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Should Scientists Communicate Uncertainty to the Public in Health Controversies? The Case of Endocrine Disrupters' Effects on Male Fertility

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ABSTRACT: Uncertain knowledge must be communicated to the public, as environmental problems can potentially reach many people. Uncertainty communication is assumed by some to increase public trust in science and policy makers, by others to produce public panic. We have used focus groups for getting insights about this assumption and more generally about peoples' attitudes following uncertainty communication, for the controversy on the effects of endocrine disrupters (EDs) on human male fertility.

KEYWORDS: uncertainty, communication, endocrine disrupter, controversy, perception, chemical risk.

1. INTRODUCTION

Scientific controversies related to public health issues are often characterized by a significant level of uncertainty. Despite this uncertainty, available knowledge must be communicated to the public, who is potentially in danger. Nevertheless, all science communicators do not share the conviction that uncertainty should be communicated to the public. Empirical work in the realm of science communication reveals skepticism among scientists, who assume that communicating uncertainty will result in a negative public reaction. Many of the scientists surveyed by Frewer et al. (2003) thought that informing the public of uncertainty would lead to increased distrust in science and scientific institutions, as well as cause panic and confusion regarding the extent and impact of a particular hazard. The general public might perceive

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reports of uncertainty within risk communications as evasiveness or as an admission of ignorance (Fessenden-Raden, Fitchen, & Heath, 1987). Lay people are supposed to expect certainty and to be disappointed by uncertainty communication, which could leave them an impression of arbitrariness (Renn, 2011).

Empirical appraisal of peoples' attitudes and feelings, as they receive messages about scientific uncertainty, is currently needed, as previous research showed contradictory results. Many studies cite beneficial effects, such as reducing public perception of risks and increasing the credibility of scientific and/or risk-assessment agencies (Funtowicz & Ravetz, 1990; Habicht, 1992; Van der Sluijs, 2002; Patt & Schrag, 2003). Citizens who are aware of uncertainty are thought to make more informed decisions (Carnegie Commission, 2011) and to be more willing to reduce catastrophic risks (Slovic, Lichtenstein, & Fischhoff, 1984).

Other results show that uncertainty can be disturbing, which can lead to denial (Slovic, Slovic, Fischhoff, & Lichtenstein, 1982; Weinstein, 1987) or even outrage (Slovic, 1993). Paradoxically, desire for certainty is nevertheless not universal—only a third of the sample in one study expressed a desire for certainty (Johnson & Slovic, 1996). Johnson and Slovic (1995) showed that communicating uncertainty has ambiguous consequences, signalling honesty to some and dishonesty to others (Johnson & Slovic, 1995, 1996).

Much of the literature in the field of experimental economics has focused on how people react to uncertainty and on whether/how the way this uncertainty is communicated influences decision making. A central result is that, in most situations, individuals tend to adopt a much more risk-averse decision stance when faced with ambiguity and poorly-defined risk (Chow & Sarin, 2001), potentially due to feeling a lack of control (Heath & Tversky, 1991). Kahneman, Slovic, & Tversky, (1982) analyzed how people assess the probability that uncertain events will occur and showed that a limited number of heuristic processes are involved; for example, representativeness, availability, and anchoring. The way in which uncertainty communication elicits these heuristics may influence people's judgments. The perception of uncertainty was influenced by whether it was communicated within a positive or negative framework (Kuhn, 1997).

The case of endocrine disruptors (EDs) and their effects on male fertility provide a good example of uncertain and controversial science; this is therefore a good case study for our theoretical investigation. EDs are “exogenous substances that alter function(s) of the endocrine system and consequently cause adverse health effects in an intact organism, or its progeny, or (sub)populations” (Commission of the European Communities, 1999). EDs are thought to contribute to the incidence of diseases such as cancer, diabetes, obesity, and reproductive disorders (decline in number and quality of sperm, testicular cancer, earlier puberty, etc.). Most, if not all the population, is exposed to them, but the ED issue is relatively new and currently controversial.

2. METHODS

In line with previous literature (Brashers, 2001, Powell, Dunwoody, Griffin, & Neuwirth, 2007), we distinguish *expressed* from *received* (or *perceived*) uncertainty, according to the assumption that the scientific message transforms during the communication process between the emitter (i.e., the scientist) and the receptor (i.e., lay public). Expressed and perceived uncertainty must be analyzed as two interrelated but different entities.

Eleven focus groups consisting of five to twelve laypeople, were organized between October 2010 and May 2011. Each group was homogenous for the following criteria, and the wide variety between the groups was intended: 1. High-revenue¹ mothers of children younger than three; 2. Low-revenue mothers of children younger than three; 3. Men and women with advanced scientific education; 4. Low-revenue men under 30 (young), without children; 5 and 6. High-revenue young men, without children (2 groups) 7. High-revenue young women, without children 8. Religious women (practicing); 9. High-revenue men and women over 40; 10. Low-revenue man and women over 40; 11. Farmers.

Each group participated in a three-hour meeting and each meeting followed the same protocol. The meetings started with a ten-minute introduction to the topic. Participants were then invited to read a one-page text, watch a short video² and then discuss both. This text + video + discussion sequence was repeated four times. The first four sequences were organized in two pairs of two; each pair included one text and one video *without (expressed) uncertainty* and *with (expressed) uncertainty*. The fifth contained uncertainty expressed by industry scientists, instead of academic scientists (as the first four).

If additional time remained, the groups would watch two or three more videos. The four texts were selected from a single popular science book and the videos were all extracted from a documentary or from scientific videos freely available on the Internet. A 20- to 30-minute group discussion followed each text + video sequence.

The meetings were video-recorded and discussions were transcribed. The transcripts were coded by two (9) researchers or three (2) researchers; each individual coding was then discussed. This process led to the identification of the following six categories of discussions:

- the reference science model (frame);
- sociopolitical and economic framing of science;
- non-scientific references for assessing the relevance of the message;
- characteristics of the communication format (text or video);
- perceived uncertainty sources;
- feelings.

Coding revealed several classes for each category.

Two categories (perceived uncertainty sources and one feeling, i.e., fear) are analyzed in the present communication.

Deviant-case analysis (Silverman, 2011) allowed us to systematically analyze the transcripts and ensured that we interpreted them as objectively as possible. The purpose of the analysis was to derive propositions that applied to all the data to arise from the focus groups. The analyst progressively modified the expression of his/her results to incorporate deviant cases.

After the presentation of each set of text and video, the participants were invited to express their judgment on the statement: *Some substances present in our environment produce a decline in male fertility, in humans*. This judgment had to be expressed using a figure on the scale proposed by Weiss (2003) (table I), as a communication tool in controversies, when

¹ We define revenue above 2000 € per household as *high* and revenue below this amount as *low*.

² The Eurobarometer report “Scientific research in the media” (2007) showed that most people in the EU get their scientific information from television.

generalists untrained in sciences must understand the merits of opposing arguments in disputes among scientific experts.

Table I. Scale of perceived degrees of uncertainty (modified).

Level (Score)	Convincingness of the evidence (Standard of proof)
10	Beyond any doubt
9	Beyond a reasonable doubt
8	Clear and convincing evidence
7	Clear showing
6	Substantial and credible evidence
5	Preponderance of the evidence
4	Clear indication
3	Probable cause: reasonable grounds for belief
2	Reasonable, articulable grounds for suspicion
1	No reasonable grounds for suspicion
0	Impossible
PP	Cannot express

At the end of each sequence (video and text), each subject chose a value from 0 to 10 corresponding to her/his PDU (Perceived Degree of Uncertainty). The statistical analysis aimed at answering two questions:

- Is there a global increase or decrease of uncertainty judgments when a researcher communicates or not uncertainty?
- Are there different patterns of change in uncertainty judgments, depending on people’s socio-economic characteristics?

Two tests are used to establish the significance or not of the results:

- the Sign test, which indicates the significance of a general decrease or increase;
- the Chi2 test of independence, which indicates the significance or not of differences between subsets of subjects, e.g., the subsets of age groups.

3. UNCERTAINTY RECEPTION: A QUALITATIVE ANALYSIS

Our definition of uncertainty is inspired by post-normal science, which distinguishes several dimensions: technical (inexactness), methodological (unreliability), epistemological (ignorance) and societal ((un)robustness) (Funtowicz & Ravetz, 1990).

According to this choice, the messages used in our empirical setting contained different types of uncertainty in the different sequences. The test messages have been structured by pair. The first sequence (text + video) did not contain uncertainty but presented epidemiological data about sperm decline. The second sequence did contain uncertainty related to the information presented in the first video, from the epistemological (referring to the strength of the causal relationship and to the available scientific knowledge about the human body), the methodological and the technical classes.

The second pair included a sequence presenting toxicological results on animal studies together with data about human exposures to EDs, and a sequence containing epistemological uncertainty associated to extrapolation from animals to humans, and epistemological uncertainty related to the causal relationship and the form of the dose-response relationship.

We found that, in reaction to scientific messages, laypeople raise more and different uncertainties than those contained in the original message communicated by researchers. In reaction to the sequences (text + video) in which uncertainty was not included in the communication, group discussions nevertheless highlighted a significant number of perceived uncertainties. Thus, even if the first sequence did not address uncertainty, during the discussions participants extensively questioned this causal relationship—they were particularly concerned about the link being weak. Many participants formulated their own multi-causal hypotheses to explain the epidemiological data presented.

Though participants received information about repeated studies that link reproductive disorders to EDs, they systematically questioned whether the data was complete. This technical uncertainty in the data was the most frequent type highlighted by participants for all the sequences of text and video, with and without uncertainty. Participants either explicitly felt that the information they received lacked precise details, or that it was simply not enough, though they did not indicate what they felt was missing. The data chosen by science communicators from all was a debated question. Participants concluded that selectively choosing data to communicate can either lead to concerns about the unavoidable simplification needed to popularize science or to suspicions about the intentions behind this selection.

Methodological uncertainty was also brought up by participants during discussions that followed sequences both with and without uncertainty. For example, the choice of parameters used to measure male fertility was questioned, in particular the choice of the sperm count as a measure of male fertility or of the pesticide content in urine as a parameter for determining the causal origin of the observed decline in sperm counts.

Several participants insisted on the importance of knowing the details of the methods together with the results themselves. The willingness of researchers to communicate details of their protocols seemed to be more relevant than the technical content of the methods itself.

Among all the types of uncertainty communicated during the focus groups, extrapolation uncertainty raised the strongest reaction. The message communicated by scientists in the second sequence about uncertainty related to extrapolation from animals to humans generated significant confusion. Arguments brought by participants for such a reaction focused the fact that animal studies have been validated—by extensive previous experience—as a viable replacement for ethically impossible human experimentation. Therefore, challenging animal studies raises radical questions both about the possibility or not to test toxicological properties of contaminants in laboratory, and about the real relevance of extrapolated results that led to marketed chemicals currently present in consumer products.

4. PANIC ABOUT CERTAINTY AND UNCERTAINTY

As shown in the introduction, some science communicators assume that communicating uncertainty would cause panic among laypeople. Our results invalidate this assumption.

After receiving scientific messages both with our without uncertainty, participants expressed panic when they perceived lack of control over the negative effects:

- messages without uncertainty that indicated a causal relationship between EDs and male reproductive disorders induced fear because of the ubiquitous nature of ED exposure, which makes it impossible to control their (known) dangers
- uncertainty communication elicited relief rather than fear, except when participants associated uncertainty with an inability to precisely identify the cause of the decline in male fertility and hence the ability to control it

All but one participant³ who expressed anxiety and fear following sequences with uncertainty also expressed the same feelings after videos without uncertainty. They associated these feelings with the inability to control potential negative health effects when the causative agent is not precisely known. These participants completely dismissed the causal relationship between EDs and male reproductive disorders when there was associated uncertainty. For this category of participants, uncertainty was enough to dismiss the scientific messages that were not associated with uncertainty.

Citizen: “At the same time, this is not necessarily more reassuring because, ultimately, the first [video] provided a cause, so one knows where to act; but here, see that this range [of factors] is open.”

Participants who felt alarmed,⁴ anxious or frightened after sequences without uncertainty associated these feelings with lack of control over the (known) effects of EDs on health because of their ubiquitous presence in daily life, their invisibility, past experience of risks, and lack of trust that policy makers can adequately control them. These feelings were also elicited by epidemiologic information on male reproductive disorders. Even though the messages transmitted by scientists were questioned on several points, they were sufficiently trusted to produce strong feelings about the negative effects of EDs.

Citizen: “Yes, this scared me a lot.”

Citizen: “Perfume fixatives are worrying. This does not make us feel like using [perfumes] anymore.”

Comparatively, women expressed fear more often than men.

5. RELATIONSHIP BETWEEN PERCEIVED UNCERTAINTY AND DEMOGRAPHIC PARAMETERS

The analysis used a total of 455 PDU (Perceived Degree of Uncertainty) score values, i.e., 5 successive scores for the question corresponding to each sequence with/without uncertainty (Q1, Q2, ..., Q5), for each of the 91 subjects, except 4 subjects who chose no value for 1 or 2 sequences.

We have examined the relation between the increase or decrease in perceived uncertainty and several demographic variables, i.e., gender (F/M), monthly household income (around 1000 Euros, 1500, 2500, 4000), post-graduate (Yes/No), scientific studies (Yes/No, with 7 non-response), practice of a religion (Yes/No, with 15 non-response), occupation (student, employee, liberal profession/senior executive, farmer or other), age group (21–29, 30–40, 41–69), and having children (Yes/No).

³ Five participants explicitly expressed this feeling after sequences 2 and 4, of which 3 were women.

⁴ 30 participants explicitly expressed this feeling after sequences 1 and 3, of which 22 were women.

Among the PDU-score differences, Q3–Q4 (message with/without extrapolation uncertainty) is the one most related to socio-economic variables.

The increase in uncertainty level following uncertainty communication is more often found for:

- older people (compared to younger ones)
- employees and liberal professions/senior executives (compared to other professions)
- low education level (compared to higher levels)

In other words, people increase easier their degree of perceived uncertainty following uncertainty communication (i.e., are more easily responsive to messages containing uncertainty), if they are in one of these categories.

The Q2–Q1 difference (i.e., perceived uncertainty following uncertainty communication in the sequence Q2) is significantly related to a few socio-economic variables, with a more important decrease from Q1 to Q2, for:

- employees (compared to other professions),
- non-scientific studies (compared to scientific studies)

The practice of religion is significantly associated to repetitive uncertainty communication, i.e., Q24–Q13.

6. A MODEL FOR THE RELATIONSHIP BETWEEN EMITTED AND PERCEIVED UNCERTAINTY

Based on existing literature and our own results, we propose a model (Fig. 1) for the communication of uncertainty associated with environmental and health risks.

This model highlights the role of each of the three components of any communication process:

- the transmitter (which is, in our case, the scientist, but can be a regulatory agency, a policy maker, a representative of an NGO or professional organization, etc.)
- the receiver (in our case, the general public, but may also be policy makers, stakeholders, etc.)
- the communication process itself, having its own characteristics. Indeed, this component is sometimes forgotten from risk or uncertainty studies, leading to incomplete focus either on the transmitter (assuming that the receiver will receive the message as intended by the transmitter, e.g., the deficit model) or on the receiver (leading to narrow formulations of the source message, in discrepancy with the diversity of uncertainty types and framings in the real world communication)

There is a process of transformation of the message during the communication process, which depends in our case not only on the substantive features embodied in the message by the transmitter (e.g., with or without uncertainty), but also on:

- the characteristics of the process (e.g., the nature of the communication support, video, text or other),

- the characteristics of the context in which the message is positioned (e.g., socio-economic, political and cultural connotations of science and/or of the particular scientific topics addressed)
- the features of the transmitter him/herself (e.g., academia or industry researcher),
- the features of the audience (e.g., socio-economic status, level of education, etc.) (Fig. 1)

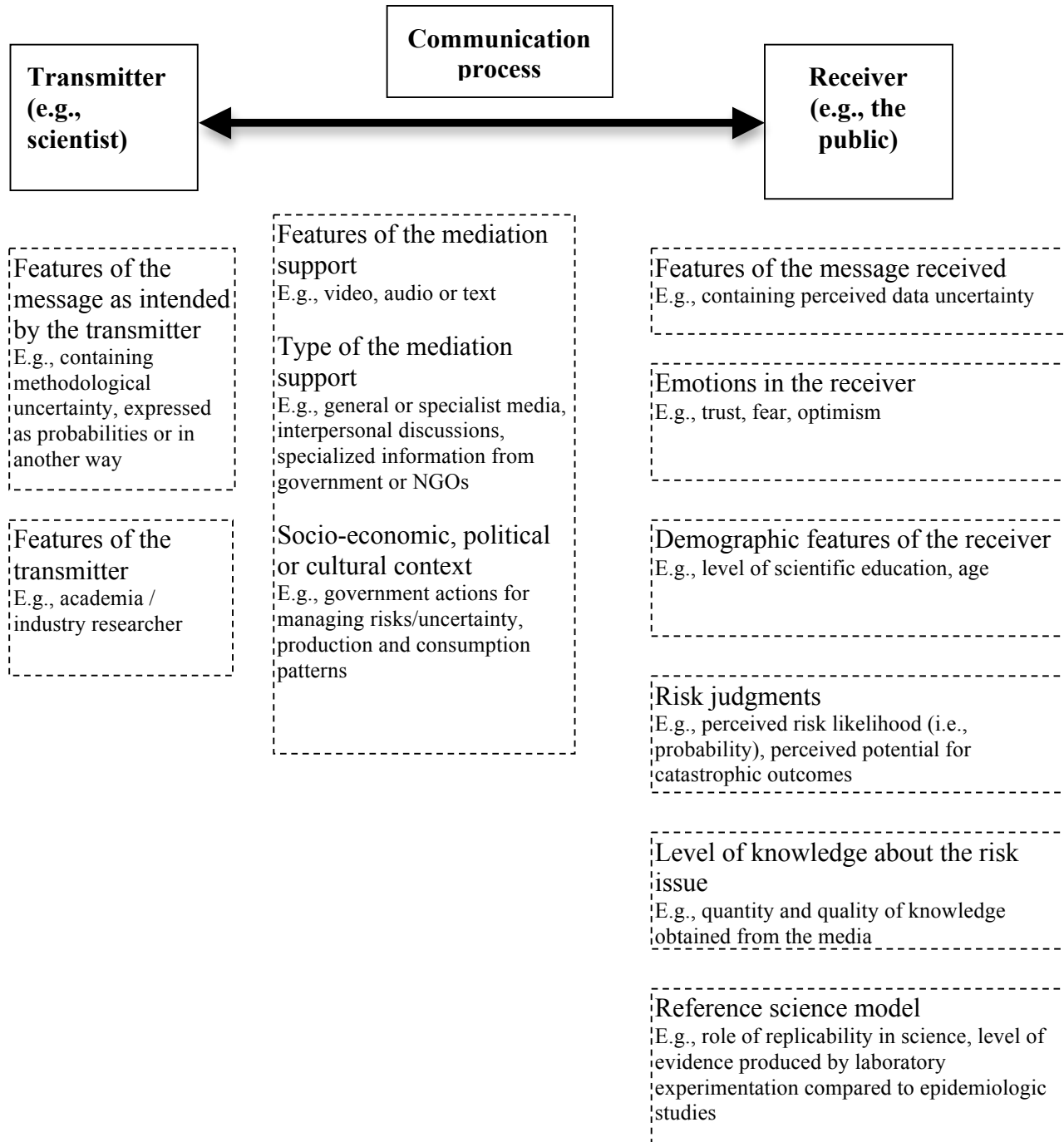


Fig.1. A model for the communication of uncertainty about health and environmental risks

The transmitter will draft his/her message according to his/her knowledge or assumptions about each of the components of the model. Anyway, some of the components remain unknown to the emitter, due to their complex influence on the communication process (e.g., the socio-economic and political context). The transmitter cannot control all the aspects influencing the reception of his/her message. These components might equally remain unknown to the receiver, who might not be conscious of (or able to explain) all the reasons of his perception of the message. Indeed, the receiver will perceive the message according to the more or less conscious appraisal of the different parts of the model. The role of each component in the reception of the uncertain message has already been or can be highlighted by research in psychology, communication, etc.

As regards to uncertainty communication, this representation helps at better separating emitted from perceived uncertainty, understanding that each of them should be defined and characterized in its own way, and at distinguishing the contextual characteristics of the communication process itself.

7. CONCLUSION

There is currently relatively little research about perceived uncertainty (Powell et al., 2007) and almost any literature about how it relates to different patterns of emitted uncertainty. Nevertheless, there is an increasing need to understand how the public perceives the uncertainty communicated by scientists or by other science communicators. Indeed, many current risks must be communicated to the public potentially exposed to important hazards, when uncertainty about them is still present and sometimes important (e.g., risks from nanotechnologies, EDs, etc.). Furthermore, there is an increasing tendency from expert bodies like regulatory agencies (e.g., European Food Safety Authority, European Chemicals Agency) to communicate uncertainty associated with their risk assessments.

Research is needed for bridging the gap between increasingly abundant practices and research on expressing uncertainty (e.g., post-normal school) and relatively scarce research about how the audience (i.e., the public, the risk managers, the regulated industry, etc.) perceive these messages.

Using a quasi-realistic experimental setting and the case study of ED effects on male fertility, we have investigated the assumptions currently made by some scientists about the potential negative effects of uncertainty communication on lay publics. In particular, we have tested the assumption found in scientists by Frewer et al. (2003) that communicating uncertainty causes panic.

Our results contradict this assumption. Participants expressed relief rather than fear in reaction to uncertainty communication, except when they associated it with an inability to precisely identify the cause of, and therefore control, the decline in male fertility. Anyway, people also highlighted that the “dangers of relief” include reduced attention to and protective measures against a risk that may ultimately prove to be real.

Messages that indicated a causal relationship between EDs and male reproductive disorders without addressing uncertainty induced fear related to lack of control, because ED exposure is ubiquitous, making it impossible for people to control the (known) dangers. This confirms previous results on the central role of lack of control in lay people risk and uncertainty perceptions (Heath & Tversky, 1991; Siegrist, 2008). Fear is consistently associated with feeling unable to act on his/her own life, and also with demands that relevant

information about risks should be easily available to everyone. Though experts disagree and policy-makers may fail to protect public health, participants demand the right and the capability to make their own choices based on the available knowledge; they do not want to be artificially protected though lack of transparency.

We found that, in reaction to scientific messages, laypeople raised more and different uncertainties than the researchers originally raised. Causal, data, and methodological uncertainty were those most often highlighted by participants.

Perceived uncertainty was systematically associated with its sources, instead of being treated as *global* uncertainty. This confirms previous work (Rogers, 1999) indicating the differential perception of various types of uncertainty. From a regulatory point of view, this is important because it indicates that communication might be more effective if each of the relevant sources of uncertainty is addressed separately. Nevertheless, current policy initiatives such as the REACH regulation, dealing with risks from industrial chemicals (among which are EDs), propose approaches expressing cumulative uncertainty, in particular probabilistic risk assessments. Such tools might create a potential of miscommunication of uncertainty and their effects on the intended audience (i.e., risk managers) should be first tested before giving them regulatory weight.

About the relationship between demographic variables and perceived uncertainty, statistical analysis showed that:

- uncertainty communication by academic researchers significantly increases the uncertainty perceived by people, on average;
- the effect of repetitive uncertainty communication (e.g., Q24–Q13) is significantly more important for people who do not practice religion;
- the higher the age and the household income, the easier uncertainty communication produces perceived uncertainty.

Also, the lower the education level and in absence of scientific studies, the easier uncertainty communication produces a change of judgment (i.e., perceived uncertainty). This facility to change opinion (i.e., perceive uncertainty) also seem to be more important for women, employees and liberal professions/senior executives, but this has to be confirmed in further experiments.

Based on these findings, our model for the communication of scientific uncertainty highlights all the complexity of the science and uncertainty communication process, which cannot be conceived as a linear transmission of information reaching the audience as the transmitter intends.

Previous literature showed an important influence of the source of uncertainty communication (i.e., public or industry scientists). Results previously reported for uncertainty communication by regulatory agencies (Johnson & Slovic, 1995, 1996) are therefore not necessarily comparable with our results obtained for uncertainty communication by researchers. We have the intuition that the reception of uncertainty will depend on the disciplines of the science communicator, and that our results obtained on communication by (eco-)toxicologists cannot necessarily be extrapolated without critical analysis to other domains of research (e.g., nuclear physicists).

Our results give a positive experimental feed-back for policies related to the public right to know, reinforcing the access to health and environmental information. They show that

lay publics are able to intelligently deal with scientific uncertainty, all by acknowledging and managing their own feelings related to it.

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