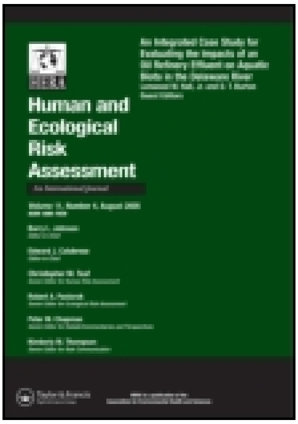

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RISK PERCEPTION/COMMUNICATION ARTICLE

Public Reactions to Risk Messages Communicating Different Sources of Uncertainty: An Experimental Test

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ABSTRACT

There is an abundant literature on the challenge of integrating uncertainties in experts' risk assessments, but the evidence on the way they are understood by the public is scarce and mixed. This study aims to better understand the effect of communicating different sources of uncertainty in risk communication. A causal design was employed to test the effect of communicating risk messages varying in type of advisory warning (*no risk and suggests no protective measure,* or *risk and recommends a protective measure*) and sources of uncertainty (*no uncertainty*, *divergence between experts*, *contradictory data*, or *lack of data*) on public reactions. Participants from the general public (N = 434) were randomly assigned to read and react to variants of a fictitious government message discussing the presence of a new micro-organism found in tap water. Multiple analysis of variance showed that to report uncertainty from divergence between experts or from contradictory data reduced the adherence to the message, but not to mention the lack of data. Moreover, the communication of diverse sources of uncertainty did not affect trust in the government when the advisory warning stated there was a risk and recommended a protective measure. These findings have important implications for risk communication.

Key Words: uncertainty, risk perception, risk communication, trust.

INTRODUCTION

Global warming, genetically modified organisms (GMOs), nanotechnologies, mobile phones, Severe Acute Respiratory Syndrome (SARS), H1N1, and Bovine Spongiform Encephalopathy (BSE) are only but a few examples of new hazards

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characterized by limited or contradictory data about their effect on human health. Despite the sources of uncertainty surrounding these issues, risk managers and government agencies must still provide relevant health responses and public information (Fraser *et al*. 2009). However, it is still unclear how the public responds to government guidance in the presence of uncertainty about risk. The literature on the effect of communicating uncertainty to the public on risk perceptions, mobilization, and trust is largely inconsistent. A potential explanation for the contrasted evidence is that different sources of uncertainty (*e.g.*, imprecision or errors in measurement, validity or strength of the evidence about risk, lack of knowledge, indeterminacy) may elicit the different public reactions.

The current study aimed to disentangle the broad concept of uncertainty by comparing experimentally different *sources of uncertainty* commonly discussed: (a) the lack of knowledge about a risk (epistemic uncertainty), (b) the contradiction in the data or (c) the contradiction between experts concerning the existence of a risk for human health (ambiguity). These were presented in the context of different *types of advisory warning* addressed to the population to announce either (a) the absence or (b) the presence of a risk in relation to a fictitious new substance found in tap water. The objective was to measure whether communicating different sources of uncertainty could moderate the effect of government advisory warnings on risk perception, risk acceptability, behavioral intentions, and trust in the source.

The Context of Risk Communication

Risk communication models have evolved substantially over the last decades (Leiss 1996). First inspired by the mechanistic and linear model of information transmission elaborated by Shannon and Weaver (1949), risk communication has been conceptualized as experts providing information that the public lacked. In the so called "*deficit model*," experts' enterprise was to convince the public about what constituted "benign risks" and "real risks" (Frewer 2004). However, as the field of risk perception and communication matured, it was acknowledged that the concept of risk is not independent of individual, social, and cultural values (Slovic 1999). Members of the public are not "irrational" when they react to risks differently than suggested by scientific experts' calculations and public health's guidance; they are simply influenced by different values and appraise risks in the perspective of their everyday lives (Alaszewski 2005).

Risk communication models have therefore evolved to become more transactional, accounting for the fact that the meaning of a message is not merely passively deciphered by members of the audience but rather actively constructed (Barnlund 1970; Bowers 1980). This transactional conception paved the way to the current "*strategic risk communication model*," which is defined by a greater partnership with the public (Frewer 2004; Macnaughten *et al*. 2005). Indeed, the emphasis is put more on consultation with the public than on persuasion (Pfeiffer 2006). Transparency is also key in the process of strategic risk communication as members of the public are considered like partners with whom a constructive dialogue about risk can take place (Leiss 1996; Palenchar and Heath 2007; Renn 1992; Wiedemann and Schuetz 2000).

The Challenges of Sharing Uncertainty in Risk Communication

In the context of increased expectations for transparency in risk communication, acknowledging sources of uncertainty associated to risks is part of the process. However, communication professionals and public health officials find communicating information about sources of uncertainty during health crises challenging (Holmes *et al.* 2009). Results from a survey completed in the United Kingdom in relation to the H1N1 outbreak, revealed that misunderstanding what was happening with the swine flu outbreak (described by the authors as uncertainty) was linked with a lower likelihood of adopting the recommended changes in behavior (Rubin *et al.* 2009). In focus groups led in Vancouver, BC, Canada, exploring perceptions about the risk of emerging infectious diseases and the use of new vaccines, participants reported being hesitant to use novel vaccines due in part to the many unknowns of new diseases and the many uncertainties surrounding new vaccines (Henrich and Holmes 2009).

Yet, in focus groups and interviews realised on the theme of uncertainty in Quebec and Ontario, Canada, participants from the lay public clearly manifested the desire for government agencies to communicate more of the different sources of uncertainty pertaining to health risks (Markon *et al.* 2008). Other research supports the view that members of the public can understand and deal with uncertainty because they deal with multiple sources of uncertainty, such as incomplete knowledge or ambiguous situations, on a day-to-day basis (Berkes 2007; Frewer 2004; Morss *et al.* 2008; Wynne 1992). However, evidence on *which* sources of uncertainty are better understood and managed by the public and *how* to communicate them is still sparse (Frewer *et al.* 2003). As a result, the debate over the outcome of communicating uncertainty to the public remains open (Beierle 2004; Carpenter 1995; Johnson 2003).

The Effect of Communicating Uncertainty to the Public

Summarizing the evidence pertaining to the consequences of communicating sources of uncertainty to the public is a difficult task, because studies often use different operationalizations of "uncertainty." In fact, the term "uncertainty" does not always refer to the probability of occurrence, as it is too often assumed in risk research (Bammer and Smithson 2008; Markon *et al.* 2011; Smithson 1999). Several researchers have emphasized the need to distinguish categories of uncertainty based on the type of questioning they raise and the way they are best managed (Babrow 2001; Bunting *et al.* 2007; Brugnach *et al.* 2008; Colyvan 2008; Klinke and Renn 2002; Smithson 1989; Walker *et al.* 2003). A categorization used by Brugnach *et al.* (2008) distinguishes between questioning about: (a) the inherent complexity of an issue (*ontological uncertainty*); (b) the lack of knowledge about an issue (*epistemic uncertainty*); and (c) the multiplicity of possible significations about the issue (*ambiguity*). This categorization also matches closely Klinke and Renn's (2002) distinction between: (a) the difficulty to identify and quantify the links of causality and non-linear relationships between the elements of a system; (b) the absence or the lack of knowledge and measurement errors; and (c) divergences or contested perspectives about the meaning of a risk. The evidence presented below describes the effect of communicating these different sources of uncertainty on risk perception, behavioral intentions, and trust in the source.

Risk perception and risk acceptability

In the literature, when there is uncertainty about a hazard, it is most often associated to increased perceived risk (Beardsworth 1990; Lofstedt 2003; MacGregor *et al.* 1994; Slovic 1987). Fox and Tversky (1995) demonstrated that conditions deemed ambiguous were perceived as more aversive compared to conditions with comparatively less ambiguity. In the work on heuristics, researchers proposed that uncertainty from probabilities can be aversive because it underlines the lack of information, and the difficulty of making decisions under such ignorance (Frisch and Baron 1988; Heath and Tversky 1991). Uncertainty from conflicting messages concerning a hazard has also been shown to increase risk perceptions (Breakwell and Barnett 2003; Dean and Shepherd 2007). Results of a study by Viscusi (1997) revealed that when two different risk estimates were provided by conflicting sources there was a tendency to neglect the lower estimate and to be influenced disproportionately by the highest one. However, when the different estimates were provided by the same source, they were then equally taken into consideration. This led Viscusi (1997) to conclude that the conflict between sources led to alarmist perceptions more than the conflicting data itself. In another study, reading conflicting information did not affect how people perceived the content of the message, but only how they appraised the sources involved (Dean 2000, cited by Dean and Shepherd 2007).

In contrast, Frewer (2004) noted that recognizing the presence of uncertainty in risk communication can diminish risk perception for people who were first very cynical about the communicators' motives. In fact, disclosing sources of uncertainty can augment the risk perceptions of those initially indifferent to some hazards, but diminish risk perceptions of those initially very concerned (Frewer 2004). For Kuhn (2000), the presence of uncertainty about a hazard can be used to either attenuate or amplify risk perceptions depending on initial environmental attitudes. The moderating role of the communication of different sources of uncertainty on risk perception needs to be further investigated.

Behavioral intentions

In the context of health care, ambiguity about treatment screening or prevention recommendations has been linked to a diminution in uptake of prevention strategies such as vaccines (Han *et al.* 2007a,b). Informing patients of different sources of uncertainty about cancer screening measures decreased their interest toward those (Frosch *et al.* 2001; Volk *et al.* 1999). As mentioned before, in the context of the H1N1 outbreak, reported confusion surrounding the swine flu outbreak was associated with a reduced likelihood of acting on the recommended behavioral changes (Rubin *et al.* 2009). However, it has also been argued that providing information acknowledging sources of uncertainty about hazards can encourage citizens to get involved in health and environmental issues (Palenchar and Heath 2007). Access to honest and diversified information can also help customers make more enlightened decisions (Leighton *et al.* 2002). In sum, public knowledge of existing sources of uncertainty is necessary to the concept of partnership and concerted actions in the health domain (Knapp *et al.* 2004). Further investigation into sources of uncertainty and public adherence to recommended behaviors is required.

Trust toward the source

Hesitation in acknowledging the presence of uncertainty to the public often stems from the fear that it will reduce trust in scientific experts and in risk management institutions (Frewer 2004; Kasperson 2008). In one of the few experimental studies to address this question, Johnson and Slovic (1995) tested the public's reaction to risk assessments that included probability intervals (versus single point estimates) on opinions of the source of information. They found that presenting this source of uncertainty was interpreted by the public as a signal that the institutions responsible for the risk assessment were honest, but less competent. A similar effect on trust was shown when communicating the existence of conflicting sources or divergent data about the presence or strength of a given risk. Some studies found that communicating conflicting information about a hazard lowered the credibility of some of the sources (Smithson 1999; Viscusi 1997). Moreover, sources with conflicting views about a hazard were perceived as less credible and trustworthy than sources agreeing on the existence of conflicting data about the same hazard (Smithson 1999). In the context of semi-experimental focus groups, presenting the advantages and disadvantages associated with different strategies to manage the red tides (an increase in *Karenia brevis algae,* which can be toxic for aquatic organisms) also diminished trust toward scientists (Scherer *et al*. 2008). Similarly, in a public debate that took place in Sweden between epidemiologists and toxicologists about the possibility that acrylamide was carcinogenic, public trust toward scientists diminished (Lofstedt 2003). Therefore, more transparency about scientific deliberations can be associated to disillusions among the public regarding the ability of science to resolve problems in an absolute way. However, it is also argued that doing so can be beneficial in making public expectations toward science more realistic in the long term (Johnson and Slovic 1995).

Additionally, there are many cases in the literature where authorities lost public trust by hiding different sources of uncertainty about health hazards. This was made salient in Wynne's study on British sheep farmers after the nuclear incident of Chernobyl (Wynne 1989). The investigation revealed that farmers, who are used to dealing with many sources of uncertainty on a daily basis, found it highly suspicious that the scientific evaluations presented by experts did not mention important sources of uncertainty such as variability. How was it possible that experts' contamination evaluations for such a wide territory were so uniform while they could themselves observe significant variability in contamination on their own farms? Scientists' "false certainty" reduced their credibility in the eyes of the farmers (Wynne 1989). The Phillips report (2000) that analyzed the "mad cow disease" crisis in Britain, mentioned that the openness necessary to gain public trust requires acknowledging uncertainty where it exists. According to many researchers in the field of risk communication, several food security crises arose partly because the elaboration of regulation policies was not transparent and the public was ill informed about the complexity of the situation (Frewer *et al*. 2002; Lofstedt 2006; Miles and Frewer 2003; Powell and Leiss 1997). In sum, there is mixed evidence on the consequences of sharing sources of uncertainty on trust. The effect may depend on the form of uncertainty presented, the method and content of message delivery, and the context of the situation.

Current Study

The overall goal of the study was to test with an experimental design, whether the effect of different types of advisory warnings about a health hazard on risk perception, risk acceptability, mobilization, and trust in the source would be moderated by the communication of various sources of uncertainty, namely, as identified by Brugnach *et al.* (2008): epistemic uncertainty (lack of data) and ambiguity (divergence between experts and conflicting data).

It was therefore decided to compare the following *sources of uncertainty* in public risk communication: (a) no mention about uncertainty; (b) mention of divergence between experts; (c) mention of contradictory data; (d) mention of a lack of data. These were put in the context of opposite *types of advisory warnings*, communicating either (a) the absence of a risk associated with the hazard and recommending no protective measure or (b) the presence of a risk associated with the hazard and suggesting adopting a preventive strategy. This allowed a comparison to be made between instances where risk is downplayed (such as with GMOs, radiations from transmission towers, H1N1 vaccine) and instances where it is emphasized (as with the H1N1 virus or new emerging diseases), all in the context of different sources of uncertainty. A fictitious health hazard, the presence of a "new microorganism in tap water," was used for this experiment because people did not carry any previous knowledge or strong values about it and it could be easily manipulated as representing a risk for health or not.

METHODS

Participants

A recruiting message was sent to a large network of individuals using the Internet. A total of 434 participants completed the survey in either English (210) or French (224). An algorithm tracking unique internet protocol (IP) addresses was used to prevent redundancy. Participants had to be Canadian (in order to keep the same frame of reference about the government) and 18 years and older. Even though this method was not intended to be representative of the general Canadian population, the sample included a wide range of sociodemographic backgrounds. More specifically, participants differed in reported location of residence, gender (66% women), province of residence (2% from Atlantic provinces; 40.7% from Quebec; 37.9% from Ontario; 13.8% from the Prairies; 4.7% from Alberta and British Columbia; 0.9% did not disclose the information). The majority of participants were less than 45 years old (31% were 18 to 24 years of age; 47.8% were 25–44; 18.1% were 45–64; and 1.8% were 65 years of age of older; 0.9% undisclosed), with a fairly high level of education (20% had completed high school;16.3% community college, 40.9% undergraduate university, 21.6% graduate university; 0.9% undisclosed).

Material

The material for the experimentation was entirely electronic and available online. It ran on the PsychData website (http://PsychData.com), a tool for creating confidential and secure online surveys. The study presented a fictitious government message about a hypothetical new substance: “the KRP56, a natural micro-organism that was detected for the first time in lakes and rivers nationwide, is resistant to water purification treatments and can be found in very small amounts in tap water." There were eight different conditions, varying messages at random between participants by both (a) type of advisory warning and (b) source of uncertainty communicated (see below). The message was followed by a questionnaire and some demographic questions.

Measures

The study was a 2 factors between-subject design. The factor I "*type of advisory warning*" had two levels and communicated (0) the *absence* of a risk associated with KRP56 and recommended *to keep drinking tap water*, or (1) the *existence* of a risk associated with KRP56 and recommended *to stop drinking tap water*. The factor II "*source of uncertainty*" had four levels: (A) no uncertainty, (B) uncertainty from divergence between experts, (C) uncertainty from contradictory data, or (D) uncertainty from lack of scientific data on the topic.

Type of messages (experimental manipulation)

All eight fictitious government messages (2 types of advisory warning * 4 sources of uncertainty) started with the same neutral contextual description of the KRP56 micro-organism, but then differed in the combination of type of advisory message and source of uncertainty mentioned (Figure 1). The full messages can be consulted in the Appendix and in Markon (2011).

Baseline questions

Pre-manipulation, four items measured baseline risk perceptions about tap water (1: “Do you think tap water represents a risk to your health? and 2: to the health of Canadians in general?”) and confidence in the government (3: “How much confidence do you have in the federal government with regards to water quality

Types of advisory warning	Sources of uncertainty: A	B	C	D
0	No uncertainty on the fact that KRP56 does not present a risk to human health, recommends to continue drinking tap water as normal	Divergence between experts on the fact that KRP56 does not present a risk to human health, recommends to continue drinking tap water as normal	Contradictory data on the fact that KRP56 does not present a risk to human health, recommends to continue drinking tap water as normal	Lack of data on the fact that KRP56 does not present a risk to human health, recommends to continue drinking tap water as normal
1	No uncertainty on the fact that KRP56 presents a risk to human health, recommends to stop drinking tap water	Divergence between experts on the fact that KRP56 presents a risk to human health, but still recommends to stop drinking tap water	Contradictory data on the fact that KRP56 presents a risk to human health, but still recommends to stop drinking tap water	Lack of data on the fact that KRP56 presents a risk to human health, but still recommends to stop drinking tap water

Figure 1. Eight experimental conditions (2 types of advisory warning * 4 sources of uncertainty).

control? and 4: health issues in general?"). These were measured on a 8-point Likert-type scale (1 = not at all, 8 = extremely).

Post-experimental questionnaire

The questionnaire following the message included 33 items measuring participants' reactions to the message and to its source. Item formulation was inspired by previous surveys investigating risk perception including the National Survey on Health Risk Perception and Acceptability in Canadians (Krewski *et al*. 1995a,b) and the Canadian National Public Survey on Perceived CBRN Terrorism Threat and Preparedness (Lemyre *et al*. 2005). The four items used to test the hypotheses measured risk perception ("to what extent do you think KRP56 represents a risk to you health?"), risk acceptability ("to what extent do you think the presence of KRP56 in tap water is acceptable for you?"), intentions to follow the behavioral recommendation ("to what extent would you consider drinking tap water if KRP56 was detected in it?"), and trust in the source ("to what extent do you trust the government about KRP56?"). All items were measured on a 8-point Likert-type scale (1 = not at all, 8 = extremely).

Procedure

The recruitment message was sent by e-mail to acquaintances of members of the research team who in turn could send it to their network (snowball sampling). This sampling method was chosen to reach a greater number of participants with more diverse sociodemographic profiles than in common undergraduate student samples. The message invited interested individuals to participate in a short study on risk perception. The link to the study led to a statement of informed consent that had to be accepted before accessing the experiment and being randomly assigned to different conditions. The informed consent briefed participants that they would be asked to "read a fictional vignette, and then evaluate the related perceived risk." Participants answered the pre-manipulation questions, and were then asked to imagine receiving a message from the government concerning a substance present in the water sources feeding into Canadian residences and read one of the aforementioned eight messages about the presence of KRP56 in tap water. A series of items investigating their perceptions, behavioral intentions and trust, followed. At the end of the questionnaire, participants answered some sociodemographic questions and had the opportunity to comment on the study. Finally they were reminded that the government message was fictitious and they were thanked for their time. They were not paid for their participation. On average, the questionnaire took less than 10 min to complete.

Data Analysis

Data were first screened to verify preliminary assumptions. It was decided to recode data values corresponding to don't know/no opinion as missing data since the pattern appeared random and less than 5% of the cases were missing, as recommended by Tabachnick and Fidell (2007, p 71). Assumptions of normality, homogeneity of variance-covariance matrices, linearity, and multicolinearity were tested with satisfactory results. Eight multivariate outliers were detected with the use of a

Mahalanobis criterion of $p < .001$, and removed from the data for a final sample of 426 cases.

A 2 × 4 between-subject multivariate analysis of variance (MANOVA) was performed to test the main effect of type of advisory warning and source of uncertainty, and the effect of their interaction on the dependant variables of risk perception, risk acceptability, and behavioral intention. A separate 2 × 4 between-subject analysis of variance analysis (ANOVA) with the same factors was performed on the dependant variable of trust in the source of the message. The decision not to include this variable in the MANOVA was both theoretical (conceptual differences) and statistical (the correlations between trust and the other dependant variables were small). For significant omnibus tests, follow-up analysis using Tukey's Honestly Significant Difference Test (HSD) was conducted to identify where the significant differences between groups lay.

RESULTS

Initial Attitudes Toward Tap Water and its Management by the Government

At baseline, participants considered the risk represented by tap water for their own health to be small ($M = 2.46$; $SD = 1.53$), as was the case for the health of Canadians ($M = 2.71$, $SD = 1.53$). Confidence in the federal government for water quality control ($M = 5.53$, $SD = 1.68$) and for health issues in general ($M = 5.26$, $SD = 1.51$) was moderate. Results from the one-way ANOVAs performed to compare the eight experimental groups on those baseline perceptions confirmed no significant difference between groups ($p > .05$, largest F (7, 424) = 1.788).

Perceptions of the Message

The 2 × 4 between-subject MANOVA performed to investigate the effect of types of advisory warning and sources of uncertainty on risk perception, risk acceptability, and behavioral intentions revealed (a) a main effect of type of advisory warning [F (3, 399) = 12.57, $p < .001$; Wilks' Lambda = 0.92; partial eta squared = .086], (b) no main effect of source of uncertainty [F (9, 393) = 1.32, $p = 0.224$; Wilks' Lambda = 0.97; partial eta squared = 0.01], and (c) a significant interaction [F (9, 393) = 2.8, $p = .003$; Wilks' Lambda = 0.94; partial eta squared = .021]. When the results for the dependant variables were considered separately for the main effect of type of advisory warning and the interaction between type of advisory warning and source of uncertainty, all reached statistical significance using a Bonferroni adjusted alpha level of .017.

Specifically, the main effect of type of advisory warning was observed for risk perception [F (1, 401) = 33.87, $p < .001$, partial eta squared = 0.078], risk acceptability [F (1, 401) = 14.60, $p < .001$, partial eta squared = 0.035], and behavioral intentions [F (1, 401) = 19.49, $p < .001$, partial eta squared = 0.046]. An inspection of the mean scores indicated that reading the message warning about a risk and recommending a protective measure (stop drinking tap water) increased *perceived risk* ($M = 5.03$, $SD = 1.62$) compared to the message indicating no risk and recommending to keep drinking tap water ($M = 4.16$, $SD = 1.58$). The *perceived acceptability* of the presence of the micro-organism in tap water was lower for participants who read a message warning about a risk and recommending to stop drinking tap water ($M = 3.19$, $SD = 1.78$) than for participants who read the other type of message ($M = 3.84$, $SD = 1.88$). Finally, warning that there was a risk and recommending to stop drinking tap water effectively decreased the *intention to drink tap water* ($M = 3.09$, $SD = 1.87$), compared to announcing no risk and recommending to keep drinking tap water ($M = 3.94$, $SD = 2.20$).

The interaction of types of advisory warning with sources of uncertainty was significant for risk perception [F (3, 399) = 6.65, $p < .001$, partial eta squared = 0.047], risk acceptability [F (3, 399) = 4.88, $p = .002$, partial eta squared = .035], and behavioral intentions [F (3, 399) = 4.25, $p = .006$, partial eta squared = 0.031].

Follow-up univariate analyses were conducted on all the dependant variables to further investigate the nature of the interaction effect and identify the significant differences between the experimental groups with Tukey's HSD post hocs. The average scores on the different measures of the dependant variables are presented below, along with the significant differences between groups ($p < .05$) for all experimental conditions. Only the differences that were of relevance for testing the hypothesis and research questions are described in more detail.

Perceived risk

Results of the post hocs indicated that perceived risk was influenced by the type of advisory warning only when the message communicated no uncertainty or the lack of data, but not when it communicated divergence between experts or contradictory data. Specifically, messages communicating no uncertainty about the absence of risk and recommending to keep drinking tap water caused lower risk perception ($M = 4.15$, $SD = 1.56$) than messages communicating no uncertainty about the presence of risk and recommending to stop drinking tap water ($M = 5.56$, $SD = 1.57$), $p < .001$. Messages communicating the lack of data about the absence of risk and recommending to keep drinking tap water also elicited lower risk perception ($M = 3.69$, $SD = 1.53$) than messages communicating the lack of data about the presence of risk and recommending to stop drinking tap water ($M = 5.43$, $SD = 1.63$), $p < .001$. Conversely, no significant differences were found between types of message when divergence between experts was communicated (no risk, keep drinking tap water: $M = 4.49$, $SD = 1.69$; risk, stop drinking tap water: $M = 4.67$, $SD = 1.63$), or contradictory data (no risk, keep drinking tap water: $M = 4.30$, $SD = 1.42$; risk, stop drinking tap water: $M = 4.62$; $SD = 1.75$).

Within the conditions revealing the same type of advisory warning, no significant differences were found at .05 between the types of uncertainty. Two marginally significant differences were, however, observed within the messages communicating the presence of a risk and recommending to stop drinking tap water: Risk perception scores were higher when mentioning no uncertainty than when mentioning divergence between experts ($p = .064$) or contradictory data ($p = .058$). Results are depicted in Figure 2.

Risk acceptability

Levels of acceptability for the presence of the micro-organism in tap water differed significantly as a function of the type of advisory warning for the messages indicating

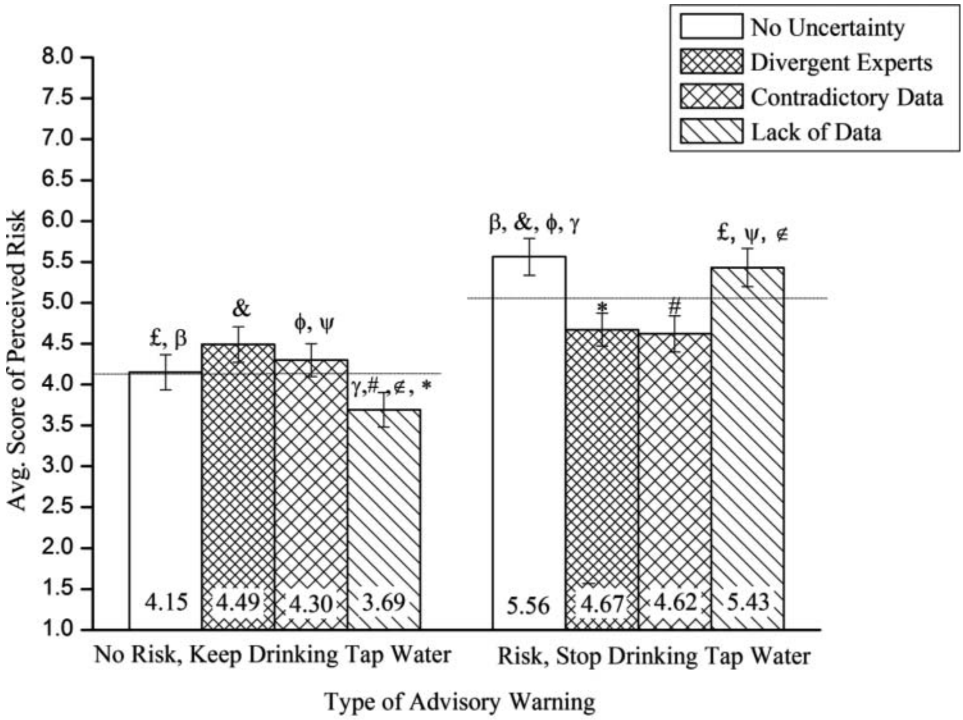

Figure 2. Average scores of perceived risk for personal health of the presence of the micro-organism in tap water by source of uncertainty and type of advisory warning. Signs that correspond indicate significant pairwise comparisons at $p < .05$.

the lack of data. Messages communicating the lack of data about the absence of risk and recommending to keep drinking tap water produced higher risk acceptability ($M = 4.57$, $SD = 1.93$) than messages communicating the lack of data about the presence of risk and recommending to stop drinking tap water ($M = 2.95$, $SD = 1.46$), $p < .001$. A marginally significant difference was also observed between the acceptability scores for messages communicating no uncertainty, as a function of the type of advisory warning. Indeed, messages communicating no uncertainty about the absence of risk and recommending to keep drinking tap water generated higher risk acceptability ($M = 3.67$, $SD = 1.92$) than messages communicating no uncertainty about the presence of risk and recommending to stop drinking tap water ($M = 2.62$, $SD = 1.75$), $p = .072$. In distinction, messages mentioning uncertainty either from divergence between experts or from contradictory data did not differ according to the type of advisory warning. Risk acceptability scores were statistically similar for the two types of messages that mentioned divergence between experts (no risk, keep drinking tap water: $M = 3.64$, $SD = 1.77$; risk, stop drinking tap water: $M = 3.60$; $SD = 1.62$), or contradictory data (no risk, keep drinking tap water: $M = 3.47$, $SD = 1.73$; risk, stop drinking tap water: $M = 3.63$; $SD = 2.12$).

When comparing together acceptability scores for the messages announcing the same type of advisory warning, the source of uncertainty did not matter uniformly.

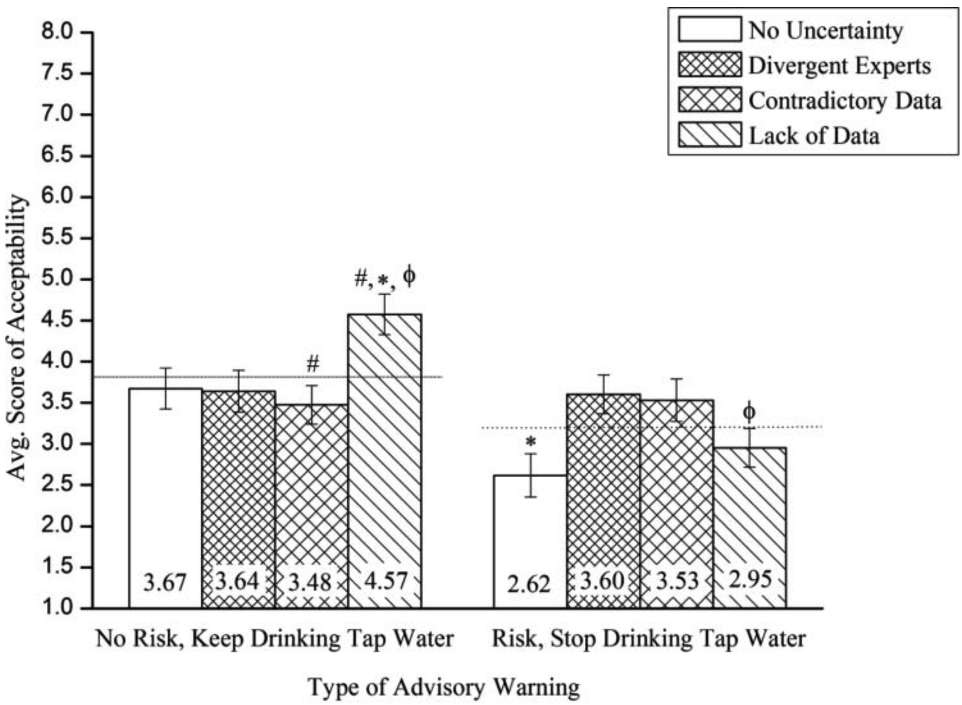

Figure 3. Average scores of acceptability of the presence of the micro-organism in tap water by source of uncertainty and type of advisory warning. Signs that correspond indicate significant pairwise comparisons at $p < .05$.

It only had a significant impact for the messages communicating the absence of a risk and recommending to keep drinking tap water. Namely, risk acceptability was lower when communicating uncertainty from contradictory data than when pointing uncertainty from the lack of data ($p = .028$). A marginally significant difference was also detected for a contrasting pair of messages both communicating the presence of a risk and recommending to stop drinking tap water: mentioning divergence between experts engendered higher risk acceptability than mentioning no uncertainty ($p = .100$). Results are depicted in Figure 3.

Intention to continue drinking tap water

When looking at contrasting pairs of messages mentioning the same source of uncertainty but different types of advisory warning, only one significant difference was observed on the behavioral intention scores. Mentioning the lack of data significantly polarized the behavioral intentions with respect to the type of advisory warning. Under the presence of that source of uncertainty, mentioning the absence of risk and recommending to keep drinking tap water effectively caused participants to consider to continue drinking tap water ($M = 4.89$, $SD = 2.10$) significantly more than when mentioning the presence of risk and recommending to stop drinking tap water ($M = 3.02$, $SD = 1.77$), $p < .001$.

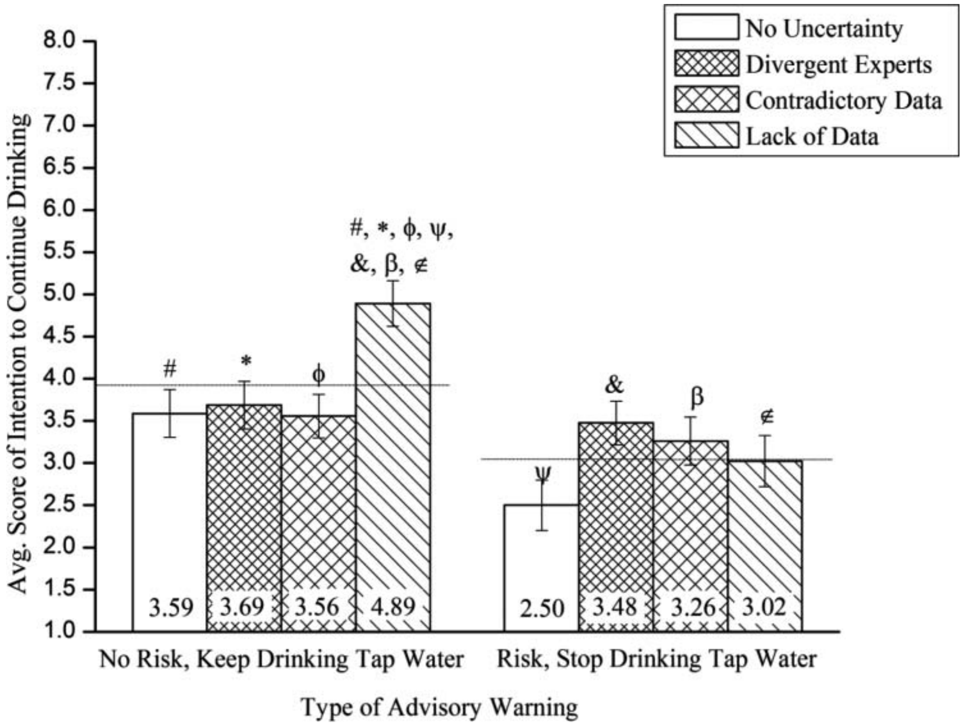

Figure 4. Average scores of intention to continue drinking tap water by source of uncertainty and type of advisory warning. Signs that correspond indicate significant pairwise comparisons at $p < .05$.

The comparisons between messages with the same type of advisory warning (but different sources of uncertainty) revealed significant differences exclusively within those affirming no risk and recommending to keep drinking tap water. Specifically, intention to continue drinking tap water was higher when mentioning the lack of data than no uncertainty ($M = 3.59$, $SD = 2.13$), $p = .021$, divergence between experts ($M = 3.69$, $SD = 2.19$), $p = .045$, or contradictory data ($M = 3.56$, $SD = 2.15$), $p = .01$. Communicating the lack of data amplified the effect of the statement about the lack of risk and the recommendation to keep drinking tap water, but this did not occur with the other type of advisory warning. Results are depicted in Figure 4.

Trust in the Source of the Message

Results from the independent 2 × 4 between-subject ANOVA investigating the effect of type of advisory warning and source of uncertainty on trust in the source revealed no main effect of type of advisory warning [F (1, 414) = 1.403, $p = .237$]. Mean scores for messages warning about a risk and recommending to stop drinking tap water was 4.45, compared to 4.23 for messages indicating no risk and recommending to keep drinking tap water. There was no main effect for source of uncertainty [F (3, 412) = 1.97, p = .117]; however, the interaction effect was significant [F (3, 412) = 3.69, p = .012].

Follow-up Tukey's HSD post hocs allowed to determine the nature of the significant differences between groups. Presented in Figure 5 are the average scores on the measure of trust, along with the significant differences between groups (<.05). No significant differences were found between contrasting pairs of messages communicating the same source of uncertainty. However, a marginally significant difference was detected between messages exposing divergence between experts but using different advisory warnings. Indeed, trust toward the source was lower when divergence between experts was mentioned in the context of a message suggesting the absence of risk and recommending to keep drinking tap water (M = 3.63, SD = 1.91), than when it was mentioned in the context of a message suggesting the presence of risk and recommending to stop drinking tap water (M = 4.64, SD = 1.82), p = .076.

When comparing messages with the same type of advisory warning, but differing in sources of uncertainty, significant differences were found among those affirming no risk and recommending continuing to drink tap water. Specifically, trust in the source was lower when mentioning divergence between experts (M = 3.63, SD = 1.91), than when mentioning the lack of data (M = 4.95, SD = 1.67), p = .006. Communicating contradictory data (M = 3.90, SD = 1.98) also lowered trust in the source compared to communicating lack of data (p =.05). Results are depicted in Figure 5.

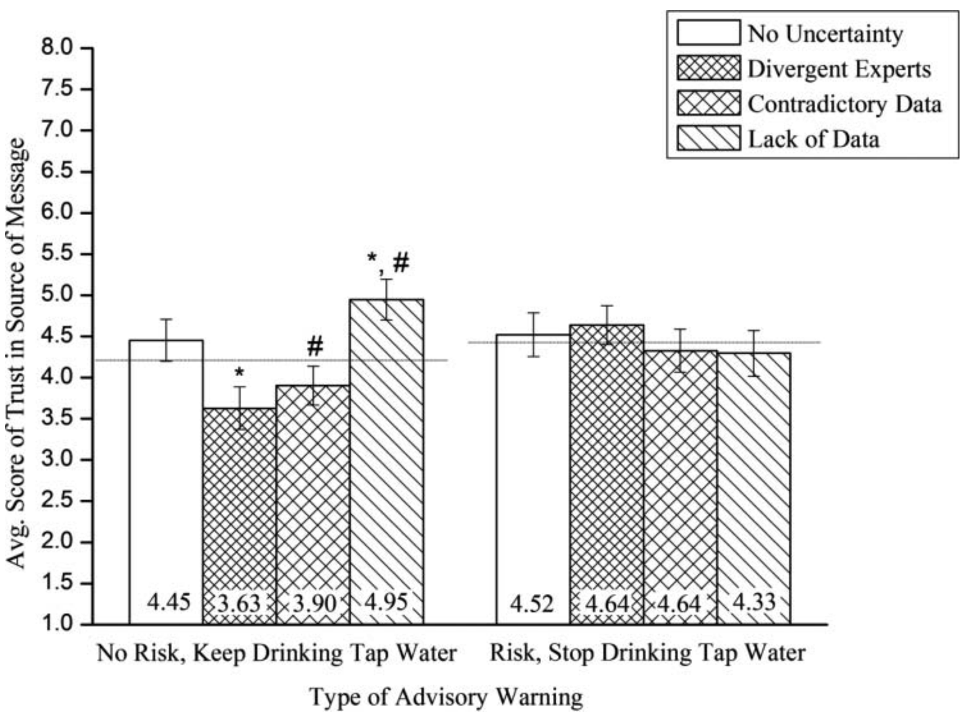

Figure 5. Average scores of trust in the source of the message by source of uncertainty and type of advisory warning. Signs that correspond indicate significant pairwise comparisons at $p < .05$.

DISCUSSION

The experimental design applied in this study tested the effect of communicating contrasted government advisory warnings ("no risk and a recommendation to keep drinking tap water" or "risk and a recommendation to stop drinking tap water") in the context of differing sources of uncertainty (no uncertainty, divergence between experts, contradictory data, or lack of data) on risk perception, acceptability, behavioral intentions, and trust in the source. In summary, the multiple analyses of variance revealed that the effect of the types of advisory warning on public reactions was moderated by the different sources of uncertainty. In general, mentioning the divergence of experts or contradictory data diminished the adherence to the content of the message, whereas communicating the lack of data did not affect the impact of the message. Mentioning uncertainty from the lack of data also did not diminish trust in the source of the message. Trust was only affected negatively when the advisory warning stated that there was no risk and recommended no protective measure while mentioning the presence of uncertainty from divergence of experts or contradictory data. These key findings are developed in more detail in the following paragraphs.

Exposing Divergence Between Experts or Conflict in the Data Can Null the Influence of an Advisory Warning

The unique design of this study using two opposing warning messages allowed demonstrating how communicating some sources of uncertainty (but not others) could cancel out the influence of an advice given by the government. Indeed, when uncertainty from divergence between experts or contradictory data was presented, scores on risk perception and acceptability of the substance remained equivalent regardless of whether the message warned about the existence of a risk or not. The type of advisory warning ("there is no risk" vs. "there is a risk") communicated about the new substance only had an influence on risk perception and acceptability when no uncertainty was communicated or only the lack of data was presented. When there was divergence over the existence of a risk associated with the substance, it appears that people discounted the words of advice given and based their judgments on more basic information, such as the novelty of the substance. This confirms previous research showing that when faced with particular sources of uncertainty, people chose to disregard institutional risk assessments and instead rely on their own experiences, instincts, and feelings about what constitutes a risk or not (Holmes *et al*. 2009).

Different Sources of Uncertainty Can Affect Adherence to a Warning Differently

In the context of this study, communicating different sources of uncertainty led to contrasting outcomes on public reactions. As stated above, presenting divergence between experts and contradictory data decreased the adherence to the message in terms of risk perception and acceptability, but sharing the lack of data did not bring participants to downplay the message. Psychological reasons could potentially explain this difference. Social and health psychology research have shown that people have a particular aversion to the lack of consistency (Festinger 1957) and to the lack of coherence (Antonovsky 1979). Without a sense of coherence, situations can seem less manageable, comprehensible, and meaningful, which in turn can cause more stress and tension (Antonovsky 1990, 1993). In the absence of a consensus, it is also difficult for people to formulate causal attributions (Kelley 1967), which also heightens a feeling of confusion. Most importantly, the existence of divergence or conflicting data may signal that there is another, most likely legitimate, position than the one defended by the government agency. In the face of uncertainty from conflict, the person may tend to counterbalance the argument given (if she cannot identify clearly to one of the opposing source). Peter Sandman (1998) proposed that in the context of risk communication, when individuals are ambivalent about a risk issue (*e.g.*, when there is divergence on the topic), they tend to focus on the side the communicator is ignoring.

The psychological correlates of uncertainty from ignorance are understood less well (Kandlikar *et al*. 2005). Fox and Tversky's (1995) comparative ignorance hypothesis suggests that ignorance might be aversive only in cases where it makes the decision-maker feel *comparatively* less informed. In a series of studies they showed that individuals did not display aversion for a prospect with missing information when examined in isolation (like in the context of our study), but they displayed ignorance aversion when they evaluated both clear and vague prospects (Fox and Tversky 1995).

Other sources of uncertainty have been compared against each other in previous studies, also yielding contrasting public reactions. For instance, Frewer (2004) demonstrated that people better accepted uncertainty associated with the scientific process than from a lack of action. Additionally, Smithson (1999) showed that people disliked uncertainty from the divergence between experts more than uncertainty associated from divergence in the data. In our study such difference in perceiving divergence between experts versus in the data was not perceptible. This might be due to the different methodologies employed to distinguish the two sources of uncertainty. Smithson's methodological strategy might have made the difference between the two more salient by comparing a scenario in which half the experts suggested there was a risk associated with a given substance, and the other half did not (*divergent experts*), with a scenario in which all experts said half of the studies suggested a risk and the other half did not (*conflicting data*). In our study, divergence in the data and conflicting data were not mutually exclusive. It was therefore easier to interpret the divergence between experts as stemming from divergence in the data, and vice-versa, making the two less distinctive.

Trust is Not Systematically Affected by the Mention of Uncertainty

Whether trust in the source is affected by communicating uncertainty to the public is a long-standing issue. Results from this study offer a nuanced answer. Indeed, trust was not affected by the presence of sources of uncertainty in the context of a message warning about the existence of a risk and recommending a new protective measure; however, in the context of a message communicating the absence of a risk and suggesting no protective measure communicating uncertainty from divergence did affect trust, compared to communicating the lack of data. The proposition that exhibiting conflicting information about a hazard makes the source sound less trustworthy (Smithson 1999; Viscusi 1997) therefore may not hold in every context. Communicating the presence of divergence between experts or in the data on the existence of a risk, but still applying the precautionary principle (recommending a protective measure in spite of uncertainty), might make the source look more responsible and benevolent than when it chooses to negate the risk and take no precaution despite dissent. However, as our findings suggest, this does not mean negating a risk and recommending to continue the usual behavior in the presence of uncertainty always decreases trust in the agency. When uncertainty from the lack of data was communicated to the public in the context of the "no risk, keep drinking tap water" message, trust in the source increased compared to the messages communicating other types of uncertainty. Therefore, as proposed by other researchers (Lofstedt 2006; Powell and Leiss 1997; Wynne 1989), openness about uncertainty may indeed help in gaining public trust. In brief, members of the public may expect the lack of scientific data to be associated with a new hazard and tolerate the status quo as long as there is no counter evidence that there may be a risk associated with the hazard. In cases in which there is divergence between experts or in the data, then negating the risk and advocating inaction is no longer seen as an acceptable and trustworthy message from public agencies.

Implications for Risk Communication and Risk Management

Many meaningful implications for both risk communication and risk management can be derived from these findings. First, this study supports the fact that the public is capable of recognizing different sources of uncertainty and distinguishing between them. Integrating them in risk communication is therefore not superfluous given that the public is very responsive to them. Second, special attention must be paid to which sources of uncertainty are communicated given that they do not have all the same repercussions on perceptions, behavioral intentions, and trust. To better anticipate the public's responses to a message and communicate more efficiently, public agencies need to be more precise about the source of uncertainty involved. Merely stating that there is uncertainty could be interpreted as divergence or lack of data, which both have very different outcomes on the public's reactions.

Third, different types of uncertainty are expected to be paired with different types of interventions. In the presence of divergence between experts and contradictory data about the existence of a risk, opting for the status quo and risk negation can make the risk agency appear less trustworthy. Renn (2005) and Bunting and colleagues (2007) proposed that different sources of uncertainty should be matched with different risk management strategies. For instance, uncertainty resulting from "divergent or contested perspectives on the justification, severity, or wider meanings associated with a given threat" should be dealt with using a strategy that promotes mutual understanding of conflicting views and values aiming at reconciling and integrating them in the long run (Bunting *et al.* 2007). In contrast, uncertainty arising from the "lack of knowledge or clarity of the scientific or technical data" should be managed by precaution-based strategies and a more resilience-oriented approach (Bunting *et al.* 2007). It seems that the public may intuitively recognize strategies that are more suited to certain types of uncertainty.

Fourth, presenting uncertainty to the public does not yield the same results when the goal of the communication is to minimize the existence of a risk for health associated to a given hazard (*i.e.*, "no risk" condition), for instance regarding new vaccines and new technologies, than when the goal is to increase awareness about the existence of a risk associated to a given hazard (*i.e.*, "risk" condition), for instance in the case of H1N1 virus and climate change. Uncertainty from divergence between experts or contradictory data is received less well in the first scenario than in the second one. In the literature, public outrage in the context of risk mostly occurs in contexts where the existence of risk associated to a given hazard was downplayed or negated by public authorities despite contrasting data on the topic, such as in the case of the BSE crisis in Europe (Lofstedt 2006; Powell and Leiss 1997).

Fifth, another crucial implication of this research is that sharing the lack of data about the existence of a risk in government risk communication does not necessarily harm the public's trust in the source nor does it diminish the adhesion to the message. This study reinforces Rogers *et al.*'s (2007) suggestion that in many contexts, "it is better to say I don't know," or admit that there is a lack of data on the topic. This can contribute to retention of credibility and trust in the communicator and in some cases even promote adhesion to the message. The communication of uncertainty from divergence between experts or contradictory data remains, however, more challenging as it can have the opposing effect. This should not serve as a pretext to hide the presence of conflicting experts or data where it exists. Other research has shown that citizens want the information about risk to include all existing sources of uncertainty comprising the nature and the extent of divergence between various experts (Frewer 2004; Markon *et al.* 2008). Doing so may also help make the general public's expectations of risk assessors, government agencies, and scientists more realistic in the long-term (Johnson and Slovic 1995). Therefore the question should not be how to conceal or downplay existing disagreements between experts, but rather how to better present to the public existing disagreements between experts in a way that does not minimize an agency's message and credibility.

One approach could be to elaborate further on the nature of the disagreements (rather than merely state the existence of divergence, like in our study), so that citizens feel more empowered and better able to forge their opinion on the subject. Offering a rationale and recognizing the frustrating nature of not knowing with certainty could also be beneficial. Indeed, *autonomy support* (Deci and Ryan 1985), which, in the context of government communication, would mean for authorities to take citizens' perspective, acknowledge their feelings and concerns, and give them pertinent information and opportunities for choice, has been associated with intrinsic motivation and internalization (Deci *et al.* 1981; Grolnick and Ryan 1989). Following Bunting and colleagues' (2007) suggestion, it might also be appropriate to mention the efforts that are made to foster dialogue and understanding between the different proponents to eventually reconcile the views. With today's ever more complex global risks, variability in assessments and views are almost unavoidable (Webster 2003). These divergences are also publicized outside the traditional channels of communication, such as the Internet. Acknowledging and qualifying the various, sometimes extreme, positions found on the different forums accessible to citizens might elicit a more productive dialogue with the public than simply disregarding them in government communications.

LIMITATIONS AND FUTURE STUDIES

Among the features of this study that could have limited the ecological validity of the findings, for ethical purposes, participants knew the hazard was fictitious. This could have made their reactions more or less salient than if the hazard had been real. The fact that the hazard was not a familiar one, however, allowed us to control for any spill-over effect due to pre-existing values and knowledge. The fictitious hazard chosen could also be manipulated more easily in the context of different types of advisory warning, thereby making the findings applicable to a wider array of situations. Nevertheless, reactions to uncertainty about the hazard chosen for this study that were novel and natural may not be applicable to the communication of uncertainty about other types of hazard (for instance, chronic, man-made, and distal). Indeed, risk perception studies using a psychometric approach have demonstrated that risk perception varies depending on different dimensions of the hazard (Fischhoff *et al.* 1978; Sjöberg 2000; Slovic 1987) and risk domain (Weber *et al.* 2002).

Future studies using the same testing paradigm could test many other types of hazard and investigate different sources of uncertainty beside the lack or data and the divergence between experts or in the data. In addition, it would be useful to vary the types of advisory warning to test the impact of communicating uncertainty when the protective measure recommends adopting a new behavior (for instance, recycling or getting a vaccine), rather than only stopping the current habits (for instance, stop drinking tap water). Finally, it is important to note that a greater proportion of women (66%) than men participated in the study, which could have influenced the results given women generally tend to perceive environmental health risks as higher than men (Flynn *et al.* 1994; Harris *et al.* 2006). Future studies could further explore how individual differences, for instance based on sociodemographics, influence reactions to the communication of uncertainty.

CONCLUSION

The presentation of sources of uncertainty in government risk communication is a challenging enterprise, but it is nonetheless critical for establishing honest and habilitating dialogue with the public. A more nuanced way to approach uncertainty would definitely be beneficial to better anticipate and address the effect of its communication to citizens. This study demonstrated that not all sources of uncertainty trigger the same reactions in the public, and that similar sources of uncertainty elicit diverse reactions depending on the context. The communication of uncertainty from divergence between experts or in the data may be especially detrimental for trust in the source when it does not respect the precautionary principle, yet, when it does, the negative effect on trust vanishes. Importantly, in the context of this study, communicating uncertainty from the lack of data had no undesired consequences on message adhesion and trust in the source; it was even beneficial when communicating it about the absence of a risk. The experimental design tested in this study could be expanded to measure the effect of a much wider variety of sources of uncertainty and types of contexts, as it is crucial to refine and deepen our understanding of the psychology of uncertainty communication. It is only logical that the intrinsic complexity of the concept of uncertainty be mirrored in the way we approach and research it.

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APPENDIX

In this section, we would like you to imagine that you receive a message from the government concerning a substance present in the water sources feeding into Canadian residences.

After reading the message, you will be invited to briefly state your opinion.

0A) Last summer, a substance named KRP56, a natural micro-organism, was detected for the first time in lakes and rivers nationwide. This substance is resistant to water purification treatments and can be found in very small amounts in tap water.

According to current scientific studies, the KRP56 micro-organism does not present a risk to human health.

Having reviewed this evidence, the government recommends continuing to consume tap water as normal, without concerning oneself about the presence of KRP56 in the water.

0B) Last summer, a substance named KRP56, a natural micro-organism, was detected for the first time in lakes and rivers nationwide. This substance is resistant to water purification treatments and can be found in very small amounts in tap water.

We know that some experts maintain that there is a risk associated to KRP56. However, others indicate that on the contrary, KRP56 does not present a risk to human health.

Having reviewed this evidence, the government recommends continuing to consume tap water as normal, without concerning oneself about the presence of KRP56 in the water.

0C) Last summer, a substance named KRP56, a natural micro-organism, was detected for the first time in lakes and rivers nationwide. This substance is resistant to water purification treatments and can be found in very small amounts in tap water.

We know that some scientific data suggests that there is a risk associated to KRP56. However, other scientific data indicate that on the contrary, KRP56 does not present a risk to human health.

Having reviewed this evidence, the government recommends continuing to consume tap water as normal, without concerning oneself about the presence of KRP56 in the water.

0D) Last summer, a substance named KRP56, a natural micro-organism, was detected for the first time in lakes and rivers nationwide. This substance is resistant to water purification treatments and can be found in very small amounts in tap water.

We know that there is a lack of scientific data on KRP56. However the available preliminary scientific data indicates that KRP56 does not present a risk to human health.

Having reviewed this evidence, the government recommends continuing to consume tap water as normal, without concerning oneself about the presence of KRP56 in the water.

1A) Last summer, a substance named KRP56, a natural micro-organism, was detected for the first time in lakes and rivers nationwide. This substance is resistant to water purification treatments and can be found in very small amounts in tap water.

According to current scientific studies, the KRP56 micro-organism presents a risk to human health.

Having reviewed this evidence, the government recommends to not consume tap water until KRP56 is eliminated from the water.

1B) Last summer, a substance named KRP56, a natural micro-organism, was detected for the first time in lakes and rivers nationwide. This substance is resistant to water purification treatments and can be found in very small amounts in tap water.

We know that some experts maintain that there is no risk associated to KRP56. However, others indicate that on the contrary, KRP56 presents indeed a risk to human health.

Having reviewed this evidence, the government recommends to not consume tap water until KRP56 is eliminated from the water.

1C) Last summer, a substance named KRP56, a natural micro-organism, was detected for the first time in lakes and rivers nationwide. This substance is resistant to water purification treatments and can be found in very small amounts in tap water.

We know that some scientific data suggests that there is no risk associated to KRP56. However, other scientific data indicate that on the contrary, KRP56 presents indeed a risk to human health.

Having reviewed this evidence, the government recommends to not consume tap water until KRP56 is eliminated from the water.

1D) Last summer, a substance named KRP56, a natural micro-organism, was detected for the first time in lakes and rivers nationwide. This substance is resistant to water purification treatments and can be found in very small amounts in tap water.

We know that there is a lack of scientific data on KRP56. However, the available preliminary scientific data indicates that KRP56 presents indeed a risk to human health.

Having reviewed this evidence, the government recommends to not consume tap water until KRP56 is eliminated from the water.