Consumer reactions to unfamiliar technologies: mental and social formation of perceptions and attitudes toward nano and GM products

Peter H. Feindt, P. Marijn Poortvliet

ABSTRACT
Using focus groups, the research analyses the mental and social processes through which consumers form perceptions and opinions about unfamiliar technologies and the derived products, taking the perception of nanotechnology and nano-products, GM and GM products as example. Our findings suggest that limited understanding of the technological principles and lack of (visible) products prevent the formation of experience-based attitudes and behavioral intentions. In this context, consumers interpret and assess cognitive interventions such as product labels or product information, as well as the trustworthiness of unfamiliar information sources, based on heuristic clues, association, mutual reassurance and previous attitudes. The established determinants of technology risk perception (e.g. knowledge, social norms, perceived risks and benefits and controllability) were the subject of constant deliberation and negotiation among participants. Consequently, the perception of risk and technology communication interventions might vary greatly across different locations and segments of the public, complicating risk communication and trust-building.

ARTICLE HISTORY
Received 5 July 2018
Accepted 19 January 2019

KEYWORDS
Nanotechnology; genetic modification; risk perception; labeling; trust; focus groups

Introduction

Like genetic modification, nanotechnology – the engineering and manufacturing of materials at the atomic and molecular scale – is another prominent example of an unfamiliar technology to face consumers. As a ‘key enabling technology’ (European Commission 2004), nanotechnology affects a wide range of sectors and products. Numerous consumer products made with nanotechnology have already entered the market (National Nanotechnology Infrastructure Network 2017), including cosmetics, textiles and household appliances. At the same time, scientific understanding of the potential health and environmental risks from engineered nanomaterials is as of yet incomplete, since the materials’ toxicity varies with ‘size, surface area,
surface chemistry, solubility and possibly shape’ (Maynard et al. 2006). The ensuing uncertainty poses great challenges for the development of appropriate risk governance strategies and might reduce public confidence in nanotechnologies (Jahnel 2015; Pidgeon, Harthorn, and Satterfield 2011; Poortvliet and Lokhorst 2016; Scheufele et al. 2007). Historic experience with other unfamiliar technologies, for example, genetically modified organisms, suggests that the public perceptions of nanotechnology and its risks will be critical for successful marketization, but also the adoption of reasonable risk-avoiding behaviors when handling nanomaterials or products that contain nanomaterials.

While manifold factors could determine consumer perceptions of nanotechnology and its applications (Frewer et al., 2014), the formation of consumer perceptions on nanotechnology and its applications are not well understood. The current paper aims to contribute to recent research on public and consumer perceptions of nanotechnology and nano-products. Seconding Gupta et al.’s (2015) call for ‘elicitation of attitudinal constructs from consumers, rather than measuring attitudes assumed to be important by the researcher,’ we pursue an in-depth research methodology. By conducting focus groups with members of the public, we aim to better understand the mental and social processes through which consumers form perceptions and opinions about this unfamiliar technology, general ideas about nanotechnology, potential motives for buying or avoiding nano-products, perceptions of benefits and risks associated with nanotechnology, the role of knowledge and product labeling, and trust in key actors. We conducted parallel focus groups exploring the same issues for GM technology to allow for a comparison across technologies and to distinguish technology specific responses from general perceptions of unfamiliar technologies. After discussing the literature about nanotechnology risk perceptions, we introduce an interpretive perspective on the interactive and mental processes through which shared understandings of novel technologies are formed and articulated. We then explain our methodological design and present the findings from six focus groups with British consumers. In the concluding section we argue that in the absence of established attitudes and readily available interpretive templates, consumers turn to contextual cues, social signals, levels of trust and earlier technology templates to form opinions. These heuristic processes complicate how established factors (attitudes, social norms, behavioral control, risk and benefit perceptions, knowledge and performance expectancies) can predict the acceptance of novel technologies.

**Nanotechnology risk perceptions**

While definitions of nanotechnology vary, the suggestion by the US National Nanotechnology Initiative to understand nanotechnology as the manipulation of matter with at least one dimension sized from 1 to 100 nanometers has become a point of reference (National Nanotechnology Initiative n.d.). Engineering on such a small scale allows for the development of materials with novel characteristics compared to their conventional, ‘bulk’ counterparts. Major novel developments are for example expected in the areas of drug delivery (Farokhzad & Langer 2009; Sosnik, das Neves, and Sarmento 2014), environmental remediation such as the cleaning-up of contaminated ground water, energy applications like high-efficiency solar panels, and ICT, for example, memory chip technology (Im et al., 2014; Kim et al., 2011). Many nano-applications target markets for domestic appliances and consumer products (National Nanotechnology Initiative n.d.): additives in polymer composite materials (e.g., tennis rackets); additives to or surface treatments of fabrics to reduce wrinkling, staining, and bacterial growth; surface coatings for novel characteristics such as water-repellent, self-cleaning, scratch-resistant, and anti-microbial (e.g., in kitchen tools); nanomaterials in cosmetics provide greater coverage, cleansing, and absorption; nanocomposites in food containers to minimize carbon dioxide or moisture leakage; high-power rechargeable battery systems, for example, for electric cars (Vance et al., 2015).
The increasing presence of nano-products is linked to various uncertainties. A Consumer Product Inventory found 1814 consumer products from nanotechnology, of which 49% did not provide the composition of the nanomaterial used and 71% did ‘not present enough supporting information to corroborate the claim that nanomaterials are used’ (Vance et al., 2015).

The development of novel technologies co-evolves with the dynamics of public perceptions (Renn and Roco 2006; Siegrist 2010). With emerging public knowledge about novel technologies, public opinion may polarize into camps of opponents and proponents (Anderson et al. 2014), because people draw from preexisting individual factors such as social and political orientations in their formation of risk perceptions. Against the GMO experience, repeated calls have been made to establish a deliberative climate that prevents polarization about nanotechnologies (Bostrom and Löfstedt 2010; Kahan et al. 2008).

Studying perceptions of nanotechnology is challenging given the vast diversity of nanotechnologies, the highly abstract and intangible nature of the concept, and the value and ethical issues underlying nanotechnologies (Pidgeon, Harthorn, and Satterfield 2011). Previous research addressed (1) general levels of nanotechnology awareness and its determinants, (2) perceptions of specific nano-product groups, (3) comparative perceptions across countries or across different groups, in particular laypersons versus experts, and (4) perceptions of nano-products pitted against products made with other technologies:

Ad 1) Surveys found public awareness of nanotechnology lower than for biotechnology. In the most recent Eurobarometer study in 2010, less than half of Europeans had heard about nanotechnology and one of four had talked to someone about the topic; awareness was much higher in Northern than in Southern Europe, among men and the higher educated (Eurobarometer 2010). While public opinion among Europeans leaned positive about the benefits of nanotechnology, a large share of the population was undecided. The survey also revealed concerns about health and environmental risks, again with large cross-country variation (idem). Other studies confirm low levels of awareness and knowledge accompanied by slightly favorable opinions about benefits compared to risks (Ho, Scheufele, and Corley 2013). Ambivalent attitudes tend to remain even after ‘balanced information’ (Fischer et al. 2013), arguably due to the lack of products available on the market (Frewer et al. 2014) or to societal issues such as those related to the contested roles of the industry and technology in (food) product development (Rogers-Brown, Shearer, and Harthorn 2011).

Ad 2) Rather than looking at general perceptions of nanotechnology, Siegrist et al. (2007a) found differing perceptions of twenty specific nanotechnologies along two dimensions: the perceived dread risk and the experience of distrust in authorities. Product categories also affect the technology assessments. Food packaging is generally perceived as less problematic than food products (Katare, Yue, and Hurley 2013; Siegrist 2008; Stampfli, Siegrist, and Kastenholz 2010); applications such as targeted drug delivery and water filtration techniques are also regarded relatively beneficial (Gupta et al. 2013). Generally, applications closer to the body are seen as riskier but not necessarily more beneficial, making rejection more likely (Steenis and Fischer 2016).

Ad 3) Siegrist et al. (2007b) discovered that laypersons perceived higher levels of risk than experts. Scheufele et al. (2007) found that experts generally associated nanotechnology with more benefits than the wider public, but also worried more about pollution and health problems, a pattern confirmed by Gupta, Fischer, and Frewer (2015). A complicating factor in the perception of nanotechnologies is that the presence and quality of a nano-material in a product cannot be directly experienced or verified. Therefore, the public relies mostly on media reports – which tend to publish rather positively on the subject by primarily using progress frames (Donk et al. 2012).

Ad 4) Compared to more established products, attitude formation toward nanotechnology tends to be influenced more by affect than cognition, but cognitions have become more influential over time (van Giesen, Fischer, and van Tijp 2016). Parallels have been drawn between the negative perception of GM technology and nanotechnologies in food products (Bieberstein et al. 2013). Consequently, perceptions and attitudes concerning GM may be used as templates and
transferred to the topic of nanotechnology when people are uncertain or unaware about nanotechnology and its applications. While ‘nano-food evokes fewer negative reactions compared with GM food’ among consumers in the US, distinct demographic backgrounds are linked to differential attitudes towards technology adoption or rejection of both nanotechnology and GM (Yue, Zhao, and Kuzma 2015).

Overall, the studies reveal significant uncertainty. Although people may be aware of the fact that they can assess the benefits and risks of specific nanotechnologies, the formation of such attitudes is hampered by the lack of perceived knowledge and clear information on the subject (Fleischer et al. 2012). Risk and benefit perceptions of nanotechnologies may be influenced by contextual or implicit features such as labeling (Siegrist and Keller 2011), which is widely desired but also tends to activate risk perceptions (Capon et al. 2015). At the same time, the absence of a coherent labeling concept for nano-products hampers market transparency. Overall, against the background of low levels of awareness and knowledge about nanotechnology among consumers, the lack of reliable labeling of nano-products is unsatisfactory against the principles of well-informed public decision-making and consumer choice. However, the effects of nanotechnology labeling on consumer attitudes and purchasing decisions are all but clear and might depend on, inter alia, risk and benefit perceptions, familiarity, trust, framing (Capon et al. 2015), and non-cognitive clues.

Understanding of unfamiliar technologies as interpretive process

In the present study, we focus on the interactive and mental processes that contribute to the formation of attitudes and perceptions around unfamiliar technologies. Against the generally low level of nanotechnology knowledge and awareness (Bostrom and Löfstedt 2010; Eurobarometer 2010), people’s responses are likely to depend on contextual cues and heuristics (Chen and Chaiken 1999; Petty and Cacioppo 1986), as well as on the interactive context. These – in combination with people’s pre-existing attitudes about technology in general and other individual characteristics like political orientation, worldviews, and level of information elaboration (Anderson et al. 2014; Ho, Scheufele, and Corley 2013; Kahan et al. 2008) – are likely to shape individual responses to nano-products (cf. Gupta, Fischer, and Frewer 2015). If confronted with descriptions of nanotechnology and nano-products people will look for contextual cues and may try to make sense, for example through comparison and analogies (Fazio 2007). Based on the limited information provided, people form expectations about the technology and the products which shape their normative and cognitive attitudes. Importantly, in contexts of uncertainty people may turn to others for behavioral cues and relevant information (Darnon, Butera, and Harackiewicz 2007; Kulik and Mahler 1989). Moreover, product-related information (such as labels) is interpreted in these contexts of uncertainty, while people can also look for and consult additional information sources like internet-based product information. However, only the more motivated and information literate consumers will likely search for further information.

Building upon the earlier lines of research discussed above, we investigate consumers’ perceptions of nanotechnology through the theoretical lens offered by behavioral and innovation research within the context of adoption of novel technologies. An influential framework is the theory of planned behavior (Ajzen 1991), which states that people’s behavioral intentions – including consumption decisions – are shaped by their attitudes, perceived social norms and perceived behavioral control. Importantly, however, the adoption of novel products is typically associated with risk taking and uncertainty because accepting novelty implies leaving the realm of the familiar. Lobb, Mazzocchi, and Traill (2007) have therefore extended the theory of planned behavior and included people’s risk perception, as well as their levels of trust in the relevant actors of the risk context, as determinants of decision-making. Our study of consumer attitude formation towards nanotechnology therefore includes these dimensions.
Besides risk perceptions and trust, knowledge can act as an antecedent in behavior because the level of knowledge about a particular subject can influence attitude formation – either negatively or positively – which in turn can influence individuals’ decisions. For instance, data from survey research among the general public suggest that accurate knowledge of biotechnology is positively related to perceived benefits (Sturgis, Cooper, and Fife-Schaw 2005) and positive attitudes (Mulder et al. 2014). Hence, both theory and empirical studies suggest that knowledge might play an indirect role in shaping attitudes (Evans and Durant 1995; Priest 2016).

Furthermore, according to the unified theory of acceptance and use of technology (Venkatesh et al. 2003; Venkatesh, Thong, and Xu 2012), the expected usefulness (performance expectancy) plays an additional role in decisions to use a novel technology. Other factors are pricing, hedonic motivations and habits. Finally, according to Rogers’ (2003) diffusion of innovation theory, further important factors are the perceived relative advantage of a novel product over conventional ones, and the perceived easiness or complexity of an innovation. In this explorative study, we use the possible determinants of technology adoption and rejection as sensitizing concepts for the analysis of our focus group discussions.

The present research

Given the large number of potential determinants identified in the literature that potentially affect consumer perceptions of nanotechnology and nano-products (Frewer et al. 2014), a better understanding of the processes through which consumers interpret nano-related information and arrive at conclusions is useful, complementing survey research based on models with a limited number of variables. The main purpose of the XXX project [anonymized for review] was to understand how consumers in several European countries interpret information and fictitious labels for nano-products, and how this would affect their purchasing decisions. Part of the research were focus groups with randomly selected participants aged 16 and above. The facilitated group discussions focused on the participants’ perceptions of nanotech applications, using nanosilver in cutting boards as anchorage example. This product was chosen because it represents a nano-product that is already marketed to consumers with an intermediate proximity to the body – it is not ingested but has direct contact with food and the body. Furthermore, according to the Consumer Product Inventory, ‘silver is the most frequently used nanomaterial (435 products, or 24%)’ (Vance et al. 2015). In order to minimize priming effects, we took a step-by-step approach with increasing levels of focus (moving from open questions about nanotechnology in general to discussion of nano-silver and the product at hand). Using this procedure, we explored the role of knowledge and semantic associations about nanotechnology, motives for buying or avoiding nano-products, perceptions of benefits and risks of such products, responses to product labeling and different sources of information, and finally, trust in relevant actors and institutions. We held parallel focus groups on a food-related GM technology-based product: GM-based soy margarine. Comparison across domestic applications of these technologies allows for distinguishing technology specific responses from general perceptions of novel technologies, and allows us to understand how levels of uncertainty and ambivalence play out across different technologies and products.

Method

Participants

Overall, six focus groups – three for each technology – were conducted with 44 participants in Cardiff, Wales during autumn 2011. A combination of random sampling and self-selection was deployed for participant recruitment. The electoral register served as the most encompassing publicly available household database, although it notably does not include persons who are not
entitled to vote in the UK, who have not registered or who have opted out of the public part of the register. Invitation letters were sent to 2000 randomly selected addresses, offering a small financial remuneration for participation. Participants were signed up on a first come first served basis, with a view to create diverse groups if possible, based on age and gender. Ten participants were registered for each of the groups. Due to no-shows, finally 44 individuals participated. The three nano-themed focus groups attracted 18 participants (6 women and 12 men; \( M_{\text{age}} = 49.7 \) years), the three GM focus groups 26 participants (12 women and 14 men; \( M_{\text{age}} = 48.4 \) years).

**Procedure**

Mostly parallel semi-structured guidelines were developed for the nano and the GM focus groups. The facilitation style aimed to stimulate lively and respectful discussion. Participants were not expected to develop solutions or reach consensus. We now detail the procedure of the nano focus groups. At the beginning of the group discussion, the participants received a very brief definition of nanotechnology by the first author (who acted as facilitator) and were asked to share their spontaneous associations first with nano-products, then with nanosilver, and finally with nanosilver chopping boards. Participants were then asked about their most important criteria when purchasing a chopping board, followed by an invitation to compare nanosilver chopping boards with conventional ones with further prompts to provide arguments for and against buying nanosilver chopping boards. Subsequently, participants were sequentially confronted with two nano-labels (designed by the research team, the first displaying the term ‘nano’ and the figure ‘10^{-9}’, the second featuring the information ‘contains nanosilver’). For each label, participants were asked about eventual recognition, ease of understanding, trust and perceived informational value. The final part of the focus groups tested how participants responded to web-based information and discussed the attribution of responsibility. These findings cannot be reported here due to space limitations.

For the GM focus groups, the initial definition was for GMOs and spontaneous associations were asked for GMO products, GMO soy and GM soy margarine. Purchasing criteria were asked for margarine and differences elicited between conventional and GMO margarine, followed by discussion of potential motives to buy or avoid GMO margarine. The product examples were first a margarine displaying a ‘GMO-free’ label and then a margarine with product information ‘is produced with GM soy’. Each focus group lasted about 120 min.

**Results**

*Perception and knowledge of unfamiliar technologies and products*

**Nanotechnology and its products**

The majority of respondents were relatively positive yet ambivalent about nanotechnology and nano-products. Most participants either acknowledged ignorance or took up the clue of smallness in mostly generic terms. Nano-products were mostly associated with high-tech (electronics, medicine, research) and rarely with everyday products. No explicit link was made to GMOs as cognitive template.

Nanosilver was associated with electronics and computers. Some participants rightly assumed that nanosilver could be used for coatings. Participants appeared to be unaware of already marketed products such as nanosilver in washing machines, socks or deodorant.

No participant was aware that nanosilver chopping boards were already on the market, and several participants stated surprise and bewilderment upon receiving this information. Participants’ imagination consistently focused on hygiene, cleaning and self-cleaning properties of the product. Understanding of the product was limited, although some participants fully
developed the idea that the nanosilver was used as a coating. Expectations about sensual characteristics were varying. Some fanciful functions (‘sharpens your knife’) and designs (‘contains electrical components’) were imagined.

**Genetic engineering and its products**

GM products were mainly associated with the following four themes: (1) artificial, synthetic or perfected food, convenience, longer shelf life or elimination of disease; (2) health and safety concerns, uncertainty and long-term effects; (3) higher productivity, ‘feeding the third world’ and GMO as an option for farmers ‘to diversify’; (4) ignorance (‘that we might consume GM products without knowing it’).

Ignorance, uncertainty and skepticism were the most frequent and partly dominant responses to GM soy and GM soy margarine. Few participants expected higher productivity from GM soy and nutritional benefits from GM soy margarine.

There were no clear and settled expectations about differences between a GM and a conventional margarine. Many participants did not expect any differences or felt they did not know enough. Main themes for differences were: price (mostly cheaper), taste and content of the product (e.g., nutritional benefits), and advantages for producers and along the food chain. There was uncertainty and controversy about whether a GM margarine could be expected to be labeled, and on the environmental impacts.

**Comparison**

While nano-products were mostly associated to high-tech (e.g., medicine) and rarely to everyday products, GM was linked to various foodstuffs and associated with food designed for convenience, higher productivity, health and safety concerns and consumer ignorance. In the absence of authentic experience and knowledge, participants looked for contextual cues to understand both products and to develop performance expectancies. With regard to the latter, at the technology level nanosilver turned out to be a more interesting and exciting topic for participants than GM soy. It was associated with electronics and computers and was (rightly) connected with coatings. Responses to GM soy were often dominated by uncertainty and skepticism with some more positive expectations about nutritional benefits and higher productivity from GM soy. At the product level, participants jointly developed benefit perceptions for both products during the conversation, often based on inductive reasoning rather than confirmed knowledge. Nanosilver chopping boards were associated with benefits such as hygiene, while the expectation from GM soy margarine was mostly price and nutritional benefits.

For both nanosilver and GM soy, participants were widely unaware of already marketed products, but some participants voiced a general suspicion that they were already deployed without consumers knowing what was going on. These utterances betrayed a low level of trust in market and regulatory transparency. Low levels of trust were also implicit when participants expressed bewilderment upon learning that nanosilver chopping boards were already marketed, and disquiet about the idea of GM soy margarine coming on their British home market. Being unaware of the actual or potential presence of these unfamiliar products was obviously felt as a loss of behavioral control, a sentiment in which participants often confirmed each other, likely looking for social signals of the appropriateness of their response.

Environmental impacts were mentioned as a difference only for the GM product, and even here only rarely. While some participants activated earlier technology templates linking GM to environmental concerns, such templates were not immediately activated when discussing nanotechnology.
Purchasing criteria

Conventional chopping boards and nanosilver chopping boards
For a large majority of participants chopping boards were very important products; for a small minority they were unimportant. When participants described their favorite chopping board, hygiene, color and design were the most prominent features. Prompted for shopping criteria (i.e., features that play a role at point of purchase), price and easily recognizable physical aspects such as weight and size were most prominent along with hygiene-related characteristics.

Most participants were unsure what to expect from a nanosilver chopping board. When prompted, participants presumed that the nanosilver board would be more expensive and easy to clean, if not self-cleaning, and have an antibacterial effect. The nano-product was also assumed to be more fashionable and stylish than a conventional one. Health concerns were discussed at some length, with participants stressing uncertainty about health impacts and citing the experience of asbestos and enamel.

Presumed motives for buying the nano-product were: first, a desire to have the latest thing and an interest in the latest technology; second, social distinction and ‘one-upmanship’; and third, the antibacterial and hygienic features of the product. Presumed motives for avoiding a nanosilver chopping board were: first, uncertainty about long-term health effects and concerns about the safety of the product; second, a lack of knowledge and understanding of the product; third, skepticism towards new technology in general and a preference for well-known products; fourth, the price if the nano-product is more expensive and does not provide visible added benefit; and finally a lack of interest.

Conventional margarine and GM-margarine
Price, taste and nutritional value are the most important criteria when purchasing margarine. Process criteria (i.e., how the product was prepared during production) neither featured among the purchasing criteria nor among the perceived differences. The brand was important for more participants than a label; however, several participants stressed that information about the product was important.

Perceived reasons for buying GM margarine were predominantly: a cheaper price, marketing and advertisement, and to a lesser degree curiosity, fashion, medical reasons, nutritional value or taste. This signals low expectations for consumer benefits from GM margarine apart from a cheaper price. Perceived reasons for avoiding GM margarine were uncertainty, ignorance and fear about GM food, but also general reservations against GM and the commercial model of food production. Environmental concerns played only a minor role.

Comparison
On average, chopping boards were a more important product for participants than margarine. For both, a low price was the most important criterion when buying the product. The brand was more important for margarine than for cutting boards.

For both products, where differences between the nano/GM and a conventional product were expected, they resonated with the most essential shopping criteria: price (both nano and GM), hygiene and being stylish (nano), and taste and nutritional value (GM). For neither the nano nor the GM product, process criteria featured among the purchasing criteria or the perceived differences. Information and uncertainty were important for both products, but in different ways: For the nano chopping boards, uncertainty about long-term health impacts were a concern among participants; in contrast, for GM margarine, participants wanted information about the product without stressing such concerns. The priority given to brand over a label indicates a preference for the familiar (brand) over the unfamiliar (label).
Presumed motives for buying the new technology product differed with much higher expectations for the nano chopping board. The main motives for purchasing a nano chopping board were linked to various expected benefits to the consumer: novelty and superior qualities. The perceived reason for buying GM margarine was predominantly a cheaper price.

The presumed motives for avoiding a nanosilver chopping board or a GM margarine were very similar: (1) uncertainty, in particular about the health impacts; (2) lack of knowledge and understanding of the product; and (3) skepticism towards new technology or general reservations towards the business model (for GM). Environmental concerns played only a minor role.

For both products, participants developed risk and benefit perceptions during the discussions, which they tended to mutually confirm. For both technologies, uncertainty and lack of knowledge fed into a lack of behavioral control. The expressed skepticism was often linked to low levels of trust. Negative attitudes were articulated toward GM only.

**Consumer information**

**Labels: Nano-product label and GM-free label**

The nano label (\(10^{-0}\)) was very critically received by participants. The dominant opinion was that the label had no meaning and needed more information and explanation. Participants who tried to attach more content to the label often came up with wrong or over-interpretations. Responses, however, need to be interpreted cautiously because the ‘cheap’ design of the label was regularly mentioned as undermining trust. This was reinforced by perceived inconsistencies between high expectations from a nano-product and the ordinary product at hand.

In contrast, for most participants the GM-label would not influence their decision to purchase a margarine. But while one participant was discouraged, no one was stimulated by the label to buy the product. None of the participants had seen this or a similar GM-free label before. Four patterns of response emerged: (1) a sense of alarm and creation of awareness, coupled with an anti-GM message; (2) reassurance in the product, mediated by label design, in particular the green color; (3) the label as a guide to avoid unwanted GM food; and (4) general cynicism and distrust in any label. The GM label would mostly have a positive or no influence on participants’ purchasing decision, but several participants would become more ‘wary’ and ‘cautious’, more information was sought and the trustworthiness of the label was an issue.

**More detailed product information**

The more detailed product information ‘Contains nanosilver’ was perceived to be more attractive and more informative than the ‘\(10^{-0}\)’ label. However, the overwhelming opinion was that the information was still not sufficient. In particular, more information was required about nanotechnology as well as the characteristics and effects of nanosilver. Participants also remarked that the differences and benefits of nanosilver were not communicated. Several participants felt that the label had no practical meaning for them, and that is was unclear whether the label was meant to be an attractor or a warning. Some participants would be enticed by the label to look for more information. In each group, participants said that they would not trust the label. It was suggested that more trust would be derived from the label being better designed and presented, backed by an approved standard, linked to a renowned brand or the product being sold by a trustworthy outlet. The label would not influence the purchasing decision of most participants, but some participants felt cautioned and discouraged from buying the product due to insufficient information. For individual participants the label would generate interest in the product.

In the GM groups, most participants had not seen the product information ‘Contains Oil from genetically modified soybeans’ or similar information before, but two participants were not sure or claimed to have seen a similar label before on a meat product. The information tended to
have a distancing effect. Participants understood that the information highlights a difference between GM and non-GM products; but many participants were insecure about the precise message or wanted more explanation, often from other sources, which indicates skepticism. The information would have a negative influence on the purchasing decision of the majority of participants. Surprisingly, for some participants this depended on whether the information was on the topside of the product. Four participants would be more inclined to buy the product because the information had made them curious and had generated interest.

**Comparison of labeling**

Since none of the participants had seen these or similar labels before, they looked for contextual clues to make sense of them. The difficulty to establish the practical meaning of the labels feeds into a lack of perceived behavioral control. The label ‘without genetic engineering’ was received much more favorably. Participants felt much more confident in interpreting this label than the ‘10⁻⁶’ label, more reassured about the product and often willing to accept the label as a guide to avoid unwanted GM food. This is consistent with the finding that the ‘without GM’ label would have a positive or no influence on participants’ purchasing decision, while the ‘10⁻⁹’ label would not influence purchasing decisions. Both the ‘no GM’ and the ‘10⁻⁷’ labels had the effect to raise awareness and make participants more cautious about the products on the market. They are likely to activate earlier mental technology templates.

**Comparison of packaging information**

Most participants had not seen this or similar information before, although two participants thought they might have seen similar GM information. Both the nano and the GM information were perceived to highlight a difference from non-nano or non-GM products, although participants often criticized that this difference was not fully explained. Participants were less confident to interpret the information on nanosilver than the information on GM soy; the nano information was more questioned with regard to its practical meaning and provoked more requests for additional information. However, in both the nano and the GM cases many participants were insecure about the precise meaning and asked for more information, often from independent sources. Lack of trust was more of a problem for the nano information. The information on nanosilver, with some participants becoming more cautious and others more curious, would have less influence on purchasing decisions than the information on GM soy which would lead the majority of participants to avoid the product. In both cases, the information did not increase perceived behavioral control in any linear way, but served as a prompt for attention and activated earlier technology templates and attitudes among some participants.

**General discussion**

**Risk perception, knowledge and product preferences**

The current research set out to investigate consumers’ reactions and the attitude formation process with regard to nanotechnology compared to GMOs. The step-by-step approach in the focus groups with an increasing level of focus in the questions revealed that on the technology level, participants reported a general sense of uncertainty in describing nanotechnology and came up with abstract images of the technology being associated with smallness and high-tech applications. On a material level, few participants rightly associated nanosilver with coatings, but little awareness existed that products containing nanosilver were already on the market. On the product level, understanding was limited and it was hard to imagine characteristics of a product that would contain nano-particles vis-à-vis a conventional product.
In the GM technology focus groups participants displayed less problems articulating associations on the technological, material and product levels. For instance, participants associated GM with unnaturalness, health and safety concerns, but also with more efficient levels of production. GM products evoked uncertainty, skepticism, self-ascribed ignorance and attribution of GM benefits to producers rather than consumers. These skeptical responses were likely reinforced by the label highlighting the absence of GM ingredients, included due to its actual use in the market, which prompted participants to deliberate why people might want to avoid GM products. The difference between nano and GM suggests that GM – a technology that has previously received much public scrutiny – evokes more established and more polarized responses. Obviously GM products are mostly evaluated against a well-established GM template – in contrast to nano-products. The focus groups responses resonate with the long-standing controversy over GM. In contrast, nano evoked more balanced responses that included positive and negative aspects. Accordingly, both risk and benefit perceptions were being formed and these were less outspoken. Participants were more uncertain about the technology and generated responses on the basis of those pieces of information that were available to them: the name, the reactions of other participants in the focus groups. Apparently, the term nanotechnology induced literal associations with ‘smallness’ or tiny particles, mediated through Apple’s ‘nano’ ipod. Some participants formed connotations with other (but unrelated) technologies such as micro-electronics that were more familiar and tended to be positively evaluated. However, while nanomaterials can be toxic or carry other hazards (depending on the specific nanomaterial), concerns about health and safety were mostly based on uncertainty and unfamiliarity, not on specific ideas about potential toxicity. In contrast, responses toward GM were more pronounced and drew more on pre-existing templates.

Apparently, this suggests that technology perception is often ambivalent. If people have not experienced products from a specific technology and little information, they engage in ‘on the spot attitude generation’, as witnessed in our focus groups (cf. Van Giessen et al., 2018). Opinions and attitudes were formed during the course of the interaction. In the absence of sufficient information and clear understanding, participants became creative in constructing meaning based on clues, common sense and previous impressions. They often confirmed each other’s constructions. This observation demonstrates the importance of the interactional context, everyday experiences with technology and shared technology history (e.g., the reference to asbestos and earlier GM controversies), all of which can be highly variable and call for comparative analysis. They form the background against which pieces of information about unfamiliar technologies and products are interpreted, in particular where participants are struggling to understand the technical principles of both technologies.

These observations have important implications. First, reducing the determinants for attitudes towards nanotechnology or other unfamiliar technologies to a small number of psychological factors – as in the cognition and emotion framework as in parts of the literature – is not sufficient and tends to overlook the importance of social and interactional context. The interactive effects during the focus groups cannot be discarded as bias that distorts the measurement of attitudes exactly because these attitudes are often formed only during the process of social interactions. Our focus groups therefore suggest both the malleability of these attitudes and behavioral intentions as well as the often complex and mediated effects of cognitive interventions such as labels and other product information.

At the same time, our findings do not contradict previous research that attitudes, social norms, perceived behavioral control, perceived risks and benefits, knowledge and performance expectations determine opinions and behavioral intentions towards an unfamiliar technology and the products derived from it. We identified all of these aspects in the statements made by the participants. However, they were often the subject of extensive deliberation. These determinants were partly produced and reproduced and often negotiated between the participants who were often not sure about their attitudes and perceptions. They tried to fill in the gaps through
heuristic processes that included the interpretation of clues, analogies from experience and shared memory and attempts at mutual reassurance about conjectural judgments and social norms. While this finding resonates with Kahneman’s (2011) theory of heuristic processes, it has not yet been observed in such detail for attitude formation towards unfamiliar technologies in a deliberative setting.

**Informational preferences and trust formation**

The findings also suggest that labels are not an easy remedy to improve consumer information and choice. Participants often struggled to interpret the unfamiliar labels used in the focus groups. The mere presence of a label was perceived as indicating an issue and participants looked for (often aesthetic) clues to determine whether the labels signaled a warning and were from a trustworthy source.

However, the state of vigilance evoked by labels is probably dependent on earlier perceptions and attitudes held by the recipients of the label information, for example if they hold a low level of trust regarding a particular kind of technology (cf. Siegrist and Cvetkovich 2001). This suggests that labeling is deeply entangled in the complexities of trust formation. On the one hand, people use their level of experienced trust to inform their decision making. On the other, with preexisting levels of high skepticism and low trust, labeling of products in controversial areas (such as GM in the present study) may activate and confirm earlier negative evaluations. In both cases, processing of information on labels will interact with established attitudes. These processes also apply to more elaborate product information – as can be found on labels – which consumers may actively solicit. Unsatisfactory encounters or lack of cues that would signal trustworthiness to a broader public can lead to dynamics of distrust and polarization (cf. Lofstedt et al. 2011). Against that background, our findings suggest that heuristics of trust vary significantly, depending on previous attitudes, knowledge and information literacy.

**Future steps**

While our study design did not aim for representativeness, the findings provide a complementary perspective to existing literature on attitudes and behavioral intentions of consumers towards unfamiliar technologies and the products derived from them. The observations presented here suggest that the determinants of technology and technology risk perception are valid, but malleable during the course of interaction. Perceptions and attitudes have not firmed up exactly because a technology and its related products are unfamiliar. The interactive study design allowed to observe the interactive processes through which attitudes are formed ‘on the spot’. The current study thereby responds to calls for in-depth research on attitude formation processes concerning unfamiliar technologies and their applications (Bostrom and Löfstedt 2010; Pidgeon, Harthorn, and Satterfield 2011; Siegrist 2010). Future studies could either extend the scope of this approach by including other technologies, products and locations, or look more in-depth into differences across product categories or specific determinants of risk perception (e.g., the interactive construction of knowledge vs. trustworthiness).

**Conclusions**

Nanotechnology and genetic modification are still unfamiliar technologies for consumers. Limited understanding of the technological principles and lack of (visible) products prevent the formation of experience-based attitudes and behavioral intentions. In this context, cognitive interventions such as product labels or information on the product packaging are interpreted based on heuristic clues, association, mutual reassurance and previous attitudes. The
trustworthiness of unfamiliar information sources is similarly subjected to heuristic assessments. The findings presented here suggest that the established determinants of technology risk perception are valid but malleable if the technology under consideration is unfamiliar. Risk and technology communication strategies therefore have to consider that the contexts of their interventions might vary greatly across different locations and segments of the public, casting doubts on any expectation about a linear relationship between knowledge provision and technology acceptance.

Disclosure statement
No potential conflict of interest was reported by the authors.

References
Ajzen, I. 1991. “The Theory of Planned Behavior.” Organizational Behaviour and Human Decision Making Processes 50 (2): 179–211. doi:10.1016/0749-5978(91)90020-T.
Anderson, A. A., D. Brossard, D. A. Scheufele, M. A. Xenos, and P. Ladwig. 2014. “The “Nasty Effect”: Online Incivility and Risk Perceptions of Emerging Technologies.” Journal of Computer-Mediated Communication 19 (3): 373–387. doi:10.1111/jcc4.12009.
Bieberstein, A., J. Roosen, S. Marette, S. Blanchemanche, and F. Vandermoere. 2013. “Consumer Choices for Nano-Food and Nano-Packaging in France and Germany.” European Review of Agricultural Economics 40 (1): 73–94. doi:10.1093/erae/jbr069.
Bostrom, A., and R. E. Löfstedt. 2010. “Nanotechnology Risk Communication past and Prologue.” Risk Analysis 30 (11): 1645–1662. doi:10.1111/j.1539-6924.2010.01521.x.
Capon, A., J. Gillespie, M. Rolfe, and W. Smith. 2015. “Comparative Analysis of the Labelling of Nanotechnologies across Four Stakeholder Groups.” Journal of Nanoparticle Research 17: 327.
Chen, S., and S. Chaiken. 1999. “The Heuristic-Systematic Model in Its Broader Context.” Dual-Process Theories in Social Psychology 15: 73–96.
Darnon, C., F. Butera, and J. M. Harackiewicz. 2007. “Achievement Goals in Social Interactions: Learning with Mastery vs. performance Goals.” Motivation and Emotion 31 (1): 61–70. doi:10.1007/s11031-006-9049-2.
Donk, A., J. Metag, M. Kohring, and F. Marcinkowski. 2012. “Framing Emerging Technologies: risk Perceptions of Nanotechnology in the German Press.” Science Communication 34 (1): 5–29. doi:10.1177/107554110417892.
Eurobarometer 2010. Special Eurobarometer 341, Wave 73.1: Biotechnology. Conducted by TNS Opinion & Social on request of European Commission.
European Commission 2004. Towards a European Strategy for Nanotechnology. COM(2004) 338 Final. Brussels: European Commission.
Evans, G., and J. Durant. 1995. “The Relationship between Knowledge and Attitudes in the Public Understanding of Science in Britain.” Public Understanding of Science 4 (1): 57–74. doi:10.1088/0963-6625/4/1/004.
Farokhzad, O. C., and R. Langer. 2009. “Impact of Nanotechnology on Drug Delivery.” ACS Nano 3 (1): 16–20. doi:10.1021/nn900002m.
Fazio, R. H. 2007. “Attitudes as Object–Evaluation Associations of Varying Strength.” Social Cognition 25 (5): 630–637. doi:10.1521/soco.2007.25.5.630.
Fischer, A. R., H. van Dijk, J. de Jonge, G. Rowe, and L. J. Frewer. 2013. “Attitudes and Attitudinal Ambivalence Change towards Nanotechnology Applied to Food Production.” Public Understanding of Science 22 (7): 817–831. doi:10.1177/0963662512440220.
Fleischer, T., J. Haslinger, J. Jahnel, and S. B. Seitz. 2012. “Focus Group Discussions Inform Concern Assessment and Support Scientific Policy Advice for the Risk Governance of Nanomaterials.” International Journal of Emerging Technologies and Society 10: 79.
Freder, L., N. Gupta, S. George, A. Fischer, E. Giles, and D. Coles. 2014. “Consumer Attitudes towards Nanotechnologies Applied to Food Production.” Trends in Food Science & Technology 40: 211–225.
Gupta, N., A. Fischer, and L. Frewer. 2015. “Ethics, Risk and Benefits Associated with Different Applications of Nanotechnology: A Comparison of Expert and Consumer Perceptions of Drivers of Societal Acceptance.” NanoEthics 9 (2): 93–108. doi:10.1007/s11569-015-0222-5.
Gupta, N., A. R. Fischer, S. George, and L. J. Frewer. 2013. “Expert Views on Societal Responses to Different Applications of Nanotechnology: A Comparative Analysis of Experts in Countries with Different Economic and Regulatory Environments.” Journal of Nanoparticle Research 15: 1838.
Ho, S. S., D. A. Scheufele, and E. A. Corley. 2013. "Factors Influencing Public Risk–Benefit Considerations of Nanotechnology: Assessing the Effects of Mass Media, Interpersonal Communication, and Elaborative Processing." Public Understanding of Science 22 (5): 606–623. doi:10.1177/0963662514117936.

Im, J.-H., I.-H. Jang, N. Pellet, M. Grätzel, and N.-G. Park. 2014. “Growth of CH3NH3PbI3 Cuboids with Controlled Size for High-Efficiency Perovskite Solar Cells.” Nature Nanotechnology 9 (11): 927–932. doi:10.1038/nnano.2014.181.

Jahnel, J. 2015. "Conceptual Questions and Challenges Associated with the Traditional Risk Assessment Paradigm for Nanomaterials." NanoEthics 9 (3): 261–276. doi:10.1007/s11569-015-0235-0.

Kahan, D. M., P. Slovic, D. Braman, J. C. Gastil, G. L. Cohen, and D. A. Kysar. 2008. Biased Assimilation, Polarization, and Cultural Credibility: An Experimental Study of Nanotechnology Risk Perceptions. Harvard Law School Program on Risk Regulation Research Paper, (08-25).

Kahneman, D. 2011. Thinking, Fast and Slow. New York: Macmillan.

Katare, B., C. Yue, and T. Hurley. 2013. “Consumer Willingness to Pay for Nano-Packaged Food Products: Evidence from Eye-Tracking Technology and Experimental Auctions." Paper presented at at the Agricultural and Applied Economics Association 2013 Annual Meeting, No. 149676.

Kim, J., A. J. Hong, S. M. Kim, K.-S. Shin, E. B. Song, Y. Hwang, F. Xiu., et al. 2011. "A Stacked Memory Device on Logic 3D Technology for Ultra-High-Density Data Storage." Nanotechnology 22 (25): 254006. doi:10.1088/0957-4484/22/25/254006.

Kulik, J. A., and H. I. Mahler. 1989. "Stress and Affiliation in a Hospital Setting: Preoperative Roommate Preferences." Personality and Social Psychology Bulletin 15 (2): 183–193. doi:10.1177/0146167289152005.

Lobb, A., M. Mazzocchi, and W. Traill. 2007. "Modelling Risk Perception and Trust in Food Safety Information within the Theory of Planned Behaviour." Food Quality and Preference 18 (2): 384–395. doi:10.1016/j.foodqual.2006.04.004.

Lofstedt, R., F. Bouder, J. Wardman, and S. Chakraborty. 2011. “The Changing Nature of Communication and Regulation of Risk in Europe." Journal of Risk Research 14 (4): 409–429. doi:10.1080/13669877.2011.557479.

Maynard, A. D., R. J. Aitken, T. Butz, V. Colvin, K. Donaldson, G. Oberdorster, M. A. Philbert., et al. 2006. “Safe Handling of Nanotechnology.” Nature 444 (7117): 267–269. doi:10.1038/444267a.

Mulder, B. C., P. M. Poortvliet, P. Lugtig, and M. de Bruin. 2014. “Explaining End-Users’ Intentions to Use Innovative Medical and Food Biotechnology Products.” Biotechnology Journal 9 (8): 997–999. doi:10.1002/biot.201400224.

National Nanotechnology Infrastructure Network 2017. “Nanotechnology Products”. National Nanotechnology Initiative n.d. “What is Nanotechnology?”

Petty, R. E., and J. T. Cacioppo. 1986. The Elaboration Likelihood Model of Persuasion, Communication and Persuasion. 1–24. New York: Springer.

Pidgeon, N., B. Harthorn, and T. Satterfield. 2011. “Nanotechnology Risk Perceptions and Communication: emerging Technologies, Emerging Challenges." Risk Analysis 31 (11): 1694–1700. doi:10.1111/j.1539-6924.2011.01738.x.

Poortvliet, P. M., and A. M. Lokhorst. 2016. “The Key Role of Experiential Uncertainty When Dealing with Risks: its Relationships with Demand for Regulation and Institutional Trust.” Risk Analysis 36 (8): 1615–1629. doi:10.1111/risa.12543.

Priest, S. 2016. Communicating Climate Change. London: Palgrave Macmillan.

Renn, O., and M. C. Roco. 2006. “Nanotechnology and the Need for Risk Governance.” Journal of Nanoparticle Research 8 (2): 153–191. doi:10.1007/s11561-006-9092-7.

Rogers-Brown, J. B., C. Shearer, and B. H. Harthorn. 2011. “From Biotech to Nanotech: Public Debates about Technological Modifi Cation of Food.” Environment and Society: Advances in Research 2: 149–169.

Rogers, E. 2003. The Diffusion of Innovations. 5th ed. New York: The Free Press.

Scheufele, D. A., E. A. Corley, S. Dunwoody, T.-J. Shih, E. Hillback, and D. H. Guston. 2007. “Scientists Worry about Some Risks More than the Public.” Nature Nanotechnology 2 (12): 732–734. doi:10.1038/nnano.2007.392.

Siegrist, M. 2010. “Predicting the Future: Review of Public Perception Studies of Nanotechnology.” Human and Ecological Risk Assessment 16 (4): 837–846. doi:10.1080/10807039.2010.501255.

Siegrist, M., M.-E. Cousin, H. Kastenholz, and A. Wiek. 2007a. “Public Acceptance of Nanotechnology Foods and Food Packaging: The Influence of Affect and Trust.” Appetite 49: 459–466.

Siegrist, M., C. Keller, H. Kastenholz, S. Frey, and A. Wiek. 2007b. “Laypeople’s and Experts’ Perception of Nanotechnology Hazards.” Risk Analysis 27 (1): 59–69. doi:10.1111/j.1539-6924.2006.00859.x.

Siegrist, M., and G. Cvetkovich. 2001. “Better Negative than Positive? Evidence of a Bias for Negative Information about Possible Health Dangers.” Risk Analysis 21 (1): 199–206. doi:10.1111/0272-4332.211102.

Siegrist, M., and C. Keller. 2011. “Labeling of Nanotechnology Consumer Products Can Influence Risk and Benefit Perceptions.” Risk Analysis 31 (11): 1762–1769. doi:10.1111/j.1539-6924.2011.01720.x.

Sosnik, A., J. das Neves, and B. Sarmento. 2014. “Mucoadhesive Polymers in the Design of Nano-Drug Delivery Systems for Administration by Non-Parenteral Routes: A Review.” Progress in Polymer Science 39 (12): 2030–2075. doi:10.1016/j.progpolymsci.2014.07.010.
Stampfli, N., M. Siegrist, and H. Kastenholz. 2010. "Acceptance of Nanotechnology in Food and Food Packaging: A Path Model Analysis." *Journal of Risk Research* 13 (3): 353–365. doi:10.1080/13669870903233303.

Steenis, N. D., and A. R. Fischer. 2016. "Consumer Attitudes towards Nanotechnology in Food Products: An Attribute-Based Analysis." *British Food Journal* 118 (5): 1254–1267. doi:10.1108/BFJ-09-2015-0330.

Sturgis, P., H. Cooper, and C. Fife-Schaw. 2005. "Attitudes to Biotechnology: Estimating the Opinions of a Better-Informed Public." *New Genetics and Society* 24 (1): 31–56. doi:10.1080/14636770500037693.

van Giesen, R. I., A. R. Fischer, and H. C. van Ttijp, 2018. Changes in the Influence of Affect and Cognition over Time on Consumer Attitude Formation toward Nanotechnology: A Longitudinal Survey Study. Public Understanding of Science 27(2): 168–184.

Vance, M. E., T. Kuiken, E. P. Vejerano, S. P. McGinnis, M. F. Hochella, Jr., D. Rejeski, and M. S. Hull. 2015. "Nanotechnology in the Real World: Redeveloping the Nanomaterial Consumer Products Inventory." *Beilstein Journal of Nanotechnology* 6: 1769–1780. doi:10.3762/bjnano.6.181.

Venkatesh, V., M. G. Morris, G. B. Davis, and F. D. Davis. 2003. "User Acceptance of Information Technology: Toward a Unified View." *MIS Quarterly* 27 (3): 425–478.

Venkatesh, V., J. Y. Thong, and X. Xu. 2012. "Consumer Acceptance and Use of Information Technology: extending the Unified Theory of Acceptance and Use of Technology." *MIS Quarterly* 36: 157–178.

Yue, C., S. Zhao, and J. Kuzma. 2015. "Heterogeneous Consumer Preferences for Nanotechnology and Genetic-Modification Technology in Food Products." *Journal of Agricultural Economics* 66 (2): 308–328. doi:10.1111/1477-9552.12090.