitamins and minerals). After this, participants were asked to answer a total of twenty-eight items about the product. Of those twenty-eight items, there were eight items regarding perceived trust, ten items regarding perceived risks and benefits, four items regarding perceived control, and four items regarding perceived feelings of dread. Each of these items could be answered with a 7-point Likert scale (1 = "do not agree at all", 7 = "agree very much"). For every product there was one question at the end of the page asking whether they would use the product at all, regardless of additive, and one question whether or not they were allergic to the product, regardless of additive. After all three products were viewed and their accompanying items answered, participants finished the survey by answering a few general questions (e.g. age and gender).

Measures

Trust. The first eight items for every product were about perceived trust. Participants rated on a 7-point Likert scale (1 = "do not agree at all", 7 = "agree very much") their degree of agreement with statements concerning trust in the mentioned product and additive (e.g. "I feel like I can trust orange juice with natural additives" or "I assume pain killers with nano-additives are only available to purchase if they are safe"). After a reliability analysis, this eight item measure showed high Cronbach's alpha values for all categories. For natural additives, food (M = 4.79, SD = 1.00) scored .90 for Cronbach's alpha, care products (M = 4.86, SD = 1.00) scored .90 as well, and medicine (M = 4.79, SD = 1.10) scored .92. For nano-additives, food (M = 4.47, SD = 1.10) scored .92, care products (M = 4.53, SD = 1.100) scored .90, and medicine (M = 4.60, SD = 1.08) scored .91. These values can also be found in Table 1.

Table 1

Descriptive Statistics and Reliability Analysis for Trust Scores.

	Natural additives				Nano-additives			
Product	N	M	SD	α[a]	N	M	SD	α[a]
Food	65	4.79	1.00	.90	60	4.47	1.10	.92
Care	65	4.86	1.00	.90	60	4.53	1.00	.90
Medicine	63	4.79	1.10	.92	57	4.60	1.08	.91

Note [a]. Cronbach's alpha calculated for an eight item measure for every product.

Risks. After the trust items, there were ten items regarding perceived risks and benefits. When participants first encounter multiple questions regarding risks, this may skew their perception of possible benefits, and vice versa. Risk and benefit items were therefore randomized and presented simultaneously. Participants were asked to rate on a 7-point Likert scale (1 = "do not agree at all", 7 = "agree very much") how much they agreed with risk statements (e.g. "I think shower gel with natural additives has many risks" or "I think orange juice with nano-additives is bad for my health"). Reliability analysis showed one of the risk items was lowering Cronbach's alpha scores. This item was left out of future analyses, leaving four items to work with. For natural additives, perceived risks on food (*M* = 3.07, *SD* = .88) scored .88 for Cronbach's alpha, perceived risks on care products (*M* = 3.15, *SD* = .76) scored .72, and perceived risks on medicine (*M* = 3.30, *SD* = .94) scored .87. For nano-additives, Cronbach's alpha for risk scores were .79 for food (*M* = 3.79, *SD* = .93), .73 for care products (*M* = 3.86, *SD* = .74), and .80 for medicine (*M* = 3.81, *SD* = .79). An overview of these numbers can be found in Table 2.

Table 2

Descriptive Statistics and Reliability Analysis for Risk Scores.

	Natural additives				Nano-additives			
Product	N	M	SD	α[a]	N	M	SD	α[a]
Food	65	3.07	.88	.84	58	3.79	.93	.79
Care	65	3.15	.76	.72	59	3.86	.74	.73
Medicine	65	3.30	.94	.87	60	3.81	.79	.80

Note [a]. Cronbach's alpha calculated for a four item measure for every product.

Benefits. Participants were asked to rate on a 7-point Likert scale (1 = "do not agree at all", 7 = "agree very much") how much they agreed with benefit statements (e.g. "I think pain killers with nano-additives have many benefits" or "I think the natural additives in orange juice are harmless to the environment"). A reliability analysis showed one out of five benefit items was lowering Cronbach's alpha scores. This item was left out of future calculations. Cronbach's alpha scores for natural additives were .86 for food (*M* = 4.40, *SD* = .97), .79 for care products (*M* = 4.36, *SD* = .78), and .85 for medicine (*M* = 4.32, *SD* = .93). For nano-additives, food (*M* = 3.99, *SD* = 1.01) scored .90, care products (*M* = 4.10, *SD* = .79) scored .86, and medicine (*M* = 4.28, *SD* = .69) scored .76. These numbers can also be found in Table 3.

Table 3

Descriptive Statistics and Reliability Analysis for Benefit Scores.

	Natural additives				Nano-additives			
Product	N	M	SD	α[a]	N	M	SD	α[a]
Food	65	4.40	.97	.86	60	3.99	1.01	.90
Care	63	4.36	.78	.79	59	4.10	.79	.86
Medicine	64	4.32	.93	.85	59	4.28	.69	.76

Note [a]. Cronbach's alpha calculated for a four item measure for every product.

Control. After trust, risks, and benefits, the survey asked participants to rate how much they agreed with statements regarding perceived control (e.g. "I know about it if there are nano-additives in the pain killers I want to buy" or "As a consumer I have enough alternatives for shower gel with natural additives") on a 7-point Likert scale (1 = "do not agree at all", 7 = "agree very much"). Reliability analysis showed that there were items lowering Cronbach's alpha in the cases of some products and were subsequently excluded from further analyses. For the remaining items for natural additives, Cronbach's alpha on food (M =3.91, SD = .85) was .59 using three items, for care products (M = 3.81, SD = 1.02) it was .69, also using three items, and for medicine (M = 3.67, SD = .96) it was .72 using four items. For nano-additives, the remaining items for food (M = 3.44, SD = 1.01) scored .76 on Cronbach's alpha, using two items, care products (M = 3.47, SD = .89) scored .73 using four items, and medicine (M = 3.74, SD = .98) scored .67 using three items. The descriptive statistics and results of this reliability analysis can be found in Table 4.

Table 4

Descriptive Statistics and Reliability Analysis for Control Scores.

	Natural additives				Nano-additives			
Product	N	M	SD	α	N	M	SD	α
Food	63	3.91	.85	.59[b]	58	3.44	1.01	.76[a]
Care	59	3.81	1.02	.69[b]	58	3.47	.89	.73[c]
Medicine	63	3.67	.96	.72[c]	59	3.74	.98	.67[b]

Note [a]. Cronbach’s alpha calculated for a two item measure.

[b]. Cronbach’s alpha calculated for a three item measure.

[c]. Cronbach’s alpha calculated for a four item measure.

Dread. The last variable per product was perceived dread. Participants rated on a 7-point Likert scale (1 = “do not agree at all”, 7 = “agree very much”) the degree to which they agreed with statements concerning dread in the mentioned product and additive (e.g. “I’m worried about the possible consequences of using shower gel with nano-additives” or “I’m afraid I wouldn’t feel well if I’d use shower gel with natural additives”). This four item measure displayed high Cronbach’s alpha for all product categories and additives. Reliability analysis for natural additives showed Cronbach’s alpha for food (*M* = 2.65, *SD* = 1.10) at .92, for care products (*M* = 2.59, *SD* = .97) it was .94, and for medicine (*M* = 3.10, *SD* = 1.05) it was .91. With nano-additives, food (*M* = 3.54, *SD* = 1.07) scored .92, care products (*M* = 3.38, *SD* = 1.05) scored .93, and medicine (*M* = 3.75, *SD* = 1.02) scored .91. Table 5 shows all the above statistics as well.

Table 5

Descriptive Statistics and Reliability Analysis for Dread Scores.

	Natural additives				Nano-additives			
Product	N	M	SD	α[a]	N	M	SD	α[a]
Food	63	2.65	1.10	.92	59	3.54	1.07	.92
Care	65	2.59	.97	.94	60	3.38	1.05	.93
Medicine	64	3.10	1.05	.91	58	3.75	1.02	.91

Note [a]. Cronbach's alpha calculated for a four item measure for every product.

Statistical analyses. To see whether there are significant differences in scores between the additives, an independent-samples t-test shall be conducted on trust, risk, benefit, control, and dread scores on all product categories. This will reveal possible differences for every product category. A one-way repeated measures ANOVA will be performed to see if the nano-fortified products are perceived differently for any of the constructs (e.g. trust). If significant differences are found, a pairwise comparison of the products will reveal the nature of that difference.

Results

An online survey was conducted among university students. They were presented one of two possible surveys, mentioning either natural additives or nano-additives. Every survey showed the same three products, namely orange juice, shower gel, and pain killers (from here on referred to as food, care products, and medicine, respectively), each with their own distinct new positive trait from the mentioned additive. The survey measured participants' perceived trust, perceived risks and benefits, perceived control, and perceived dread for these products. The data presented here is accompanied by tables.

Trust

An independent-samples t-test was conducted to compare the trust scores for natural additives and nano-additives. Significant differences were found for food (natural: *M* = 4.79, *SD* = 1.00; nano: *M* = 4.46, *SD* = 1.10), $t\ (123) = 1.735$, $p = .043$ (one-tailed) and care products (natural: *M* = 4.86, *SD* = 1.00; nano: *M* = 4.53, *SD* = 1.00), $t\ (123) = 1.850$, $p = .034$ (one-tailed), but only after dividing two-tailed *p* results in two to end up with the one-tailed results. With these results hypothesis 1 (nano-additives will have lower perceived trust than natural additives) was partially confirmed. The scores for both natural additives and for nano-additives were above 4 (in the survey this was the answer: "don't agree, don't disagree"), indicating they would both sooner be trusted rather than distrusted. This, in spite of nano-additives scoring significantly lower on perceived trust than natural additives. Table 6 gives an overview of the descriptive statistics and results of the independent-samples t-test.

Table 6

Descriptive Statistics and Independent-Samples T-Test Comparing Trust Scores for Natural and Nano-Additives for All Products.

Product	Additive	N	M	SD	*t*	p^a
Food	Natural	65	4.79	1.00	1.735	.085*
	Nano	60	4.46	1.10		
Care	Natural	65	4.86	1.00	1.850	.067*
	Nano	60	4.53	1.00		
Medicine	Natural	63	4.79	1.10	.925	.357
	Nano	57	4.60	1.08		

Note [a]. Two-tailed *p* results.

*. As a one-tailed result this is significant at the .05 level.

A one-way repeated measures ANOVA was performed to compare scores between nano-fortified food, care products, and medicine ($n = 57$). No significant difference was found, Wilks' Lambada = .979. *F* (2, 55) = .588, p = .559. Food (*M* = 4.50, *SD* = 1.09), care products (*M* = 4.55, *SD* = 1.00), and medicine (*M* = 4.60, *SD* = 1.08) were not perceived significantly different when it came to trust. An overview of the results of this calculation can be found in Table 7.

Table 7

Descriptive Statistics and One-Way Repeated Measures ANOVA for Trust Scores for Nano-Additives Comparing Food, Care Products, and Medicine (n = 57).

Product	M	SD	Δ	p^a
Food –	4.50	1.09	-.06	1.000
Care	4.55	1.00		
Food –	4.50	1.09	-.11	.836
Medicine	4.60	1.08		
Care –	4.55	1.00	-.05	1.000
Medicine	4.60	1.08		

Note [a]. Adjustment for multiple comparisons: Bonferroni.

Risks

In order to compare risk scores for natural additives and nano-additives, an independent-samples t-test was performed. There were significant differences for all product categories, namely food (natural: *M* = 3.07, *SD* = .88; nano: *M* = 3.79, *SD* = .93) with *t* (121) = -4.373, *p* < .0005 (two-tailed), care products (natural: *M* = 3.15, *SD* = 3.86; nano: *M* = 3.86, *SD* = .74) with *t* (122) = -5.278, *p* < .0005 (two-tailed), and medicine (natural: *M* = 3.30, *SD* = .94; nano: *M* = 3.81, *SD* = .79) with *t* (123) = -3.292, *p* = .001 (two-tailed). On basis of these results, hypothesis 2 (nano-additives will have higher perceived risks than natural additives) was accepted. All scores were below 4 ("don't agree, don't disagree"), indicating the participants, on average, disagreed more than they agreed with items stating a certain product and additive involved risks or hazards. Nano-additives still had significantly higher perceived risks than natural additives though. An overview of the descriptive statistics and results of the independent-samples t-test can be found in Table 8.

Table 8

Descriptive Statistics and Independent-Samples T-Test Comparing Risk Scores for Natural and Nano-Additives for All Products.

Product	Additive	N	M	SD	*t*	*p*[a]
Food	Natural	65	3.07	.88	-4.373	.000
	Nano	58	3.79	.93		
Care	Natural	65	3.15	.76	-5.278	.000
	Nano	59	3.86	.74		
Medicine	Natural	65	3.30	.94	-3.292	.001
	Nano	60	3.81	.79		

Note [a]. Two-tailed *p* results.

A one-way repeated measures ANOVA was conducted to see whether perceived risks showed any significant differences between nano-fortified food, care products, and medicine ($n = 57$). No significant differences were found, Wilks' Lambda = .997, $F(2, 55) = .091$, $p = .913$, multivariate partial eta squared = .003). Food ($M = 3.81$, $SD = .92$), care products ($M = 3.84$, $SD = .74$), and medicine ($M = 3.83$, $SD = .78$) were not perceived significantly different from each other when it came to perceived risks. This data is also displayed in Table 9.

Table 9

Descriptive Statistics and One-Way Repeated Measures ANOVA for Risk Scores for Nano-Additives Comparing Food, Care Products, and Medicine (n = 57).

Product	M	SD	Δ	p^a
Food –	3.81	.92	-.04	1.000
Care	3.84	.74		
Food –	3.81	.92	-.02	1.000
Medicine	3.83	.78		
Care –	3.84	.74	.01	1.000
Medicine	3.83	.78		

Note [a]. Adjustment for multiple comparisons: Bonferroni.

Benefits

Comparing scores for natural additives and nano-additives was done by performing an independent-samples t-test. Food (natural: *M* = 4.40, *SD* = .97; nano: *M* = 3.99, *SD* = 1.01), *t* (123) = 2.306, *p* = .023 (two-tailed), and care products (natural: *M* = 4.36, *SD* = .78; nano: *M* = 4.10, *SD* = .79), *t* (121) = 1.814, *p* = .036 (one-tailed) both showed significant differences between natural and nano-additives. The results for care products had to be calculated into a one-tailed result in order to achieve significance, though. All mean scores except for one (3.99, nano-food) were above 4 (“don’t agree, don’t disagree”), indicating that participants generally agree more with statements regarding benefits than they disagree with them. Natural additives were still perceived to have significantly more benefits than nano-additives in food and care products categories, thereby partially confirming hypothesis 3 (nano-additives will have lower perceived benefits than natural additives). An overview of the above results can be found in Table 10.

Table 10

Descriptive Statistics and Independent-Samples T-Test Comparing Benefit Scores for Natural and Nano-Additives for All Products.

Product	Additive	N	M	SD	*t*	*p*[a]
Food	Natural	65	4.40	.97	2.306	.023*
	Nano	60	3.99	1.01		
Care	Natural	63	4.36	.78	1.814	.072*
	Nano	60	4.10	.79		
Medicine	Natural	64	4.32	.93	.275	.784
	Nano	59	4.28	.69		

Note [a]. Two-tailed *p* results.

*. As a one-tailed result this is significant at the .05 level.

A significant difference for perceived benefits for nano-fortified products (n = 59) was found using a one-way repeated measures ANOVA, Wilks' Lambda = .882, F (2, 57) = 3.811, p = .028, multivariate partial eta squared = .118. Food (M = 3.97, SD = 1.01) and medicine (M = 4.28, SD = .69) showed a mean difference of -.31 (food – medicine), p = .025. There were no significant differences between food and care products (M = 4.08, SD = .79) and care products and medicine.

Table 11

Descriptive Statistics and One-Way Repeated Measures ANOVA for Benefit Scores for Nano-Additives Comparing Food, Care Products, and Medicine (n = 59).

Product	M	SD	Δ	p^a
Food –	3.97	1.01	-.11	.897
Care	4.08	.79		
Food –	3.97	1.01	-.31*	.025
Medicine	4.28	.69		
Care –	4.08	.79	-.19	.224
Medicine	4.28	.69		

Note [a]. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the .05 level.

Control

An independent-samples t-test was conducted to compare control scores for natural and nano-additives. Significant differences were found for food (natural: M = 3.90, SD = .85; nano: M = 3.44, SD = 1.01), t (120) = 2.748, p = .007 (two-tailed), and care products (natural: M = 3.81, SD = 1.02; nano: M = 3.47, SD = .89), t (117) = 1.990, p = .049 (two-tailed). All scores were below 4 (“don’t agree, don’t disagree”), indicating participants on average disagreed more than they agreed with items stating they felt in control. The food and care products with nano-additives received lower scores for perceived control than did the products with natural additives, thereby partially confirming hypothesis 4 (nano-additives will have lower perceived control than natural additives). For medicine (natural: M = 3.67, SD = .96; nano: M = 3.74, SD = .98) there was no significant difference between additives. An overview of this data can be found in Table 12.

Table 12

Descriptive Statistics and Independent-Samples T-Test Comparing Control Scores for Natural and Nano-Additives for All Products.

Product	Additive	N	M	SD	*t*	p^a
Food	Natural	63	3.90	.85	2.748	.007
	Nano	59	3.44	1.01		
Care	Natural	61	3.81	1.02	1.990	.049
	Nano	58	3.47	.89		
Medicine	Natural	63	3.67	.96	-.446	.657
	Nano	60	3.74	.98		

Note [a]. Two-tailed *p* results.

A one-way repeated measures ANOVA was conducted to see whether perceived control showed any significant differences between nano-fortified food, care products, and medicine (*n* = 57). There was a significant difference between the products, Wilks' Lambda = .863, *F* (2, 55) = 4.365, *p* = .017, multivariate partial eta squared = .137. Food (*M* = 3.44, *SD* = 1.03) and medicine (*M* = 3.73, *SD* = .99) showed a mean difference of -.29 (food – medicine), *p* = .028. Care products (*M* = 3.46, *SD* = .89) and medicine showed a mean difference of -.28 (care – medicine), *p* = .032. There was no significant difference between food and care products. Table 13 offers an overview of this data.

Table 13

Descriptive Statistics and One-Way Repeated Measures ANOVA for Control Scores for Nano-Additives Comparing Food, Care Products, and Medicine (n = 57).

Product	M	SD	Δ	p^a
Food –	3.44	1.03	-.02	1.000
Care	3.46	.89		
Food –	3.44	1.03	-.29*	.028
Medicine	3.73	.99		
Care –	3.46	.89	-.28*	.032
Medicine	3.73	.99		

Note [a]. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the .05 level.

Dread

The independent-samples t-test for perceived dread showed significant differences for all products. Food (natural: *M* = 2.64, *SD* = 1.10; nano: *M* = 3.54, *SD* = 1.07), *t* (120) = -4.582, *p* < .0005 (two-tailed), care products (natural: *M* = 2.59, *SD* = .97; nano: *M* = 3.38, *SD* = 1.05), *t* (123) = -4.409, *p* < .0005 (two-tailed), and medicine (natural: *M* = 3.10, *SD* = 1.05; nano: *M* = 3.75, *SD* = 1.02), *t* (120) = -3.440, *p* = .001 (two-tailed) all showed nano-additives scoring significantly higher on perceived dread, so hypothesis 5 (nano-additives will have higher perceived dread than natural additives) was accepted. It is worth noting that all scores were below 4 ("don't agree, don't disagree), which means participants generally disagreed with items stating a presence of feelings of dread. An overview of these results can be found in Table 14.

Table 14

Descriptive Statistics and Independent-Samples T-Test Comparing Dread Scores for Natural and Nano-Additives for All Products.

Product	Additive	N	M	SD	*t*	p^a
Food	Natural	63	2.64	1.10	-4.582	.000
	Nano	59	3.54	1.07		
Care	Natural	65	2.59	.97	-4.409	.000
	Nano	60	3.38	1.05		
Medicine	Natural	64	3.10	1.05	-3.440	.001
	Nano	58	3.75	1.02		

Note [a]. Two-tailed *p* results.

The one-way repeated measures ANOVA showed a significant effect for differences in dread scores among products (*n* = 57), Wilks' Lambda = .808, *F* (2, 55) = 6.546, *p* = .003, multivariate partial eta squared = .192. Dread scores for care products (*M* = 3.34, *SD* = 1.06) were lower than for medicine (*M* = 3.73, *SD* = 1.02), showing a mean difference of -.39 (care – medicine), *p* = .002. Food (M = 3.51, SD = 1.08) and care products, and food and medicine did not show any significant differences.

Table 15

Descriptive Statistics and One-Way Repeated Measures ANOVA for Dread Scores for Nano-Additives Comparing Food, Care Products, and Medicine (n = 57).

Product	M	SD	Δ	*p*[a]
Food –	3.51	1.08	.17	.157
Care	3.34	1.06		
Food –	3.51	1.08	-.22	.174
Medicine	3.73	1.02		
Care –	3.34	1.06	-.39*	.002
Medicine	3.73	1.02		

Note [a]. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the .05 level.

Overview

The independent-samples t-tests that were conducted showed twelve (out of a maximum of fifteen) significant differences. Risks and dread showed significant differences for all product categories, whereas trust, benefits, and control showed significant differences for only food and care products. The hypotheses accompanying risk and dread scores were accepted (nano-additives will have higher perceived risks/dread than natural additives), while the hypotheses accompanying trust, benefits, and control were partially accepted (nano-additives will have lower perceived trust/benefits/control than natural additives).

The repeated measures ANOVA's showed no differences between nano-fortified products for trust and risk scores. Benefit scores were significantly higher for medicine than for food. The same difference was found for control scores, as well as medicine scoring significantly higher than care products. Medicine also scored higher than care products on perceived dread.

Medicine was the only product that sometimes lacked a significant difference in scores between natural and nano-additives. When it came to differences between products, medicine consistently scored higher than the product it was paired with.

Discussion

An online survey was conducted measuring perceived trust, risks, benefits, control, and dread for three product categories, namely food, care products, and medicine. These products all had unique benefits that came from either natural additives or nano-additives. This made it possible to see whether nano-additives are perceived differently from natural additives, and whether nano-fortified products yielded differences in perception as well.

Additives

Comparing the scores on perceived trust, risks, benefits, control, and dread revealed a negative perception towards nano-additives as compared to natural additives. Slovic' (1987) psychometric paradigm offers a framework from which to view the results on the survey and answer research question 1 (how are nano-additives perceived in food, care products, and medicine compared to natural additives?). Hypothesis 1 (nano-additives will have lower perceived trust than natural additives) was partially confirmed. A significant difference was found for food and care products, but not for medicine. This means that at least for food and care products, trust can explain part of all the differences found between natural and nano-additives. The lower trust for nano-additives could also be reflected in the results for perceived risk. Hypothesis 2 (nano-additives will have higher perceived risks than natural additives) was accepted due to nano-additives scoring significantly higher on perceived risks than natural additives. Lower trust in nano-additives is correlated to its higher perceived risks. Lower perceived benefits for nano-additives can be the result of lower levels of trust for nano-products (Slovic, 1987), but possibly also because higher risks imply lower benefits as well (Finucane, Alhakami, Slovic, & Johnson, 2000). Hypothesis 3 (nano-additives will have lower perceived benefits than natural additives) was partially confirmed due to medicine not showing a significant difference in scores. Nano-additives were perceived to have lower benefits than natural additives. Hypothesis 4 (nano-additives will have lower perceived control than natural additives) was also partially confirmed, and also because of a lack in significant results for medicine. Lower perceived control for nano-additives as compared to natural additives also falls in line with Slovic (1987)'s psychometric paradigm, stating higher risks also lead to lowered feelings of control. Also consistent with the paradigm were the overall significantly higher scores on dread when it came to nano-additives as compared to natural additives, thereby confirming hypothesis 5 (nano-additives will have higher perceived dread than natural additives).

The results from this data, with participants preferring natural additives over nano-additives, are in line with results from earlier studies (Siegrist, Stampfli, & Kastenholz, 2009). Overall, compared to natural additives, nano-additives scored significantly higher on risks and lower on benefits. The lower scores on perceived trust and control and higher scores on dread offer part of the explanation for these findings. Social and cultural influences were not accounted for in this study. Similar to the case of GM foods, Europeans seem to be less optimistic than North Americans about nanotechnology (Gaskell, Ten Eyck, Jackson, & Veltri, 2005), despite both populations having low public awareness and limited knowledge on the subject (Cobb & Macoubrie, 2004; Lee, Scheufele, & Lewenstein, 2005). A single study conducted in both North America and Europe, measuring perceptions of nanotechnology based on variables described in, for example, Slovic's psychometric paradigm, should reveal to what degree North Americans are more positive towards nanotechnology than are Europeans. A more accurate estimation can then be made on what role culture plays in the perception of nanotechnology.

Products

Comparing perceived trust, risks, benefits, control, and dread scores between nano-fortified products yielded no consistent significant results. For trust and risks all products scored more or less the same, there were no significant differences. For benefits, medicine scored significantly higher than food, while for control, medicine scored significantly higher than food and care products, and for dread, medicine scored significantly higher than care products. Taking into consideration that medicine was the only product to lack significant results three times when comparing natural additives and nano-additives, along with the aforementioned results, medicine does not seem to be judged in the same way food and care products are. Food and care products, when comparing the different additives, consistently both showed significant results, and the repeated measures ANOVA revealed no instances in which one was scored significantly different from the other. The second research question (how are different nano-fortified products (food, care products, medicine) perceived compared to each other?) can be considered answered based on the results of this study. Public perception regarding nano-fortified medicine deserves a more in-depth look to see what made medicine stand out, compared to the nano-fortified food and care products.

Further Research and Conclusions

Some added benefits are a better fit than others for certain products. Orange juice with added drug delivery capabilities is less likely to find public support than the same juice with added micronutrients. A study on which benefits the public prefers for certain products can help manufacturers come up with new products and can help researchers understand more about the public's perception of nanotechnology. It is likely that the benefits people demand most have to do with improving human health and/or detecting and curing diseases, based on Cobb and Macoubrie (2004). Positively perceived products will probably turn out to be the best basis for adding benefits to, as Siegrist, Stampfli, and Kastenholz (2009) found that improving already positively perceived products increases willingness to buy more than when negatively perceived products are improved.

This study found significant differences in the perception of natural additives when compared with nano-additives when added to orange juice (food), shower gel (care product) and pain killers (medicine). On perceived risks and perceived dread, the products with nano-additives all had significantly higher scores than did the products with natural additives. On perceived trust, benefits, and control, scores were significantly lower for nano-additives for food and care products. Medicine showed no significant results on these variables. When comparing scores between products, medicine got significantly higher scores than food on benefit and control items, and higher scores than care products on control and dread items. From these results, it looks like food and care products are perceived differently from medicine. Not only is this of significance for future studies regarding these products, but it also underlines that there may be many more nuances in the public’s perception waiting to be uncovered.

References

Arnall, A. H. (2004). *Future Technologies, Today's Choices. Nanotechnology, Artificial Intelligence and Robotics: A Technical, Political and Institutional Map of Emerging Technologies*. London, UK: Greenpeace Environmental Trust.

Bieberstein, A., Roosen, J., Marette, S., Blanchemanche, S., & Vandermoere, F. (2013). Consumer choices for nano-food and nano-packaging in france and germany. *European Review of Agricultural Economics*, 40(1), 73-94.

Cacciatore M. A., Scheufele D. A., & Corley E. A. (2011). From enabling technology to applications: The evolution of risk perceptions about nanotechnology. *Public Understanding of Science* 20(3): 385–404.

Chen, L., Remondetto, G., & Subirade, M. (2006). Food protein-based materials as nutraceutical delivery systems. *Trends Food Science & Technology* 17: 272–283.

Cobb, M. D., & Macoubrie, J. (2004). Public perceptions about nanotechnology: Risks, benefits and trust. *J Nanopart Res* 6:395–405.

Cook, A.J. & Fairweather, J.R. (2007), "Intentions of New Zealanders to purchase lamb or beef made using nanotechnology", *British Food Journal*, Vol. 109, pp. 675-88.

Dreher, K. L. (2004). Health and environmental impact of nanotechnology: toxicological assessment of manufactured nanoparticles. *Toxicological Sciences* 77: 3–5.

Drexler, K. E. (1992). *Nanosystems: Molecular Machinery, Manufacturing, and Computation*. New York: John Wiley & Sons.

Epstein, S. (1994). Integration of the cognitive and the psychodynamic unconscious. *American Psychologist, 49,* 709-724.

Felt, U., Fochler, M., Mager, A., & Winkler, P. (2008). Visions and Versions of Governing Biomedicine: Narratives on Power Structures, Decision-making and Public

Participation in the Field of Biomedical Technology in the Austrian Context. *Social Studies of Science* 38(2): 233–57.

Ferber, D. (1999). Risks and Benefits: GM Crops in the Cross Hairs. *Science* 286: 1662–6.

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

Gaskell, G., Bauer, M. W., Durant, J., & Allum, N. C. (1999). Worlds apart?: The reception of genetically modified foods in Europe and the USA. *Science* 285, 1664.

Gaskell, G., Ten Eyck, T., Jackson, J., & Veltri, G. (2005). Imaging nanotechnology: Cultural support for technological innovation in Europe and the United States. *Public Understanding of Science* 14:81–90.

Hoet, P. H. M., Brüske-Hohlfeld, I., & Salata, O. (2004). Nanoparticles – known and unknown health risks. *Journal of Nanobiotechnology* 2: 12–14.

Kuzma, J. & VerHage, P. (2006). *Nanotechnology in Agriculture and Food Production*. Washington, DC: Woodrow Wilson International Center for Scholars. http://www.nanotechproject.org/file_download/files/PEN4_AgFood.pdf. Accessed September 2013.

Lee, C.-J., Scheufele, D. A., & Lewenstein, B. V. (2005). Public attitudes toward emerging technologies. *Sci Commun* 27:240–67.

Newman, M.D., Stotland, M., & Ellis, J.I. (2009). The safety of nanosized particles in titanium dioxide- and zinc oxide-based sunscreens. *Journal of the American Academy of Dermatology*, 61(4).

Oberdörster, G., Maynard A., Donaldson, K., Castranova, V., Fitzpatrick, J., Ausman, K., (...), & Yang, H. (2005). Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy. *Particle & Fibre Toxicology*; 2:8.

Oberdörster, G., Oberdörster, E., & Oberdörster, J. (2005). Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. *Environmental Health Perspectives*, Vol. 113, pp. 823-39.

Rozin, P., Spranca, M., Krieger, Z., Neuhaus, R., Surillo, D., Swerdlin, A. and Wood, K. (2004). Preference for natural: Instrumental and ideational/moral motivations, and the contrast between foods and medicines. *Appetite*, Vol. 43, pp. 147-54.

Shatkin, J. A. (2013). *Nanotechnology: Health and Environmental Risks, Second Edition.* Boca Raton, FL: Taylor & Francis Group.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends Food Sci. Technol*. 19:603–8.

Siegrist, M., Cousin, M.-E., Kastenholz, H., & Wirk, A. (2007a). Public acceptance of nanotechnology foods and food packaging: The influence of affect and trust. *Appetite* 49:459–66.

Siegrist, M., Keller, C., Kastenholz, H., Frey, S., Wiek, A. (2007b). Laypeople's and experts' perception of nanotechnology hazards. *Risk Analysis* 27:59–69

Siegrist, M., Stampfli, N., & Kastenholz, H. (2009). Acceptance of nanotechnology foods: a conjoint study examining consumers' willingness to buy. *British Food Journal*, 111(7).

Siegrist, M., Stampfli, N., Kastenholz, H. & Keller, C. (2008). Perceived risks and perceived benefits of different nanotechnology foods and nanotechnology food packaging. *Appetite* 51: 283–290.

Slovic, P. (1987). Perception of Risk. *Science,* New Series, Vol. 236, No. 4799, pp. 280-285.

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1982). Why Study Risk Perception? *Risk Analysis* 2(2): 83–93.

Weiss, J., Takhistov, P., & McClemens, D. J. (2006). Functional materials in food nanotechnology. *Journal of Food Science* 71: R107–R116.