KNOWING MUCH WHILE KNOWING NOTHING

Perceptions and Misperceptions About Nanomaterials

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Abstract. Nanomaterials are not technological newcomers. However the use of an integrative concept to describe the diverse and complex array of these very small products is new. This chapter aims to describe some of the attitudes and risk perception studies about these materials. Furthermore it will be presented an empirical research where we will introduce some of the psychological factors that could help in understanding the psychometrics of the nanomaterials risk perception. One could conclude that despite the agreement that there is a widespread lack of knowledge, people can still apply attitudes and deduce a risk perception estimate that differs essentially according to the application domains. Furthermore risk perception about nanomaterials can be easily modified if some new negative phenomena arrive. In this context the design of a good risk communication strategy is particularly important especially because according to many studies and the one to be presented, the nano experts have difficulty in understanding what the factors that underlie lay people’s judgments are.

1. Knowing Much

European citizens seem to be generally optimistic about the contribution of technology to our way of life. An index of optimism shows a high and stable level for computers and information technology and solar energy from 1991 to 2005. Over the same period the index for biotechnology declined steeply from 1991 to 1999. From 1999 to 2005 the trend reversed, and now biotechnology is back to the same level of optimism seen in 1991. Optimism about nanotechnology has increased since 2002 – the ratio of optimists to pessimists being eight to one.
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According to an Eurobarometer study [33] (see Figure 1), the European public is not risk-averse about technological innovations that are seen to promise tangible benefits. In fact, in all of the areas studied (except for nanotechnology, in which the percentage of non-response was high in all countries), most respondents declared that they believed the new technologies development will have a positive effect in society in the next 20 years.

While the majority is willing to delegate responsibility on new technologies to experts, making decisions on the basis on the scientific evidence, a substantial minority would like to see greater weight given to moral and ethical considerations in decision taking about science and technology and to the voices of the public. As an example, there is widespread support for medical (red) and industrial (white) biotechnologies, but general opposition to agricultural (green) biotechnologies in all but a few countries.

Europeans support the development of nanotechnology, pharmacogenetics and gene therapy. All three technologies are perceived as useful to society and morally acceptable. Neither nanotechnology nor pharmacogenetics are perceived to be risky. While gene therapy is seen as a risk for society, Europeans are prepared to discount this risk as they perceive the technology to be both useful and morally acceptable.

In a set of questions asking for opinions on these four technologies (gene therapy; pharmacogenetics; GM food; and nanotechnology), respondents were first asked if they had ever heard of them. Figure 2 shows the percentages of respondents in each EU Member State who said they had heard of each of the applications.

Respondents were then asked whether they thought the different technologies were morally acceptable, useful for society, risky for society, and whether they should be encouraged. Figure 3 shows EU-wide mean scores for assessments of these applications, on a scale ranging from +1.5 to −1.5.
Knowing Much While Knowing Nothing: Perceptions and Misperceptions about Nanomaterials.

The European public is most positive about nanotechnology, followed by pharmacogenetics, and then gene therapy, though on balance it regards the latter as risky. By contrast, GM food is predominantly perceived as negative.

As the judged usefulness of technologies declines perceived risk increases, along with a decline in perceptions of moral acceptability and overall levels of support. For nanotechnology and pharmacogenetics, agreement that they should...
be encouraged goes along with the perception that they are not risky. This is mirrored in the case of GM food, for which overall opposition is accompanied by perceptions of relatively high risk. By contrast, gene therapy is supported despite the tendency for it to be perceived as risky; it seems that the risk attached to gene therapy is tolerable, whereas for GM food it is unacceptable.

There is clear evidence of differences in evaluations between those who have heard of a technology and those who have not. Specifically, those who say they have heard of gene therapy, pharmacogenetics and nanotechnology tend to express notably more positive views than those who are unfamiliar with them. For these

![Figure 4. Support for four technologies [33].](image)
technologies people who are familiar with them are more likely than people who are not familiar with them to agree that they are morally acceptable, useful and should be encouraged, and more likely to disagree that they are risky.

Looking a little more closely at overall levels of approval (whether the technologies should be encouraged) we see varying levels of support across countries. Figure 4 shows the stacked percentages of respondents who either ‘agree’ or ‘totally agree’ that each application should be encouraged.

These different attitudes towards this category of new technologies according to the type of the specific applications is a very important feature that will come across the whole chapter. Specifically, despite the global positive evaluation of these new technologies, the attitudes and, for that matter, the risk perception is strongly qualified by the specific attitudes towards the particular application. This psychological framing will be discussed in the next sections.

2. While Knowing Nothing

Previously, we showed that people’s knowledge of nanotechnologies is low and people have a positive opinion about its usefulness and moral acceptance, showing slight concerns about its risks. However, how can people have these evaluations about nanotechnologies not knowing what they actually are?

This section’s aim is to answer this question and discuss possible social-technical implications that are relevant to risk management. To begin with, a review of some research about the nature of human judgment and decision under uncertainty will be presented, focusing on three features: (1) the evaluations formation process, (2) how affect strongly influences evaluations, (3) and judgmental heuristics involved in these.

First of all, if people never heard of “nanotechnology” before how can they evaluate its risk? People can form judgments in two different ways [1]. If they already have some information about the evaluation target, let’s say “nanotechnology”, they can form an evaluation based on the data stored in memory. Otherwise, the evaluation can be formed on-line after the acquisition of an initial piece of information and then revised and updated as each subsequent piece of information is acquired [12]. For example, in our own research participants were first told “Nanotechnology deals with the development of procedures in which materials are created or manipulated in the atomic and molecular scale” and latter on, by filling the questionnaire they could infer that nanotechnologies deal with general applications (“food, military...”) and different products (“sunscreen, toys, cancer treatments”). Even if one might think that this information was kind of poor, with the respondents themselves stating their perceived knowledge regarding general nanotechnologies applications as low (M = 2.06; SD = 0.91), results illustrate that even with this minimal amount of information they still formed opinions that were consistent throughout the sample.

In fact, when not privy to specific and direct evidence necessary for an inductive inference about an attribute, people tend to draw from whatever sources of information they have available [11]. In some instances, attributes are inferred
from more global judgments or expectancies, such as a superordinate categorization of the target (e.g., [2]) or an overall attitude towards the target [4, 18]. Besides that, stronger inferences or evaluations are drawn with the passage of time, as memory of the absence of initial information fades [19]. This means people can simply judge nanotechnologies as technologies in general for example, and as time goes by, this judgment becomes less doubtful. We highlight that the first pieces of information that people receive tends to have more impact on evaluations than latter information [7, 13]. Even if the original information may be forgotten or inaccessible, its evaluation remains in memory and available for recall when it is needed. First impressions do matter!

It’s also important to note that negative information has more impact than positive information [13]. Risk managers should pay special attention to this issue: one single and unfortunate accident involving nanotechnologies might be more remembered than years of good practice and improvements on nanotechnologies different applications.

Continuing our discussion, how can people make a consistent risk estimate based on poor information? To make an evaluation we don’t necessarily gather all relevant information and deliberate about it. Many times our evaluations follow much easier and faster paths. If we analyze most our evaluations and decisions we can notice they reflect an apparent lack of “rationality”. Human decision “fail” to be explained by economic models: people do not decide in order to maximize profit or minimize costs all of the time [22]. For example, think about your house or car. Did you search all your options and settle for the better price/quality option or did you just knew that there was “something” about it that made it worthy?

This “something”, sometimes has to do with affect. Many times people intuitively use it instead of reason because usually rational choices consume more cognitive resources and time, while affect-based decisions and judgments allow the opposite. This means that instead of comparing nanotechnologies advantages and disadvantages, people might rely on their spontaneous feelings towards it. The point is that these feeling can be the result of very simple and basic psychological process, such as the degree of exposure or familiarity with the subject [10, 31], which influence people are usually not aware of. Because they derive not from conscious evaluations but from unconscious and automatic affective evaluations towards the object, they can produce an “I don’t like it, but I don’t know why” phenomena. This justifies that “liking” may support attitudes or choices that cannot be justified by people’s “rational” beliefs. This doesn’t mean that people are irrational! It means that in certain cases their judgments are based on affect. Functionally, these judgments are easier and faster and, in “known” situations, they prove to be “correct”. So, to the question: “Do you think nanotechnologies are risky?” we can unknowingly be answering “Oh yes, I don’t like it!”

Other times, this “something” might have to do with the “boundaries” of intuitive rationality. The research program on judgmental heuristics, by the Nobel Prize Daniel Kahneman and his colleague Amos Tversky, illustrates that people’s intuitive judgments (the judgments that spontaneously and effortlessly come to mind) are biased by factors that “reasonably” should be irrelevant. Specifically, the researchers found (a) persistent errors in estimates of known quantities and
statistical facts and (b) systematic discrepancies between the regularities of intuitive judgments and the principles of probability theory, Bayesian inference, or regression analysis. This means that when an individual has to judge a risk, his intuitive judgment probably will not have correspondence to its statistical meaning. We emphasize that this happens both to lay people and to people with statistical knowledge! Surprisingly, even the intuitive judgments of statistically sophisticated researchers don’t conform to statistical principles with which they are thoroughly familiar [26].

So, how do people judge things intuitively? In making predictions and judgments people rely on a set of heuristics or rules of thumb. Sometimes these yield reasonable judgments, other times they lead to severe and systematic errors. One can distinguish between “individuals” heuristics, such as the availability or ease with which particular mental contents come to mind [27], seriously influenced by the mass media’s coverage’s and “contextual” heuristics, like anchoring, the presence of contextual information that temporary raise its availability in individuals memory [27], and framing, with alternative formulations of the exactly same situation making different aspects of it accessible in memory, thus leading to different judgments [29]. On top of that, people don’t seem to be aware of these biases and tend to have a great confidence on the accuracy of their judgments [27]! So, when asked “Do you think nanotechnologies are risky?” we can unknowingly be answering “Oh yes, I’m absolutely sure they are risky! Just yesterday I saw on TV what a nanotechnology produced sunscreen did to a little child’s skin.”

3. Going Beyond Knowledge: Predicting Nanotechnologies Acceptance and Risk Perception

To answer this question we must comprehend the intuitive rules of risk perception. Fischhoff et al. [5], followed the work on judgmental heuristics and combined a compendium of hazards situational characteristics known to cause, at least, “strange” risk perceptions, i.e., perceptions that diverge from risk technical assessments.

Introducing the so called Psychometric Paradigm, the researchers describe nine characteristics which allow us to predict risk perception across specific hazards: (1) voluntariness of risk (do people get into risky situations voluntarily?), (2) immediacy of effect (to what extent is the risk of death immediate – or is death likely to occur at some later time?), (3) knowledge about risk to those exposed (to what extent are the risks known precisely by the persons who are exposed to them?), (4) science knowledge about risk (to what extent are the risks known to science?), (5) control over risk (if people are exposed to each risky activity or technology, to what extent can they, by personal skill or diligence, avoid death while engaging in the activity?), (6) newness (are risks new and novel or old and familiar?), (7) chronic-catastrophic (is this a risk that kills people one at a time – chronic risk – or a risk that kills large numbers of people at once – catastrophic risk?), (8) common-dread (is this a risk that people have learned to live with and can think about reasonably calm, or is it one that people have great dread for – on
the level of a gut reaction?), (9) severity of consequences (when the risk from the activity is realized in the form of a mishap or illness, how likely is it that the consequence will be fatal).

Testing across a wide range of hazards, research has shown that considering these dimensions in addition to perceived benefits, it is possible to predict lay people’s risk perceptions and acceptance judgments, despite people’s individual differences. Furthermore, these characteristics tend to be highly intercorrelated (for example, hazards judged to be voluntary tend also to be judged as controllable) and can be effectively reduced to two factors by means of factor analysis [23]. One first factor, that explains most of the data and is usually labeled “dread risk”, apparently discriminates between high- and low- risk technology activities, with the high end being characterized by perceived lack of control, dread, catastrophic potential, fatal consequences, and the inequitable distribution of risks and benefits (e.g., nuclear weapons technology). The second factor, “unknown risk”, is defined at its high end by hazards judged to be unobservable, unknown, new, and delayed in their manifestation of harm (e.g., chemical technologies). Many studies have also found a third factor, related to the number of people exposed to risk.

Lay people’s risk perceptions and attitudes are closely related to the position of a hazard within this type of factor space. The higher a hazard’s score first on “dread risk” and second on “unknown risk”, the higher its perceived risk and the more people wish to reduce it.

Siegrist et al. [21] have adapted this paradigm for the examination of nanotechnology hazards (adding characteristics such as “trust in governmental agencies” and “ethical justification”). Their results shown that perceived dreadfulness of applications and trust in governmental agencies are also important factors in determining perceived risk, with the author’s suggestion that public concerns about nanotechnology would diminish if measures were taken to enhance laypeople’s trust in governmental agencies.

We followed this psychometric paradigm and developed a study in order to understand different nanotechnologies risk perceptions, partially replicating the study by Siegrist et al. [21] and adding other variables and general nanotechnology applications not considered by them.

Two hundred and sixty-nine participants filled a two-part web based questionnaire on “nanotechnologies and society” voluntarily. From these, 24.8% were males and 75.2% were females, 74.5% had a high-school degree, 21.8% a university degree, 3.3% a master’s degree and 0.4% a Ph.D. The mean age was 24.9 and participants were mostly from the Lisbon area. Initially, they received the first part of the questionnaire, in which they were given a definition of nanotechnologies (“Nanotechnology deals with the development of procedures in which materials are created or manipulated in the atomic and molecular scale, in order to create new products whose properties have different characteristics compared to materials created or manipulated on the basis of other types of technologies”) and nanoparticles (“Particles with a dimension less than 100 nm that can be formed by natural processes or manufactured through nanotechnology processes, having applications in various fields such as medicine, pharmacy, clothing, food and telecommunications”). The aim was to give baseline information
that was equal to all participants, independent of their prior knowledge. Following this information, they rated six general nanotechnology applications in a five point scale based on eight risk perception attributes: Probability of health damage (1 = very improbable; 5 = very probable); Worries about risks (1 = not worried; 5 = very much worried); Voluntariness of risk (1 = voluntary; 5 = involuntary); Knowledge of risk to those exposed (1 = known precisely; 5 = not known); Adverse health effects strength (1 = not at all; 5 = very strong); Control over risk (1 = controllable; 5 = uncontrollable); Trust in institutions responsible for protecting people’s health regarding the technology (1 = no trust; 5 = much trust); Ethically justifiable to develop the application (1 = absolutely justifiable; 5 = not at all justifiable).

In the second part, participants had to rate 20 specific nanotechnology applications, in the same 8 risk perception attributes. However, given the length of the questionnaire with the 20 specific nanotechnology applications, we divided it in two parts with 10 specific applications each, with the participants being randomly ascribed to one of them.

From these, seven scales were created by averaging results on each item, creating composite measures with good psychometric properties overall and reliability indexes (Cronbach’s Alpha). The scales are as follows: General Nanotechnology Risk (α = 0.73); Clothes Nanotechnology Risk (α = 0.73); Food Nanotechnology Risk (α = 0.72); Communications Nanotechnology Risk (α = 0.74); Medical Nanotechnology Risk (α = 0.68); Military Nanotechnology Risk (α = 0.81); Overall Nanotechnology Risk Perception, developed through the aggregation of all these general and specific nanotechnology risk ratings (α = 0.81).

The results show that the Overall Nanotechnology Risk Perception (considering both general and specific applications) is neutral (neither positive nor negative) with this view being highly consistent across the sample (M = 3.00; SD = 0.44), the same happening for the General Nanotechnology Risk (M = 2.89; SD = 0.55).

Of these general applications, food (M = 3.38; SD = 0.63) and military applications (M = 3.39; SD = 0.74) are perceived as significantly more threatening than any of the others (p < .000). The lowest perceived level of threat is obtained for the clothes application (M = 2.79; SD = 0.58), followed by the communications application (M = 2.95; SD = 0.63) and the medical application (M = 3.08; SD = 0.56). These results seem to highlight more the general evaluations toward the applications than the specific evaluations regarding their risks.

The results concerning the eight psychometric risk attributes for the Overall Nanotechnology Risk Perception are presented in Table 1. As we were expecting, results show that the “Knowledge of Risk to those Exposed” is the attribute with the highest mean and, in the absence of knowledge, the attribute “Ethically Justifiable to Develop the Application” is the one with the lowest.

Analyzing these eight psychometric attributes for the general nanotechnology risk applications, some major differences arise.

For the clothes application, the results show that the participants consider that there is a high lack of “Knowledge of Risk to those Exposed” (M = 3.63; SD = 1.05), with the lowest results being for the “Worries about risks” (M = 2.41; SD = 1.01),
“Probability of health damage” (M = 2.44; SD = 1.04), “Adverse health effects strength” (M = 2.56; SD = 0.78) and “Control over risk” (M = 2.52; SD = 0.91), and the other attributes being around a medium point.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack knowledge</td>
<td>3.4907</td>
<td>0.72977</td>
</tr>
<tr>
<td>Involuntary</td>
<td>3.1838</td>
<td>0.60379</td>
</tr>
<tr>
<td>Lack trust</td>
<td>3.0148</td>
<td>0.64362</td>
</tr>
<tr>
<td>Health damage</td>
<td>3.0023</td>
<td>0.65461</td>
</tr>
<tr>
<td>Effects strength</td>
<td>2.9870</td>
<td>0.54246</td>
</tr>
<tr>
<td>Worries</td>
<td>2.9164</td>
<td>0.66749</td>
</tr>
<tr>
<td>Uncontrollable</td>
<td>2.8519</td>
<td>0.63891</td>
</tr>
<tr>
<td>Ethically unjustifiable</td>
<td>2.7047</td>
<td>0.62721</td>
</tr>
</tbody>
</table>

For the food application, results in Figure 5 show a high lack of “Knowledge of Risk to those Exposed”, as well as medium-high “Worries about risks”, “Probability of health damage”, lack of “Voluntariness of risk”, “Adverse health effects strength”, with the other attributes being around a medium point.

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Figure 5. Nanotechnologies food risk.
For the communications application, the results show a medium-low lack of “Knowledge of Risk to those Exposed” (M = 3.41; SD = 1.10), with the lowest results being for the “Ethically justifiable to develop the application” which a low value in this scale meaning that people consider it to be justifiable (M = 2.41; SD = 1.10), for “Control over risk” (M = 2.75; SD = 0.99) and “Worries about risks” (M = 2.76; SD = 1.07), with the other attributes being around a medium point.

For the medical application, the results show a medium-low lack of “Knowledge of Risk to those Exposed” (M = 3.53; SD = 1.02), with the lowest result being for the “Ethically justifiable to develop the application”, being this the most ethically justifiable application of all the general applications (M = 2.29; SD = 0.92), with the other attributes being around a medium point.

For the military application, results in Figure 6 show the highest consistency comparing to the other applications, with all the attributes scoring medium-high or medium-low (all results are above point 3 in the scale).

Regarding the specific applications, mean values for the perceived risks can be seen in Table 2. The one perceived as more threatening is Ammunition with a medium-high perceived level of threat, followed by Water Sterilization, Sunscreen and Toys Coating. The one’s perceived as less threatening were Cancer Treatment with Nanocapsules, Medical Nanorobots, Data memory and Storage of Hydrogen as a Gasoline Substitute. Once again, these results seem to reflect more the general evaluations regarding the applications than the specific evaluations regarding their risks.
A Principal Components Analysis (PCA) was performed to assess the underlying psychological factors in the risk assessment of the general and specific applications of nanotechnology. For this we averaged the ratings for each of the eight attributes over participants and aggregated the data across applications (following the procedure suggested by Willis et al. [31], and performed a PCA on this data with a varimax rotation.

Given the results on the screen-test and the percentage of variance explained considering the factors extraction, as seen in Table 3 we decided for three factors with 84.78% of variance explained: Factor 1 – Dread (including “Probability of health damage”, “Worries about risks” and “Adverse health effects strength”); Factor 2 – Unknown (including “Knowledge of risk to those exposed” and “Control over risk”); Factor 3 – Trust & Ethics (including “Trust in institutions responsible for protecting people’s health regarding the technology” and “Ethically justifiable to develop the application”).

### TABLE 2. Perceived risks for the 20 specific applications.

<table>
<thead>
<tr>
<th>Application</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammunition</td>
<td>3.5329</td>
<td>0.67142</td>
</tr>
<tr>
<td>Water sterilization</td>
<td>3.2412</td>
<td>0.56518</td>
</tr>
<tr>
<td>Sunscreen</td>
<td>3.2103</td>
<td>0.63596</td>
</tr>
<tr>
<td>Toys coating</td>
<td>3.1159</td>
<td>0.53760</td>
</tr>
<tr>
<td>Food packaging</td>
<td>3.0365</td>
<td>0.55487</td>
</tr>
<tr>
<td>Textiles coating</td>
<td>3.0251</td>
<td>0.60469</td>
</tr>
<tr>
<td>Building materials protection</td>
<td>2.9990</td>
<td>0.53873</td>
</tr>
<tr>
<td>Car paint</td>
<td>2.9461</td>
<td>0.56479</td>
</tr>
<tr>
<td>Photographic paper</td>
<td>2.9091</td>
<td>0.58095</td>
</tr>
<tr>
<td>Release of medication</td>
<td>2.8844</td>
<td>0.55434</td>
</tr>
<tr>
<td>Implants coating</td>
<td>2.8805</td>
<td>0.61551</td>
</tr>
<tr>
<td>Monitors</td>
<td>2.8565</td>
<td>0.59994</td>
</tr>
<tr>
<td>Food biosensors</td>
<td>2.8510</td>
<td>0.61244</td>
</tr>
<tr>
<td>Tires</td>
<td>2.8471</td>
<td>0.62260</td>
</tr>
<tr>
<td>Lightweight building materials</td>
<td>2.8318</td>
<td>0.55332</td>
</tr>
<tr>
<td>Skis</td>
<td>2.7996</td>
<td>0.56768</td>
</tr>
<tr>
<td>Hydrogen storage</td>
<td>2.7975</td>
<td>0.57061</td>
</tr>
<tr>
<td>Data memory</td>
<td>2.7653</td>
<td>0.59224</td>
</tr>
<tr>
<td>Medical nanorobots</td>
<td>2.7418</td>
<td>0.56440</td>
</tr>
<tr>
<td>Cancer treatment</td>
<td>2.6684</td>
<td>0.54212</td>
</tr>
</tbody>
</table>
TABLE 3. PCA loadings with a varimax rotation.

<table>
<thead>
<tr>
<th></th>
<th>Dread</th>
<th>Unknown</th>
<th>Trust &amp; ethics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health damage</td>
<td>0.656</td>
<td>0.486</td>
<td>−0.120</td>
</tr>
<tr>
<td>Worries</td>
<td>0.932</td>
<td>0.120</td>
<td>−0.032</td>
</tr>
<tr>
<td>Involuntary</td>
<td>0.085</td>
<td>0.876</td>
<td>0.298</td>
</tr>
<tr>
<td>Lack of knowledge</td>
<td>−0.173</td>
<td>0.896</td>
<td>0.301</td>
</tr>
<tr>
<td>Effects strength</td>
<td>0.878</td>
<td>−0.142</td>
<td>0.324</td>
</tr>
<tr>
<td>Uncontrollable</td>
<td>0.879</td>
<td>−0.130</td>
<td>0.284</td>
</tr>
<tr>
<td>Lack of trust</td>
<td>0.253</td>
<td>0.486</td>
<td>0.691</td>
</tr>
<tr>
<td>Ethically unjustifiable</td>
<td>0.106</td>
<td>0.272</td>
<td>0.895</td>
</tr>
</tbody>
</table>

Loadings above 0.50 are signaled

Following the PCA analysis, a spatial representation of the general and specific nanotechnology applications was performed. For the sake of parsimony and clarity and of the interpretation, we performed another PCA analysis with only two factors, explaining 74.22% of the variance, with the attributes reorganized in this way: Factor 1 – Dread (including “Probability of health damage”, “Worries about risks”, “Adverse health effects strength” and “Control over risk”); Factor 2 – Unknown, trust and ethics (including “Knowledge of risk to those exposed”, “Trust in institutions responsible for protecting people’s health regarding the technology”, “Ethically justifiable to develop the application” and “Voluntariness”). Figure 7 represents all the applications in this two-dimensional plot, developed from the two factors scores, labelled by application.

From this representation, we can see that the most trustworthy institutions responsible for protecting people’s health regarding the technology are associated with general and specific medical applications, with these being the applications also with a higher knowledge of risk to those exposed, more control over exposure and where is more ethically justifiable to develop the application. However, at the same time, they also have a medium level of dread.

The applications with higher perceived risk are the ones where there is the lowest knowledge, control over exposure, trust and ethical justification, combined with a high perceived dread risk, namely the one’s associated with general and specific military applications and general food applications.

The applications perceived as safer or with the lowest perceived risk, are the ones where there is a higher knowledge, control over exposure, trust and where is more ethically justifiable to develop the technology, combined with low levels of perceived dread risk, namely data memory, food biosensors and hydrogen storage.
Thus, even in the absence of information, people did judge nanotechnologies in a consistent way, in accordance with intuitive judgments rules, and currently they perceived them as moderately risky. Some applications stand out (military, food), we believe not because people had more knowledge about them but because of their evaluations towards technologies operating in those fields, along with a low sense of control over exposure, distrust in institutions and perceived poor ethical justifications.

4. Coping with Nanotechnologies Perceived Risk

In a negative scenario, if risk management isn’t successful it’s possible that when people hear more about nanotechnologies in the future they will start evaluating it as risky, because it is not only a matter of information but also attitudes. The point is that even if public concerns about risks don’t turn out to be true, as might be the case for nanotechnologies, the perception of being in risky circumstances is a stressful situation [15] that might actually induce psychological, physical and behavioral consequences (e.g. [32]).

How might people act in this situation? One way to cope with it is by means of social comparison [6]. There are evidences that in certain groups under threat,
people who cope better are the ones who perform explicit self-evaluation against a less fortunate target (downward evaluations), expressing peoples clear efforts to regulate emotions by making the person feel better in comparison with worse-off others [25]. For example, cancer patients that engage in this kind of comparisons cope better with the disease than those who don’t. As Taylor and Brown [25] argue, the healthy human mind seems to cordon off negative information, creating positive illusions that help coping and are particularly adaptive when one is threatened by adversity. In our case people might compare nanotechnologies with other events, reevaluate them and psychologically accept being in a risky situation.

A way to cope is reflected in the so-called “NIMBY” effect. This acronym stands for “Not In My Backyard”. It’s a phenomenon that strikes whenever a community has been chosen to host a hazardous facility or a facility that will carry some cost for the local residents. Describes the fact that people usually agree with the need to build some hazards facility but are against building that construction near their home (e.g. [9, 17]). In this case, people cope with the situation not by reevaluating it but by changing it. We argue that nanotechnologies, due to its “nano” operative nature, can put people into a somehow similar phenomenon: “Not In My Body” (NIMB) [1]. NIMB would describe people agreeing with the general need to use nanotechnologies but refusing to use nanotechnologies that would “enter” their body, (consider, for example, the differences in the clothes and food applications). We recall the psychometric analysis of our data illustrated that most of its variance was explained by a factor that combined attributes concerning people’s health (“Dread” factor).

So, we analyzed if it might be important to isolate the risk perception of nanotechnologies to the body level, comparing it with the risk for the self, other people and family. Participants in our study evaluated the risk of nanotechnologies in general to self, to their own body, to their family and to other people, perceived general control regarding the general applications, the adverse health effects due to nanoparticles entering the body to evaluate the NIMB effect, and the knowledge perception, in Likert type 5 point scales (1 = Totally disagree; 5 = Totally agree).

Once again we created scales by averaging results on each item, creating composite measures with good psychometric properties overall and reliability indexes (Cronbach’s Alpha). The scales are as follows: Perceived Nanotechnology Risk to the Body, for the general applications ($\alpha = 0.81$); Perceived Nanotechnology Risk to Self, for the general applications ($\alpha = 0.81$); Perceived Nanotechnology Risk to the Family, for the general applications ($\alpha = 0.80$); Perceived Nanotechnology Risk to Other People, for the general applications ($\alpha = 0.86$); Perceived Control over Nanotechnology Risk for the general applications ($\alpha = 0.73$); NIMB effect ($\alpha = 0.88$); Perceived Knowledge of Nanotechnology Risk for the general applications ($\alpha = 0.90$).

To what concerns an assessment of the general applications the results for other variables show no significant differences in the level of perceived exposure to the risk, namely between the perceived risk to self, to their own body, to their family and to other people, with all having a medium value and the highest value
being the perceived risk to self (M = 3.09; SD = 0.76). Also the perceived level of general control over the nanotechnologies risk is medium (M = 2.95; SD = 0.77), the same happening with the perceived adverse health effects due to nanoparticles entering the body (NIMB, M = 3.03; SD = 0.83). The level of knowledge, however, is perceived as low (M = 2.06; SD = 0.91). Besides that, this scale has the highest internal consistency index (α = 90.): people’s knowledge toward general applications is only slightly differentiated.

These results confirm our suspicions: with the current state of lack of knowledge people do not evaluate nanotechnologies in general as threatening and have a moderate perceived level of general control. Currently there are also no differences between the perceived risk to them (or their body) and their family (usually comparatively higher when people are in stress) and the risk to other people (usually comparatively higher when people are successfully coping with stress).

We also performed a Multiple Regression Analysis to find out how the perceived risk for the five applications could be better explained by these variables. As previously theorized, the model that explained most data variability (52.7%; p < .001) predicts the mean risk for the five applications raises when there is an increase both in Perceived Nanotechnology Risk to Self (β = 0.379; p < .001) and Perceived Nanotechnology Risk to the Family (β = 0.247; p < .05) and vice-versa; at the same time decreases when there is an decrease in Perceived Control over Nanotechnology Risk (β = -0.220; p < .001) and vice-versa. Thus, by analyzing risk to self, family and control, we can predict people’s risk perception for these five applications. Perceived control might play a leading role in nanotechnologies risk management.

5. What the Experts Think Laypeople Think: Perceptions and Misperceptions About Nanomaterials

Nanotechnologies possible “dread” and actual “lack of knowledge” makes it highly vulnerable to the impact of an unfortunate event (such as an accident, sabotage, contamination or a product tampering). Even if its specific or direct impact is small, the indirect effect might be extremely powerful and even tamper with the field’s development. This might happen because of the social informativeness or “signal potential” of that event that might be perceived as a harbinger of further and possibly catastrophic mishaps [23]. An example refers to the consequences of GMO contamination of natural non-modified plants in the surrounding fields and the negative publicity it brought to GMO production.

As for any activity or technology with a certain probability of risk associated to it, experts in the field acknowledge the need to develop risk management and communication strategies for the general public. Given the newness of this technology and its present neutral perceived level of threat, we are at the right moment to develop them and prevent the negative impact of an unfortunate event. The problem is that, in spite of being new it shares one characteristic with other older technologies, which makes the process of risk management and communication more difficult, if not paid attention to. This characteristic is that there seems to be
a huge gap between how technicians and lay people evaluate risks, with this gap existing whether the risk is known or not, i.e. it is not only a matter of knowledge level but also of perceptual and cognitive processes that technicians and lay people privilege in order to “calculate” risk [23, 28].

The work on risk perception has systematically highlighted the differences between the expert’s and laypeople’s assessments, emphasizing the formers technical and objective character and the latter’s biases, inconsistencies and risk perception illusions [14]. There is no doubt that the concept “risk” means different things to different people. For example, when experts judge risk their responses correlate highly with technical estimates of annual fatalities, with their assessment being based on the factual data they have. Lay people usually go beyond this information with their judgment of “risk” being based on other criteria, such as the perceived threat to future generations or the equity in the distribution of risks [23], as identified by the psychometric risk paradigm. Moreover, this perception is systematically influenced by socio-demographic and cultural variables (e.g. [8]).

This is not surprising, since people and technicians are “trained” to evaluate risks in different ways. In fact, experts are trained during their education and work to evaluate risks in a set of established, shared and standardized criteria (i.e. all professionals in the field are supposed to evaluate in the same manner). This level of agreement is not so high when we talk about laypeople since that different cultural experiences, frequency of exposure to the risks, socio-demographic characteristics, personality type and other individual and social group differences makes them use different criteria in different contexts for different risks. This means that the difference between laypeople and experts is not only a matter of knowledge but also about the framing with which they assess risks. Therefore, both groups were “trained” either through experience, knowledge or both, to evaluate with different criteria and eventually reached a point in which they could do this spontaneously, without much rational thought associated with it. Particularly, the experts were trained to frame and judge the risks and the situation in a less intuitive way but, again, this is only a question of training since that given the right conditions, laypeople can also evaluate under the same criteria as the experts and experts can also fall prey to their intuitive assessments and judge under the same criteria as laypeople. We will get back to this point later on. For now, we will give next some examples of these different risk judgments between experts and laypeople.

One example comes from Savadori et al. [20] who used the psychometric paradigm to examine the difference between expert and layperson risk perception on different biotechnology applications, specifically food and medical applications. Results regarding food applications showed that lay people judged the risk as higher than the experts did. The main factors which could explain most of the judgment’s variance both for laypeople and experts were related to perceived harm, dread and usefulness. Additionally to these, people also made their evaluation in terms of newness and level of scientific knowledge of the risk associated with biotech food applications, having a broader perception than the experts for this application. Results regarding medical applications also showed that lay people judged it as higher than the experts, however here the factors considered by lay
people were less, when compared to the experts. The factors that explained laypeople’s evaluation of the risk associated with medical biotech applications were perceived harm and usefulness, while the experts considered these but also the level in which would expose themselves and many people to the risk, its newness and level of scientific knowledge.

These results show that although the risk’s newness and level of scientific and social knowledge about it are important factors, people can still judge a risk as high, even though these factors are not considered in the judgment, as it was the case for people’s evaluation of medical biotech applications risk. Therefore, although people appear to be irrational, since they systematically evaluated the risks for the medical and food biotech applications as long as five other applications as higher than the experts did, their evaluation depends on the nature of the hazards, with different judgment criteria being used for different hazards. Equally interesting, the experts have gone beyond their specialized knowledge and expertise to make their judgements, using the same criteria as people did, but for different types of applications.

In a different study also comparing expert and laypeople, Siegrist et al. [21] used the same psychometric paradigm to analyze the risk perception for various nanotechnology applications. Results showed that people’s nanotechnology risk judgements were higher and their trust in authorities responsible for protecting people’s health regarding the technology was lower, than for the experts. However, results regarding perceived benefits were not significantly different between laypeople and experts. To what concerns the factors influencing individual differences, the best predictors of people’s perceived risk regarding nanotechnologies in general were: perceived nanotechnology benefits, social trust and attitudes regarding technology in general (perceived benefits and fears). For the experts risk perception, the best predictor was only social trust, basing their judgements only on this but not on their attitudes or perceived benefits. We consider this to be an expected result given the fact that they work in the area and apparently consider that the control over these risks should be handed in to the people in the same area as them, since that they are the ones with the highest knowledge level.

Considering all this, we can infer that if some unfortunate negative event happens regarding some kind of nanotechnology application, as long as it doesn’t undermine the perceived trust in authorities responsible for protecting people’s health regarding the technology, experts risk perception regarding nanotechnologies should remain “untouched”, independently of the type of application. The same is not expected to happen with laypeople’s perception, given that their judgements are also based on their attitudes and perceived nanotechnology benefits and that even in the absence of specific knowledge about the nanotechnology application for which the unfortunate negative event might happen, they can still make their judgments.

Moreover, the magnitude of the risk perception increase should be higher for those applications identified as more dreadful, unknown and distrusted, as identified in Siegrist et al. [21] and in our own study presented before, based on the psychometric paradigm (although this should happen only until a certain level, due
to a ceiling effect resulting from the presence of normal adaptation processes [15, 16]).

Finally, given the similarities of some nanotechnology applications in terms of their perceived dreadfulness, lack of knowledge, trust and ethical assurance that we identified (e.g. food and military general applications), it is expected that if an unfortunate negative event happens for one of them, a spreading activation effect should be expected [3] translating into a heightened risk perception for the other applications perceived as similar in terms of these psychometric attributes (as it might happen for example with any activity associated with the term “nuclear”). For the reason presented before, regarding the maintenance of a high level of trust as perceived by the experts, these changes aren’t expected to occur so suddenly and with such a high magnitude, for the experts.

In spite all of this, there are still many misconceptions in the literature regarding the differences between experts and lay people. It is a fact that, as we seen, they both evaluate risks in a different way but that doesn’t mean, as sometimes is implicit in the literature and most of the times explicit in the real world, that experts are better than people at judging risks. In fact, this is somewhat of an illusory conclusion, since for example laypeople can also evaluate annual fatalities if they are asked to [23] and perform accurate frequency estimates of causes of death, making difficult estimations based only on their judgments, in the absence of any other information [14]. The opposite is also true, in the sense that experts are “only humans” and there is no assurance that their judgments are immune to biases, when they are forced to make evaluations that go beyond the data they have [24].

As the psychometric approach shows, these divergences occur systematically but can be successfully framed in a participated risk management process, as long as we consider both expert and lay people different “languages” and “valuations”, that go beyond the level of existing knowledge about a technology.

However, most of the times what hampers with risk communication and management strategies it is not the existence of these different ways in which experts and people evaluate risks. What often does the harm is that these strategies are designed on a misperception of these differences and are based on the expert’s expectations and implicit knowledge about how people think and perceive risks. This implies the design of strategies in order to match how the experts think people think or how people will react to a certain level of risk, and not to match how people actually think or might react.

It is obvious from what we have shown before that the experts evaluate risks in a different way from the lay people and that both, given the right conditions, can have similar risk evaluations. However, how good are they to evaluate how people perceive risks i.e., how much of a good intuitive psychologist are they?

To answer this question we performed a study with an expert sample asked to fill the questionnaire while attending our nanotechnology meeting, with all participants giving their informed consent after a brief explanation of the research aims. This sample was comprised of 24 experts with interests and/or experience in the nanotechnology area, which answered a questionnaire on “nanotechnologies and society” voluntarily. From these, 60.9% were males and 39.1% were females and...
the mean age was 47.59, with 34.8% coming from Europe, 26.1% from the USA, 17.4% from Canada, 13.0% from Brazil and 8.7% from other countries. These experts worked in areas such as Nanotoxicology and nanomaterials (N = 6), Ecotoxicology (N = 5), Risk assessment (N = 5) and other nanotechnology and risk assessment related areas.

In this study, the participants had to fill the same questionnaire as in our study presented before but without the 20 specific applications. However, differently from study 1, they were presented a set of statements, for which they were asked to choose the response (from the possible 5) that most matched the opinion of the general public, i.e., what nanotechnology experts believe to be the laypeople’s perceptions on this field. This is an original framing, since most of the literature on risk assessment analyses how the experts perceive the risks but not how the experts perceived how people in general perceive the risks, i.e. what the experts think laypeople think.

The introduction was stated as follows: “As you’re probably aware one of the most recent fields of technological research is the field of nanotechnology. Like several other technological breakthroughs nanotechnology is likely to prompt specific perceptions and attitudes by the general public. In this study we are interested in studying what nanotechnology experts believe to be the perceptions of the general public on this field, i.e., the layperson’s beliefs about several features of nanotechnology.” Therefore, the items were similar to study 1 but with a different framing, as seen in the following example: “The general public views the probability of health damage derived from nanotechnology as (1 = Very unlikely 5 = Very likely).”

The results showed that the experts consider the layperson’s General Nanotechnology Perceived Risk to be moderate (M = 3.21; SD = 0.47) but significantly higher than the risk perception level that laypeople reported in study 1 (M = 2.89; SD = 0.55; p = .005), which shows that they think people consider nanotechnologies more threatening than laypeople actually consider. However, to what concerns the general applications, experts have an accurate view by considering that food (M = 3.40; SD = 0.46) and military applications (M = 3.36; SD = 0.68) are seen as the most threatening, while the applications to clothing (M = 2.87; SD = 0.43), medicine (M = 2.89; SD = 0.44) and communications (M = 2.92; SD = 0.45) considered to be the least threatening, with no significant differences compared to what laypeople reported in study 1.

The results concerning the eight psychometric risk attributes for the General Nanotechnology Risk Perception show that in the same way as in people’s perception in study 1, they also consider the “Knowledge of Risk to those Exposed” as the attribute with the highest mean, meaning that the experts consider that there is a high level of lack of knowledge in laypeople. However, they consider this lack of knowledge to be higher (M = 3.75; SD = 58) than what people report (M = 3.49; SD = 73), although this being only marginally non-significant (p = .079). The same happens for “Trust in institutions responsible for protecting people’s health regarding the technology”, with the experts considering that this lack of trust is perceived as higher (M = 3.27; SD = 1.02) than it actually is (M = 3.02; 0.64; p = .075).
The only significant misperception in these, refers to the “Voluntariness of risk”, i.e. experts consider that people’s exposure to nanotechnologies risk is more involuntary (M = 3.44; SD = 0.57) than actually people consider it to be (M = 3.18; SD = 0.60; p = .035). This can be seen as the work of a defense mechanism, in which people deny and try not to think about the fact that they might be exposed to a risk unknown to them and to which they didn’t chose voluntarily to be exposed to, showing a natural adaptation process that lowers the stress in this sense [16, 25]. This was demonstrated in our study with the laypeople’s sample, in which perceived control was one of the best negative predictors of perceived risk, meaning that an increase in one implies a decrease in the other. Differently, the expert’s defense mechanism regarding nanotechnologies is to trust the authorities. 

When we consider the eight psychometric attributes for the five general nanotechnology risk applications, the differences arise. We found a very good level of expert’s accuracy in judging people’s perception for the communications and military nanotechnology applications, with no significant differences between laypeople and experts. Moreover, we found a good level of accuracy for the clothes application, with the only difference being in terms of trust, with the experts considering it to be significantly higher (M = 3.33; SD = 1.20) than actually people perceive it (M = 2.92; SD = 0.83; p = .027) and also a rather good accuracy regarding the food application, with the differences being in terms of trust and voluntariness, with the experts considering trust to be significantly higher (M = 3.46; SD = 1.10) than actually people perceive it (M = 3.10; SD = 0.88; p = .056), and the involuntariness in the exposure to the risk to be significantly higher (M = 3.92; SD = 0.88) than actually people perceive it (M = 3.44; SD = 1.02; p = 0.026).

The lowest level of accuracy was for the medical nanotechnology application, with the experts considering the worries about the risk to be significantly lower (M = 2.58; SD = 0.97) than actually people perceive it (M = 3.27; SD = 1.10; p = .003), the effects strength to be significantly lower (M = 2.71; SD = 0.81) than actually our sample perceive it (M = 3.23; SD = 0.88; p = .006), the health damage to be significantly lower (M = 2.71; SD = 1.04) than actually people perceive it (M = 3.22; SD = 1.08; p = .027), the lack of control over exposure to the risk to be significantly higher (M = 3.38; SD = 1.17) than actually people perceive it (M = 2.84; SD = 0.95; p = .009), the involuntariness in the exposure to the risk to be lower (M = 2.88; SD = 1.19) than actually people perceive it (M = 3.29; SD = 1.00; p = .059).

Concerning the general applications, the results for other variables showed only one misperception. As we expected, the experts consider the perceived adverse health effects due to nanoparticles entering the body (NIMB effect) to be higher (M = 3.60; SD = 0.81) than actually people perceive it (M = 3.03; SD = 0.83; p = .001).

A PCA Analysis was performed to assess the underlying psychological factors in the risk assessment the experts consider that the people have, regarding the five general applications of nanotechnology. For this, we averaged the ratings for each of the eight attributes over the expert sample and aggregated the data across
applications. A PCA was performed on this data with only one factor being extracted, explaining 74.93% of the variance. All attributes saturated above 0.60 on this factor, except for the attribute “control over exposure” (saturation of ~0.926) which lost its explanatory power among the others.

This shows that the expert’s judgments of people’s perception have an overall narrower explanatory level, compared to the underlying factors for people’s actual perception (given that there were three factors identified in study 1, for the laypeople’s perception). This misperceptions and lack of knowledge about what and how people think, significantly affects the experts intuitive and non-factual predictions of how people will judge a certain risk for a certain nanotechnology application, and consequently how they will react to that risk. This is a very dangerous endeavor since that if experts do this without knowing anything about human cognitive functioning and behavior, instead of managing and communicating risk with the aim of reducing it, they will actually increase it and also the possible negative reactions and manifestations associated to it.

These misperceptions are evident in Figure 8 which represents the general applications in a two-dimensional plot, developed from the two factor scores resulting from another PCA we performed, labeled by application. We should
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warn however that the confidence in this analysis is lower than the one performed in study 1, since that the two factors obtained in this one are not completely independent, even after performing a varimax rotation, which can insert a certain error level in the analysis. In spite of this, we’ll present the results since the differences from the laypeople’s two-dimensional plot are very clear, even discounting the measurement error.

In this figure, we can see that only the military and food applications are in the same quadrant as in study 1. All the other applications are influenced by misperceptions regarding the risks, especially to what concerns the medical applications, which are considered to have a high level of knowledge, trust and ethical justification and a low level of dreadness. However, according to laypeople’s perception they would be in a different quadrant, characterized by a moderate knowledge of risk to those exposed, control over exposure and ethical justification but, at the same time, with a medium level of dread.

In a nutshell, we can see that while experts are accurate in analyzing lay people perceived nanotechnologies risk in general considering the eight psychometric attributes, this accuracy disappears when they have to consider the five applications based on these same eight attributes. This demonstrates that their implicit knowledge about laypeople’s cognitive functioning cannot compensate for the differences between applications, i.e. they think people evaluate the risks always in the same manner.

Also, intuitively the experts judge the high level of lack of specific knowledge to be the main cause of differences between applications and since that they consider people to have similar lack of knowledge in every application, then there shouldn’t be differences. Since that in the Siegrist’s et al. [21] study the experts risk perception regarding nanotechnology was best predicted by social trust, we can infer that experts expect that people in the absence of knowledge regarding the applications, also use trust as a criteria for their judgments. However, as we saw in our results, there is a misperception about the trust level in the food and clothes nanotechnology applications. Moreover, as we know from the same study, people use criteria as perceived nanotechnology benefits, social trust and attitudes regarding technology in general (perceived benefits and fears) to make their risk assessments. This might explain why the highest misperception was for medical nanotechnology applications, which seems to be more influenced by attitudes and perceived benefits than any of the others. This is exactly where the experts implicit knowledge about laypeople’s functioning fails, by not considering that differences in risk assessments might occur given the presence of attitudes and other perceptions, i.e. they seem to be only accurate in assessing laypeople’s perception when these influences are not so strong.

6. Conclusions

From the above results and discussion one can extract several important conclusions that qualify the usual reflections about the nanomaterials’ risk perception and attitudes.
The first point that is important to stress is that the widespread positive attitudes about nanomaterials might actually be based on the global attitudes about technology. When people are asked to evaluate specific nano applications, this global positive picture starts to fade. The details of this process were analyzed and our revision and research was able to shed some light on the psychological process that underlies the formation of specific attitudes and risk perception based on small amounts of information.

Worth mentioning is the somewhat sharp differences within the evaluation of global applications where food and military ones show a different profile. When we detailed even further the specificity of nano applications, a factorial picture also illustrated that some applications like ammunition and food have higher risks, while others have comparatively much lower risks (e.g., medical). Thus, and as mentioned above, even in the absence of information, people did judge nanotechnologies in a consistent way, in accordance with intuitive judgments rules, and currently they perceive them as moderately risky (i.e. people “know much” in spite of their overall moderate to high lack of knowledge). Some applications stand out (military, food), we believe not because people had more knowledge about them but because of their evaluations towards technologies operating in those fields, along with a low sense of control over exposure, distrust in institutions and perceived poor ethical justifications. Additionally to this, the individual perceived control was also one of the most important factors.

Comparing experts and lay people perceptions of nanotechnologies one can easily conclude that experts have somewhat a misguided perception of people’s evaluations. One of the reasons for this mismatch is the fact that the complexities of the factors that guide lay risk perception are much more subtle and diverse than expected by the experts. The complexity of values and perceived benefits that are behind the attitudes and risk perceptions regarding specific applications are not fully understand by the experts.

The data and literature revised above also points out a potential negative scenario of hypothetical events related with nanomaterials. Given the lack of knowledge shown by people across studies and the specific values and ethical factors implied in the specific domain applications, a negative attitude and higher risk perception can be facilitated in that context, if no risk management and communication strategy is developed to address these specific factors.

All of this stresses the importance of a participated strategy that could take into account the specificities of lay people worldviews connected with the nanotechnology application domain and also the factors that are important for risk evaluation such as e.g., perceived control. The understanding of these processes probably has to start within the nanotechnology expert’s community who, most probably, will be in the front line of a potential crisis.
References


