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ORIGINAL RESEARCH PAPER

Spontaneous Comparison of Nanotechnology and Controversial Objects among Laypersons, Scientists and Environmentalists

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Abstract Nanotechnologies are a controversial topic, as they seem promising but also cause concern. Previous research has highlighted the potential link between nanotechnologies and other hazardous technologies. The aim of this research was to analyse the discourse on this topic by three groups of participants: laypersons, scientists and environmentalists. Thirty-four people (13 laypersons, ten scientists and eleven environmentalists) were interviewed using a semi-structured interview. Lexical and thematic analyses showed that scientists engage in explanatory discourse and perceive fewer risks than laypersons and environmentalists. The latter two groups describe applications and list the main actors in the development of nanotechnologies. Environmentalists are significantly more likely to make spontaneous associations with other technologies, such as electromagnetic waves, and perceive more risks than the other two groups. Contrary to our expectations, laypersons make fewer associations with biotechnologies than experts or environmentalists. The results are discussed in terms of the interest of a qualitative approach to uncovering new objects spontaneously associated with nanotechnologies, as well as in terms of a risk governance framework.

Keywords Nanotechnologies · Semi-structured interviews · Scientists · Laypersons · Environmentalists · Risk perception

Introduction

Nanoscience and nanotechnology are considered to be the technological revolutions of the 21st century [1]. In addition to applications in science and engineering [2], nanotechnologies are spreading into many other areas, such as health, for pain control [3] or treatment of Alzheimer's disease [4], veterinary medicine [5], construction [6], cosmetics [7], and food and agriculture [8, 9]. However, there is no agreed definition of nanotechnology [10]. This field of research, which is highly coveted by industry, is developing in a context in which many stakeholders (researchers, industrialists, politicians, associations…) are interested in assessing the risks and benefits, and recalling the need to regulate the development of nanotechnologies [11, 12]. Stone et al. [12] proposed a risk governance framework for current and future nanotechnology. Their framework highlights the importance of considering the perceptions of different stakeholders

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(e.g., consumers, customers, companies, regulators, industry, workers, insurance companies…) when drafting legislation. Underlying these concerns is the question of anticipating the problems that have arisen with other technologies, such as biotechnology: negative attitudes towards biotechnology have led to defensive behaviour towards Genetically Modified Organisms (GMOs). Societies are trying to avoid repeating the same scenario with nanotechnologies [13, 14]. Some of the stigma of risk management failures on issues such as asbestos or GMOs is still present [15–17]. Using a qualitative methodology, we aim to explore the risk perceptions of three actors: laypersons, scientists and environmentalists. Indeed, the issue of expertise has already been the subject of some research comparing laypersons and scientists. On the other hand, to the best of our knowledge, the perceptions of individuals who are sensitive to environmental issues have only been the subject of a few studies. One survey questioned NGOs, but the researchers did not report a comparative analysis with other groups [9]. It is to be expected that these individuals will have different perceptions from laypersons and scientists, due to their sensitivity to environmental issues in relation to other technologies.

Slovic's work [18] on risk perception sheds light on citizens' judgments about hazardous activities and technologies that are unfamiliar and incomprehensible to them. Although citizens have little information about nanotechnologies, they still have opinions, which some authors explain by ideological predispositions [19] but may also be due to judgement heuristics or cognitive shortcuts [20].

Research on risk perception shows that "proximal" (as opposed to distal, see [21] for a description) variables, such as the feeling of fear elicited by an object and the lack of knowledge about that object, are important determinants of perceived risk [22]. A review of the literature from 1978 to 2005 on the influence of distal variables on risk perception showed that the effect of age is contradictory, that women perceive more risk overall than men, that people with lower levels of education perceive more risk than people with higher levels of education, and that laypersons perceive more risk than experts [23]. According to Slovic, while technologically sophisticated analysts use risk assessment to evaluate hazards, the majority of citizens rely on intuitive risk judgments, typically referred to as "risk perceptions" [18, p. 236].

Some research on risk and benefit perceptions of nanotechnology has shown that proximal variables, such as feelings of fear, are correlated with higher risk perceptions [24, 25]. In contrast, and contrary to their expectations, Priest and Greenhalgh (2011) did not observe a change in risk perception as participants became aware of the risks associated with nanotechnology [26]. With regard to the distal variables, the results are consistent with the work on risk perception. Age has no effect on perceiving more risks than benefits, and more educated participants perceive fewer risks than benefits [24, 25, 27]. While some studies have shown that women perceive more risk than men [25, 27], one study found no relationship [24].

In the United States, Priest and his collaborators have investigated laypersons' and experts' perceptions of the risks and benefits of nanotechnology in several areas: agriculture and food, environment, health, new materials, electronic performance, and economics [26, 28–30]. Overall, this research has shown that the perception of benefits is higher than the perception of risks in all application areas. In addition, laypersons perceive more risks than scientists in the different areas, except for those related to health and the environment where laypersons perceive less risks than scientists [26].

However, these results were obtained by means of guided questions in which the participants were explicitly asked to evaluate the risks and benefits of pre-identified objects, but the psychometric method does not make it possible to know whether the different layperson and expert groups would have spontaneously evoked risks and benefits regarding nanotechnology. Furthermore, this method does not allow the identification of spontaneous associations with other objects and the valence of these associations [23, p.381]. However, the association with other objects may partly explain the assessment of risk perception. Burri [31] analysed focus groups and showed how an upstream public with little information about nanotechnologies uses analogies with other technologies and nature to understand this object.

The transfer effect from one object to another is theorised in the social representation framework, which posits that the emerging social representation

of an object goes through a process of anchoring and objectification [32]. A new object becomes part of the cognition of individuals and social groups through association with other known objects and through collective processes [33, 34]. It can be concluded that if a new object is anchored in an old object that is negatively connoted, the new object may also be negatively connoted. Although nanotechnologies are becoming more widespread in society, previous research on the perception of nanotechnologies has shown that the general public does not have a clear understanding of what they are [35, 36]. Although Brunel et al. [13] found no association between nanotechnology and GMOs, their study did not investigate whether nanotechnology is associated with other technologies or more general objects. Brondi and Neresini [36] showed among other things how the social representation of nanotechnology is embedded in the social representations of science and technology and how it has evolved from a descriptive to an evaluative approach, and from a neutral to a controversial issue over a five-year period. They found that the group that reported having talked or discussed nanotechnology the most was the most critical. It can therefore be assumed that the way in which new objects are discussed or presented to the public is likely to influence public attitudes and decisions.

The aim of the current research is to assess the risk perception of nanotechnology among laypersons and experts using a qualitative method. Therefore, we will analyse spontaneous discourse on nanotechnology by laypersons, scientists (experts) and environmentalists. We will carry out a lexical analysis to compare the content of their discourse on nanotechnologies, and their benefit and risk assessments. A thematic analysis will allow us to analyse the spontaneous associations with other objects. Based on psychometric and qualitative research on risk perception of nanotechnology, we expect that laypersons will perceive more risks and will make more analogies with other objects than experts. Although, to our knowledge, no study has investigated the perceptions of environmentalists, research on anchoring processes [33, 34] leads us to hypothesise that they will make different analogies than laypersons due to their knowledge of other technologies and controversial objects.

Method

Population

Between December 2012 and December 2014, 34 people participated in this study which took place in France. The mean age was 48.66 years (SD = 14.20; RG[23–71]). We interviewed 13 laypersons (eight women), ten scientists (three women) working on nanotechnology, and eleven environmentalists interested in the topic (six women).

Procedure

The interview began with an open question asking the participants to talk about nanotechnology: *"Please, talk to me about nanotechnology."* We used non-directive techniques to help the interviewees develop their ideas (repeating their last words, rephrasing, asking for further comments on an undeveloped concept…) [37]. The second part of the interview consisted of a direct question asking the participant to give their opinion on the perceived risks and benefits of nanotechnology. This question was only asked if the participant did not mention these issues during the non-directive part of the interview. Other questions were asked at the end of the interview (e.g., the first time they ever heard about nanotechnologies…), but these were excluded from the analysis as they were not systematically asked.

Content Analysis

We used the open-source software IRAMUTEQ to perform the automatic lexical analysis. The lexical analysis was carried out according to Reinert's method called co-occurrence text analysis [38, 39]. One of the aims of this method is to group in the same class discourses that use the same vocabulary within an elementary context unit (ECU, which roughly corresponds to the length of a sentence) into the same class by means of a descending hierarchical classification. This method also calculates a posteriori potential links between the different classes of discourse detected and previously identified variables (in our study, the group with three modalities: laypersons, scientists and environmentalists).

A thematic analysis of the controversial issues was then performed: the data were classified by

differentiation and then grouped by analogy to arrive at exhaustive and mutually exclusive categories [40]. The direction of the association was also coded as simple evocation (no association with nanotechnology), analogy with nanotechnology, or contrast with nanotechnology.

Results

The whole corpus consists of the 34 participants' answers to the open question (5146 tokens). The top-down hierarchical classification identified three classes of ECUs (i.e., classes of discourse). A total of 1666 ECUs were identified, of which 91% were classified. The remaining ECUs (9%) were not classified because their lexical composition was not similar enough to the composition of the three classes of ECUs. The first class differs from the other two.

Content of the Classes

Class 1

This class represents 38% of the classified ECUs. It is characterised by words from a descriptive and technical lexicon (see Table 1 for the Chi^2 associated with each word): molecule, property, scale, object, physics, chemistry, small, atom, surface, device, cell, electronics, make, DNA, particle, nanoobject, manometric, size, nano, nanometre, molecular. The group of scientists was associated with this class ($Chi^2 = 507.56$). Here are two extracts containing the words "molecules" and "properties":

> "These nanoparticles are born from solid materials and molecules, they will have certain properties because they are solid particles and certain properties because they are very small particles and no longer behave like solid materials" (male participant, scientist).

> "*They can have the properties of the molecule or the solid, but with properties that are exalted then in the chemical properties, since we have objects that are all small"* (male participant, scientist).

Class 2

This class represents 39% of the classified ECUs. It included an application-oriented lexicon and actors: thing, technology, find, research, world, industry, country, computer, think, possibility, researcher, nanotechnology, human, part, sell, produce, thing, development, economic, exist. Both laypersons and environmentalists were associated with this second class ($Chi^2 = 94.08$; $Chi^2 = 48.67$ respectively). Here are extracts containing the word "thing" and the word "technology":

> "*New technologies, I* mean*, really advanced stuff that if you're not interested in it, you don't know about it"* (female participant, layperson).

> "*It is about technologies that are in the infinitesimally small, but I have to say that I am totally ignorant on* this *subject"* (female participant, layperson).

Table 1 Significant lexical forms and Chi^2 of thematic classes 1 to 3

Class (N° and thematic)	Significant lexical forms (Chi^2)
1. Description	Molecule (126.59), property (95.06), scale (88.9), object (87.52), physics (96.15), chemistry (52.28), small (49.49), atom (42.34), surface (40.79), device (40.79), cell (40.26), electronics (35.78), make (35.74), DNA (34.18), particle (33.77), nanoobject (32.53), nanometric (30.74), size (27.01), nano (25.74), nanometer (24.33), molecular (24.33),
2. Application and actors	Thing (61.19), technology (45.39), find (41.02), research (36.98), world (28.48), industrial (26.54), country (25.74), computing (23.02), think (21.02), possibility (20.85), researcher (19.92), nanotechnology (19.87), human (19.82), part (19.06), sell (18.39), produce (18.32), thing (16.38), development (16.01), economic (15.95), exist (14.98)
3. Risks	Health (74.83), debate (63.72), risk (50.20), negative (42.16), scientific (40.46), danger (33.59), public (33.36), citizen (32.09), problem (29.30), breathe (28.75), length (27.64), term (27.52), positive (26.84), protection (26.84), dangerous (26.69), toxic (25.60), law (25.42), body (24.43), beware (23.47), ethics (21.58)

"*There is a desire to create a technology from the infinitely small, a source of improvement in the* manufacture *and efficiency of a range of products"* (male participant, environmentalist).

Class 3

This class represents 23% of the classified ECUs. It groups evaluative words and seems to reflect the risks associated with nanotechnologies: health, debate, risk, negative, scientific, danger, public, citizen, problem, breathing, length, term, positive, protection, dangerous, toxic, law, body, caution, ethics. The environmentalist group was associated with this third class ($Chi^2 = 129.52$). Here are extracts containing the word "health" and the word "risk":

"There were environmental *risks, so health risks, and we saw repeated damage to flora and fauna"* (female participant, environmentalist).

"People who handle them *are exposed to new risks because nanoparticles can pass through the skin, they can pass through the brain barrier, so we know that"* (male participant, environmentalist).

Risk Discourse

We looked at the distribution of the words "risk" and "benefit" for each of the three groups. The first observation in our corpus is that the word "benefit" was never used. We identified the word "interesting" as a word with a positive valence, so we looked for the distribution of this word. For the words "risk" and "interesting" in the Fig. 1, we read on the ordinate the probability associated with the positive (up) or negative (down) specificity of these words for each group. As we can see, the probability of the word risk is higher for the group of environmentalists than for the other two groups. The opposite is observed for the word interesting.

Spontaneous Associations With Miscellaneous Objects

The thematic analysis resulted in five categories: miscellaneous technologies (nuclear power, satellites, electromagnetic waves, 3D printers…) mentioned by 22 participants (65%), biotechnologies (GMOs, cloning, stem cells…) mentioned by 21 participants (62%), health scandals (asbestos, drugs, mad cow disease, contaminated blood…) mentioned by 19 participants (56%), environmental issues (global warming, pollution, greenhouse gases, oil spills…) mentioned by 16 participants (47%), and social issues (terrorism, finance, discrimination…) mentioned by eight participants (24%) (see Table 2 for frequencies).

The environmentalists all mentioned miscellaneous technologies spontaneously, whereas half of the scientists (5 out of 10) and less than half of the laypeople (6 out of 13) did so. A chi-squared test showed that this difference was significant: $\chi^2(2, N = 34) = 8.91$, $p = 0.012$, $V = 0.51$. On the other hand, almost all scientists mentioned biotechnologies spontaneously, as did the majority of environmentalists (7 out of 11), while a minority of laypersons mentioned

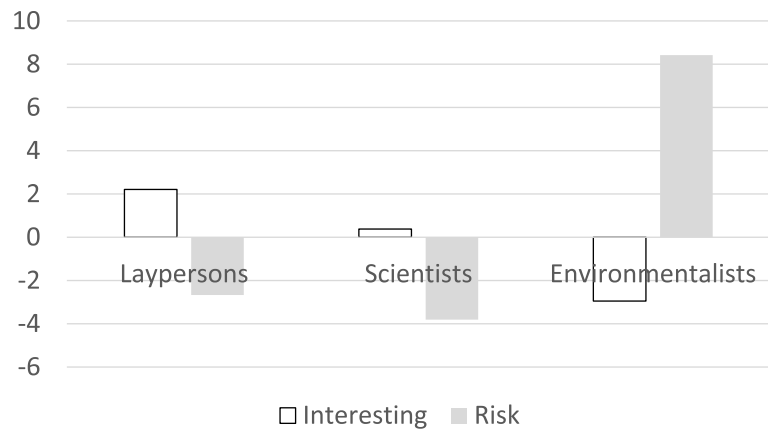

Fig. 1 Specificity (valence) probability of the words "interesting" and "risk" in function of groups of participants

Table 2 Spontaneous associations with controversial objects

	Group		
	Environmentalists ($n=11$)	Laypersons ($n=13$)	Scientists ($n=10$)
Miscellaneous technologies	**11**	**6**	**5**
Simply evoked	3	2	2
Analogy with nano	7	4	1
Contrasted with nano	1	0	2
Biotechnologies	**7**	**5**	**9**
Simply evoked	1	1	3
Analogy with nano	5	4	2
Contrasted with nano	1	0	4
Health scandals	**7**	**5**	**7**
Simply evoked	0	2	2
Analogy with nano	7	3	4
Contrasted with nano	0	0	1
Environmental issues	**7**	**5**	**4**
Simply evoked	1	4	0
Analogy with nano	6	0	4
Contrasted with nano	1	4	0
Societal issues	**4**	**2**	**2**
Simply evoked	3	1	1
Analogy with nano	1	1	1
Contrasted with nano	0	0	0

them (5 out of 13). A Fisher exact test showed that this difference was significant: $F(2,34)=6.38$, $p=0.042$, $V=0.43$. No other differences in themes and direction of the association reached significance.

Discussion

As expected, and as psychometric research on both nanotechnology and other topics has shown, experts perceive less risk from nanotechnology than laypersons and environmentalists [23]. The neutral and objective tone used by scientists leaves little room for affect. Although both laypersons and environmentalist groups describe applications and list the main actors in the development of nanotechnologies, the discourse of the laypersons group is rather poor in terms of defining nanotechnologies or perceived risks: their discourse reveals little knowledge about this object and is hardly evaluative [35, 36]. Contrary to our expectations, laypersons do not make more spontaneous associations with objects than other groups. In fact, they make fewer associations than the experts on biotechnology (see [13] for a similar result). This could be due to a lack of knowledge about science in general (e.g., [41]). Finally, the lexical and thematic analyses show that the environmentalists mention more risks than the other two groups and at the same time make significantly more analogies with various technologies, and especially controversial ones (nuclear power, electromagnetic waves…). This finding is in line with the work on the link between risk perception and anchoring to other objects [31, 33, 34].

Although our sample is too small to be representative of the general population, the qualitative approach used in our study allowed the participants to express their perceptions about nanotechnology in their own words (see also [42]). Our study revealed new objects compared to those traditionally used in the literature (e.g., GMOs) which could be evaluated for their impact on the perception of nanotechnology-related risks. Framing effects [43] based on these new objects could be revealed, and this further enhances the understanding of how individuals form opinions and assess risks about nanotechnologies. It could also provide new anchors to better communicate nanotechnology to the public [44].

Finally, from the perspective of a risk governance framework, decision makers are encouraged to consider the perceptions of different actors when designing legislation [9, 11]. The results of this research raise questions about how to access these perceptions. When using focus groups or public debates with actors with different interests and backgrounds, one may find that they focus on different aspects of the object, as we observed here, with specific discourses associated with each group. These heterogeneous points of view can either facilitate or hinder the debate. Testing this hypothesis could be the subject of future research.

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